

*Development of a California Geospatial Intermodal Freight
Transport Model with Cargo Flow Analysis*

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Abstract

This project further develops the Geospatial Intermodal Freight Transportation (GIFT) model, configures the model with California-specific data, and uses the configured model in a case study of the possible benefit of shifting freight transportation from trucks to rail. The result is a model that describes the energy and environmental impacts of goods movement through California's marine, highway, and rail systems. The GIFT research team has employed a Geographic Information System (GIS)-based model that integrates three transportation network models (road, rail, water), joined by intermodal transfer facilities (ports, railyards, truck terminals) in a single GIS "intermodal network" modified to capture energy and environmental attributes. A Case Study was performed to explore the difference in emissions under Least-travel-time versus least-CO₂ routing of goods movements, identifying how emissions savings can be achieved through modal shifts from road to rail. The Case Study estimates CO₂ emissions to be approximately 2.89 million metric tons (MMT) of CO₂ attributable to the container traffic of the three major West Coast ports (LA-Long Beach, Oakland and Seattle) using a least-time scenario (which comprises mostly trucks). Our estimation of a total reduction of approximately 1.7 MMT of CO₂ occurs through a nationwide modal shift of West Coast port-generated goods movement; within California state air basins, this reduction is near 0.5 MMT CO₂. Overall, this research demonstrates how the GIFT model, configured with California-specific data, can be used to improve understanding and decision-making associated with freight transport at regional scales.

Executive Summary

Background

California represents a major international gateway for goods movement and is a domestic partner of other states providing goods movement for North America. California has also become a leader in improving transportation environmental and energy performance. U.S. reliance on the freight transportation system has been growing considerably for some time (Bureau of Transportation Statistics, 2005; Greening, Ting, & Davis, 1999; Schipper, Scholl, & Price, 1997b; Vanek & Morlok, 2000). These trends are likely to continue in the coming decades due to increasing international and domestic trade (U.S. Energy Information Administration, 2007). Many researchers expect that along with this increase in overall freight transport there will be an increase in intermodal freight transport where goods are moved along a combination of highways, railways, and waterways (Arnold, Peeters, & Thomas, 2004; Ballis & Golias, 2002, 2004; T. Golob & Regan, 2001; T. F. Golob & Regan, 2000; Shinghal & Fowkes, 2002). With this increasing freight transport activity, it is expected that congestions, emissions, and energy use will increase at a similar pace (Komor, 1995; Koopman, 1997; Schipper, Scholl, & Price, 1997a). Policymakers and planners must develop operational and infrastructure improvement strategies to increase the efficiency of freight movement to reduce demand for transportation fuels and mitigate environmental impacts (Nijkamp, Reggiani, & Bolis, 1997).

The Geospatial Intermodal Freight Transportation (GIFT) model includes highway, railway, and waterway transportation networks of the U.S. and Canada, plus the international ocean shipping network. GIFT integrates these three transportation modes at intermodal transfer facilities, including ports, railyards, and truck terminals; freight can move from one transportation mode to another through these facilities. Along with the intermodal transportation network model, GIFT provides models of trucks, trains, and marine vessels, capturing their emissions, energy use, operating cost, and operational characteristics such as speed and freight capacity. By combining these in a Geographic Information System (GIS) with built-in route optimization computations, GIFT can find transportation routes that are the shortest distance, least emissions, least time, least operating cost, and least energy. Adding in models of the freight volume and shipping origins and destinations, GIFT helps agencies and researchers understand the environmental, economic, and energy impacts of freight transportation and tradeoffs of alternate improvement decisions.

Methods

In this research, we improved the GIFT model and we configured the model with California-specific data on freight volume and origins and destinations for port-generated traffic (freight entering or leaving the major west-coast ports, including Los Angeles, Long Beach, Oakland, and Seattle, Washington). We compiled international, national, and California-specific data from a number of public and proprietary sources. These include data on shipping origins and destinations; freight volumes; truck, train, and ship performance and costs; and intermodal transfer facility performance and costs. We evaluated advantages and shortcomings of each data source. We found that publicly available data was sufficient quality to be included in California-specific GIFT modeling.

We then modified the GIFT model to meet California port-generated study objectives, and evaluated model performance through a case study. We demonstrated that GIFT can be configured with a variety of data sets, each selected to address the specific environmental, economic and energy characteristics of goods movement of interest in a specific case study. We documented how to configure GIFT with specific data and how to use the resulting model to perform case studies.

We then performed a case study to illustrate use of the model for estimating international and domestic goods movement in all modes against available commodity flow data in selected regions of California (i.e., regions near ports). The case study compared the difference in emissions under least-travel-time versus least-CO₂ routing of goods movements through three major California ports (Los Angeles, Long Beach, and Oakland) and through the Port of Seattle, Washington. The case study identified essential trade-offs and provided recommendations on steps to improve, validate, or expand case study results.

Results

Using the GIFT model with California-specific data on the transportation network, intermodal facilities, vehicle performance (energy, emissions, operating cost), and freight flow (origins, destinations, and volumes), we characterized the least-time and least-CO₂ emissions freight flows. We found least-time routes were dominated by truck traffic along parts of interstates I-5, I-10, I-15, I-40, and I-90. The model estimated a total of approximately 2.9 million metric tons (MMT) of CO₂ emissions occur over the course of the year due to freight moving in and out of these three ports on the West coast (assuming that all freight moves by truck). Of these, the majority of emissions (~79% of total) are due to traffic moving in and out of the port of Los Angeles-Long Beach.

In the least-CO₂ scenario, most freight was routed through the rail network because of low emissions involved with moving freight by train. Our estimation of a total reduction of approximately 1.7 MMT of CO₂ occurs through a nationwide modal shift of West Coast port-generated goods movement; within California state air basins, this reduction is near 0.5 MMT CO₂.

Conclusions

The Case Study provides two primary insights. First, the Case Study quantifies port-related intermodal goods movement through the state of California and beyond. Second, the idealized use of least-CO₂ routing constraints illustrates how emissions savings can be achieved through modal shifts. In terms of savings in emissions, it is estimated that a total of ~60% reduction in CO₂ emissions is achievable by a modal switch from road to rail. Both of these insights have relevance for consideration of system-wide improvements that may achieve energy savings, CO₂ reductions, and associated benefits for air quality.

The GIFT model provides the necessary flexibility and configurability to incorporate case-specific and region-specific data from numerous sources. Application of the GIFT model in other projects has been of significant value to regional and national goods movement evaluation and planning. Configured with California-specific data, the GIFT model results may be of significant value to the Air Resources Board in evaluating tradeoffs among numerous environmental, energy, and economic attributes of goods movement in the State of California. In the future, GIFT can continue to be an important analytical and planning tool for California decision makers. We identified further opportunities for similar trade-off case studies and for model improvements.

1 Introduction

1.1 Project Purpose

The project purpose is to further develop the Geospatial Intermodal Freight Transportation (GIFT) model and provide it with California-specific data and inputs, resulting in an intermodal freight transport model that describes the energy and environmental impacts of goods movement through California's marine, highway, and rail systems. Employing a Geographic Information System-based (GIS) model that integrates three model networks (road, rail, water) in a single GIS "intermodal network" modified to capture energy and environmental attributes, the project will contribute to improved decision-making associated with freight transport at regional scales. Specifically, the model will allow evaluation of: (1) the energy and environmental impacts associated with California freight movement; (2) decisions related to various highway and intermodal facility infrastructure development and resiliency; and, (3) decisions aimed at improving freight movement efficiency in California (see Task 1 technical memorandum).

The project included five main tasks, each with a technical memorandum as a deliverable. These tasks were as follows:

- Task 1: Refined research plan. This task presented a research plan in consultation with ARB staff. The submitted research plan contained a work plan, project schedule, and a review of the relevant research work, data sources, and literature. This plan formed the basis for focus on energy and environmental attributes of the goods movement related to western ports (Los Angeles/Long Beach, Oakland, and Seattle).
- Task 2: Data compilation plan. This task obtained and reviewed data from sources identified in the RFP and during the development of the Task 1 Refined Research Plan. We evaluated the advantages and shortcomings of each data source and compiled the data for subsequent tasks. The technical memorandum from this task included discussion of assumptions made and surrogate data developed to fulfill required data elements. The memorandum also summarized the strengths and limitations of the compiled data. This data compilation identified data with sufficient quality to be included in California-specific modeling to meet the goals of this project.
- Task 3: Model selection and modification. This task focused on two activities: (i) selection of an appropriate model; and, (ii) modification of the model to meet project objectives. The task concluded with a memorandum that described the selection, formulation, and modification of the model. The GIFT model was selected as appropriate to use the data compiled in executing the research plan.
- Task 4: Model evaluation. This task evaluated the intermodal freight transport model developed in Task 3 using California-specific data compiled in Task 2. The task concluded with a technical memorandum written that described the evaluation of the model. This evaluation determined that GIFT can successfully use several data sets to evaluate the energy and environmental characteristics of goods movement related to port activity, and determined that origin-destination information recently provided to the ARB through independent contract could be used in the case study. Case study specifications were finalized in the model evaluation task.
- Task 5: Case study. This task involved development of a case study to illustrate the model performance for estimating international and domestic goods movement in all modes against available commodity flow data in a selected region of California. The case study compared environmental tradeoffs associated with alternate routing of goods movement through major state ports. The task concluded with a technical memorandum that described model performance for the case study, and provided recommendations on steps to improve, validate, or expand case study results.

This final report represents a summary of the project and is the final deliverable.

1.2 Background

California represents a major international gateway and domestic partner of goods movement for other states, and has become a leader in improving environmental and energy performance of transportation. U.S. reliance on the freight transportation system has been growing considerably for some time. (Bureau of Transportation Statistics, 2005; Greening, Ting, & Davis, 1999; Schipper, Scholl, & Price, 1997b; Vanek & Morlok, 2000) These trends are likely to continue in the coming decades due to increasing international and domestic trade. Many researchers expect that along with this increase in overall freight transport there will be an increase in intermodal freight transport (Arnold, Peeters, & Thomas, 2004; Ballis & Golias, 2002, 2004; T. Golob & Regan, 2001; T. F. Golob & Regan, 2000; Shinghal & Fowkes, 2002).

With increasing freight transport activity, it is expected that congestion, emissions, and energy use will increase at a similar pace (Komor, 1995; Koopman, 1997; Schipper, Scholl, & Price, 1997a). For example, currently, freight transport emits about 470 million metric tonnes of CO₂ (MMTCO₂) per year, or about 8.3% of fossil fuel CO₂ combustion emissions, and about 7.8% of total CO₂ emissions (U.S. Energy Information Administration, 2007; U.S. Environmental Protection Agency, 2006). Policymakers and planners must develop operational and infrastructure improvement strategies to increase the efficiency of freight movement to reduce demand for transportation fuels and mitigate environmental impacts (Nijkamp, Reggiani, & Bolis, 1997).

Operationally, intermodal freight transport sustainability is understudied both in terms of theory and application, and the environmental impacts of such transport are only beginning to be evaluated systematically (Bontekoning, Macharis, & Trip, 2004; Macharis & Bontekoning, 2004). Researchers need to develop new methodologies, data management techniques, and computing infrastructure, and to integrate these into analytical tools that can be used to improve planning and decision making. The model developed by our interdisciplinary team of researchers and transportation professionals can assist in improving the environmental performance of goods movement. The model uses currently available commodity flow, vehicle activity, emissions, and other data to describe ocean-going vessel, truck, and rail emissions associated with goods movement in and through the state. Moreover, it recognizes that freight data will improve over time and can flexibly accept best data for modes, ports, and transfer facilities. This model will provide capacity to evaluate alternative strategies to improve performance and meet targets for energy conservation, air quality, and CO₂ reduction. This work is consistent with California research objectives described in the 2007-2008 Air Pollution Research Plan (Mora & Barnett, 2007).

2 Methodology

2.1 Overview

This project closely relates to research our team has been conducting at the national and regional level. In particular, several projects for the U.S. Department of Transportation and the Great Lakes Maritime Research Institute co-funded an initiative to develop an intermodal freight network optimization model that is now named GIFT. The GIFT model was the first geospatial model to explicitly include energy and environmental objectives (e.g., least carbon emissions, least Particulate Matter (PM) emissions, least NO_x emissions, etc.) in its optimization routines (Falzarano et al., 2007; Hawker et al., 2007; Winebrake, Corbett, & Meyer, 2007). GIFT demonstrated an approach that allowed decision makers to quantify the energy and environmental impacts associated with freight transport, and importantly, to compare alternative modes and routes and their impact on a range of energy and environmental attributes. These comparisons allow for tradeoff analysis (e.g., least cost v. least carbon cargo flows).

Our current understanding of some of these models' benefits and limitations has proven to be valuable, particularly with regard to our development of GIS-network models for energy and emissions; we believe this is an advantage to ARB. A general approach of GIS-network models can be illustrated through a simple example. Figure 1 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 network segments (represented by lines connecting the nodes) may be accessible only by truck, or ship, or rail. Some points may be accessible by multiple modes. Nodes and segments 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 interport segments.

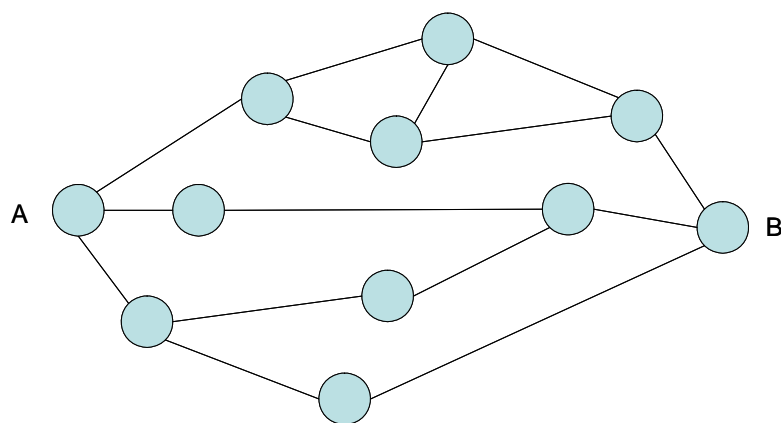


Figure 1. Example Freight Network from “A” to “B”

When developed to be a descriptive model of multimodal freight activity, we solve the network according to *least cost* transport of freight from A to B, a traditional context for the application of optimization routines. (Note that we use the term “cost” in a generalized optimization modeling context to reflect the objective that we wish to minimize for a given network analysis problem). To analyze routes, each route from node *i* to node *j* must include “attribute data” that helps characterize attributes along that route. That dataset could include information about mode accessibility, economic costs, average speed, distance, emissions, among others.

Recognizing the value of other GIS based freight analysis tools, such as the Freight Analysis Framework (FAF) and GeoMiler (Lewis & Ammah-Tagoe, 2007), we worked to explicitly integrate energy and environmental attributes into freight network analyses in GIS. This was the first time that a team fully integrated energy and environmental emissions attributes, such as carbon emissions, into the ArcGIS network analysis environment in order to conduct environmental impacts studies associated with freight movement. We applied these approaches regionally through a funded project to study the environmental characteristics of freight transportation in the Great Lakes Region.

By adding energy and environmental attribute information to segments of the national highway, rail, and waterway network, we can report environmental performance measures associated with current freight flows (Figure 3). In this way, such a model could directly address project requirements for this research. When run with existing freight route data, such a model could output the energy and environmental impacts associated with cargo flows along the network. In addition, the model could also be programmed to evaluate alternative cargo flow patterns that minimize energy consumption and emissions of CO₂, PM₁₀, NO_x, SO_x, and volatile organic compounds (VOCs) and compare these network solutions with

least cost or shortest distance intermodal routes for moving freight. This project's application of GIFT to evaluate CO₂ emissions brings significant power to ARB in terms of visualizing scenarios where future policy decisions may mitigate infrastructure capacity constraints or otherwise improve multimodal infrastructure for goods movement.

2.2 The GIFT Model

All of these principles have been used by our team to develop a current model we call the Geospatial Intermodal Freight Transport (GIFT) Model (Figure 2) that we have identified for use in this project. We configured the GIFT model with California-specific data (transportation networks, intermodal transfer facilities, and attributes of trucks, trains, and ships) that is responsive to ARB requirements. We built GIFT in ArcGIS 9.3 using ArcGIS Network Analyst on top of previous research and existing work for the Great Lakes. To date, the intermodal network construction uses road, rail, and waterway features from the 2005 version of the National Transportation Atlas Database (NTAD), currently maintained by the US Department of Transportation's Bureau of Transportation Statistics (BTS). NTAD also includes data on intermodal facility locations, although this project identified other data sources.

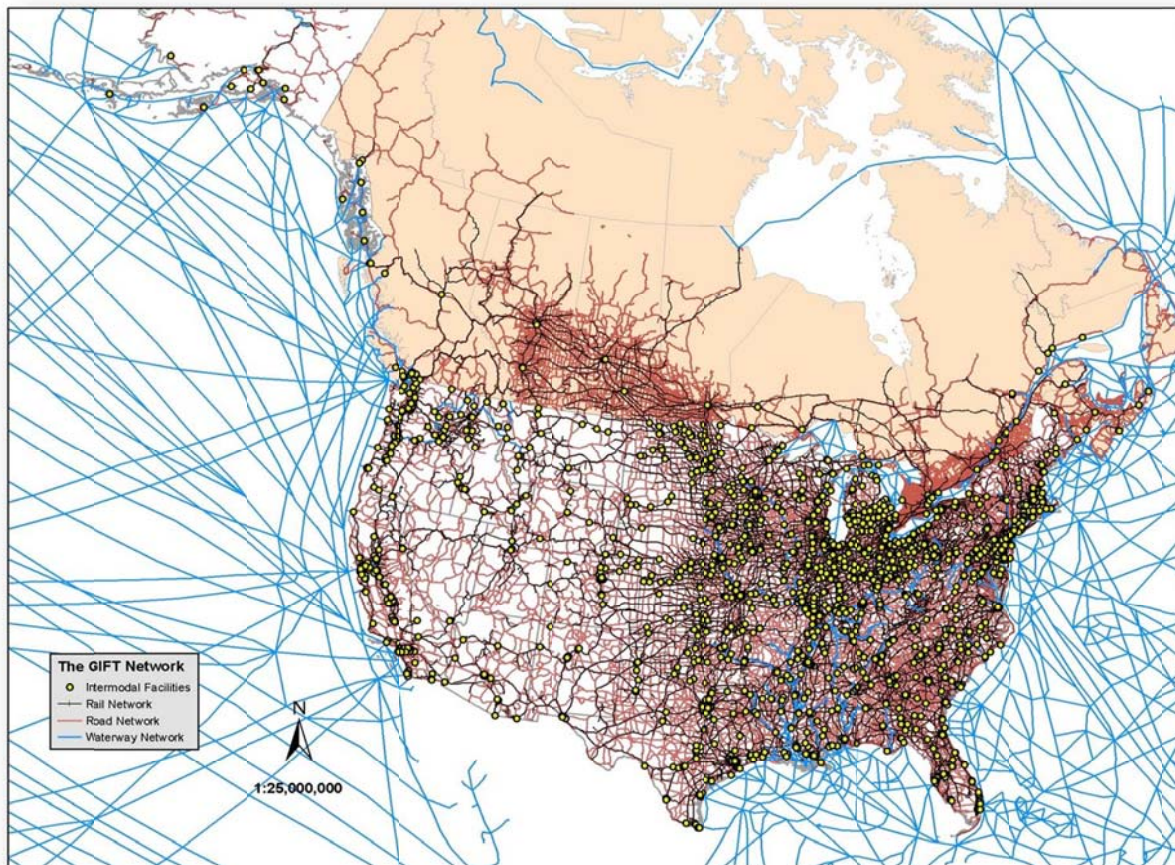


Figure 2. The GIFT Intermodal network

The key to building the intermodal network is to create nodes (modal transfer points) where the independent modal networks (road, rail, and waterway) intersect at an intermodal facility. We created geographic data features (arcs) to describe: (1) road-to-facility connections; (2) water-to-facility connections; and (3) rail-to-facility connections. This construct allows freight to transfer from one freight mode to another through these intermodal transfer facility connection arcs. In addition, we created

attributes for each intermodal arc that account for cost, time, energy, and emissions associated with such transfers (Figure 3).

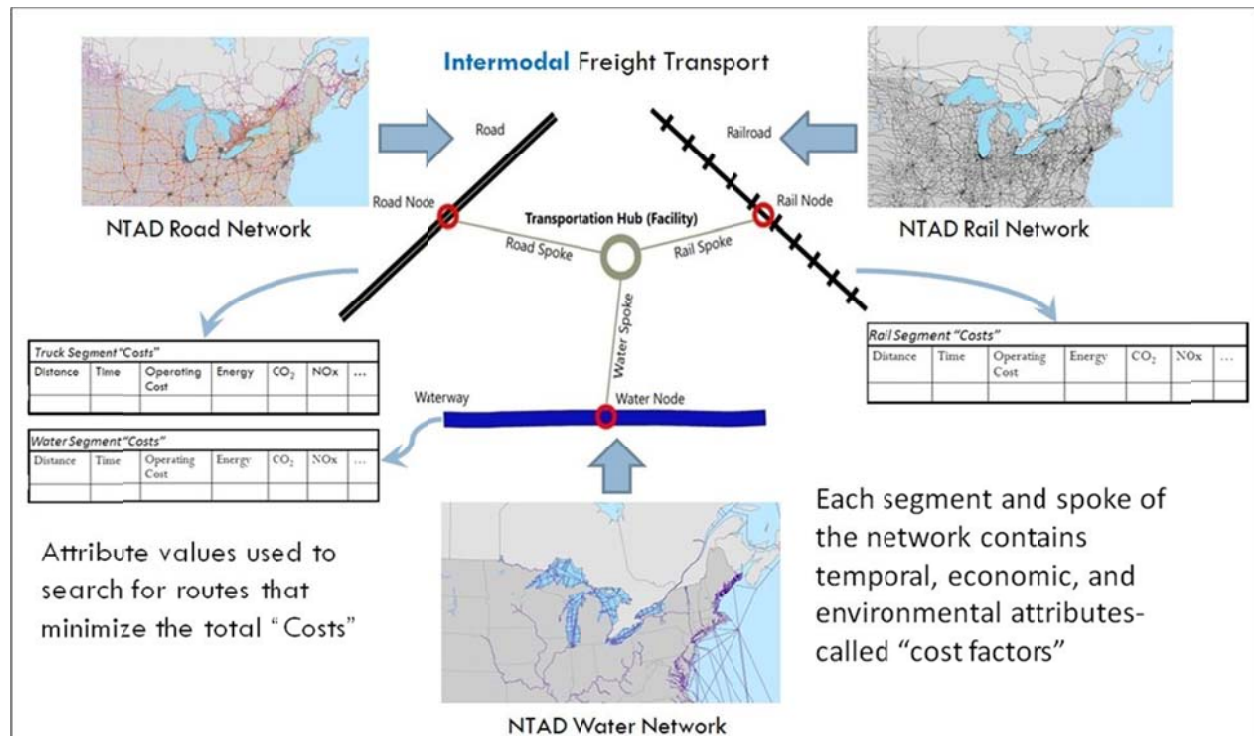


Figure 3. Connecting Road, Rail and Waterway networks at Intermodal Facilities

The GIFT team discussed ArcGIS environment network functions in related work for East Coast and Great Lakes domains (Hawker, et al., 2007). An example of the analysis tools we integrated and developed is presented in Figure 4 an *integrated intermodal transportation network example* for a part of the U.S. Eastern Seaboard. This map shows three "shortest paths" through the network for cargo traveling from Buffalo, NY to Miami, FL. Each shortest path uses a different optimization variable, usually resulting in a different route and combination of transportation modes. The blue line represents the *least-time of delivery* route which primarily uses highway to deliver freight to Miami. The green line represents a *least carbon* route that includes both rail and trucking in an intermodal context, with appropriate intermodal transfers. Finally, the brown line represents the *least cost* route that combines some landside and waterside segments. Environmental emissions, energy use, time-of-delivery, and cost values for each of these routes are calculated by GIFT, thereby allowing decision makers to evaluate tradeoffs and explore various kinds of infrastructure development alternatives (the potential to take landside-highway and rail, and waterside networks to create an intermodal network for freight transport).

By integrating total cargo flow data into the model, we provide the ability to explore not only the energy and environmental impacts of such flows, but also alternative flow patterns that minimize key decision objectives, such as least carbon, least PM, and least energy-consumption.

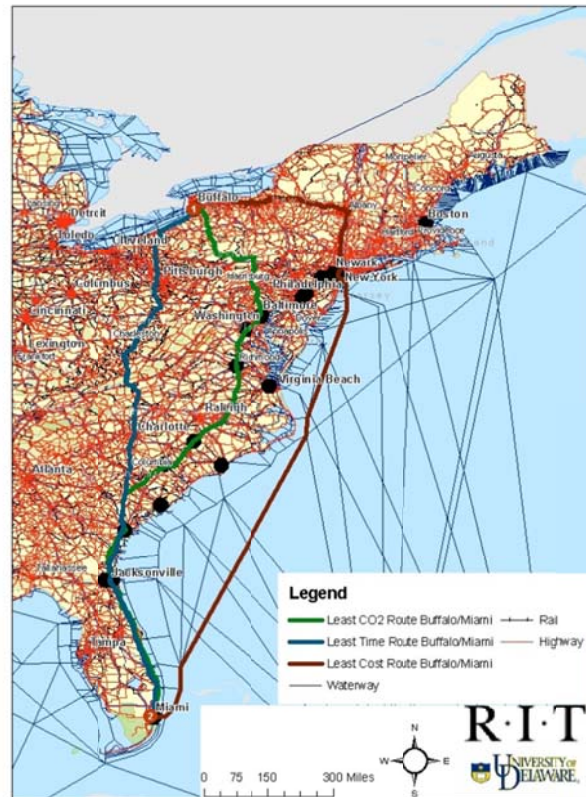


Figure 4. Intermodal Freight Transport Model Example

2.3 Structure of the GIFT Model

The basic structure and use of the GIFT model is summarized in Figure 5. This section describes details of the data items selected to construct and configure a version of GIFT that facilitates understanding the impacts of port-generated traffic in California and enables case study analysis of the trade-offs of various policies.

Data used in GIFT include the following:

1. Geospatial data for transportation networks
 - a. Roadways
 - b. Railways
 - c. Waterways
2. Geospatial data for intermodal transfer facilities
 - a. Ports
 - b. Railyards
 - c. Truck terminals
 - d. Which transportation network segments the transfer facilities connect
3. Operational characteristics of road, rail, and waterway traversal
 - a. Speeds
 - b. Operating cost

4. Operational characteristics of transfer facilities
 - a. Time associated with intermodal transfers and other delays such as reconfiguring trains in a rail yard or queuing containers at a port
 - b. Operating cost
5. Emissions and energy of vehicles on transportation networks
 - a. Emissions of CO₂, Particulate Matter, and other criteria pollutants
 - b. Energy consumed by vehicles
6. Emissions and energy of transfer facilities operations
 - a. Emissions of CO₂, Particulate Matter, and other criteria pollutants of cargo handling equipment, vehicle support equipment (such as ship hoteling power) and other facility operations
 - b. Energy consumed by cargo transfer operations
7. Freight flows
 - a. Originations and destinations of cargo entering or leaving California ports
 - b. Volumes of cargos along the various origination and destination paths

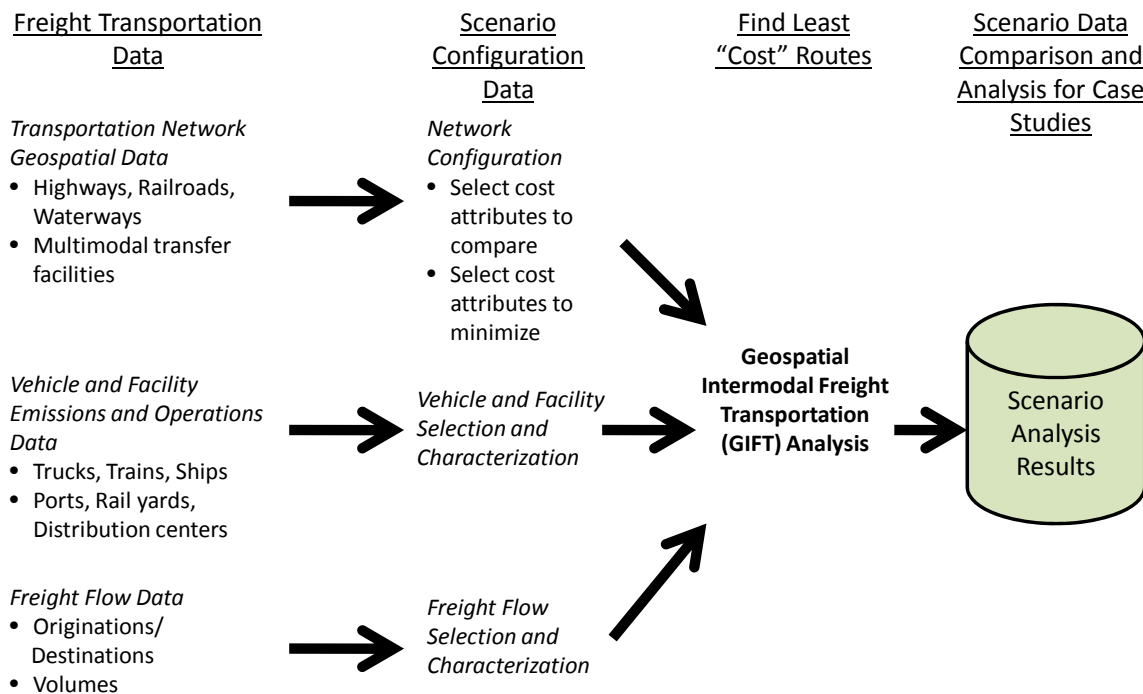


Figure 5. Structure and Use of the GIFT Model

2.3.1 Transportation "Costs"

A primary purpose of the GIFT model is to use operational costs, time-of-delivery, energy use, and emissions from freight transport to evaluate tradeoffs among these criteria in an intermodal routing context. To accommodate a wide variety of operational scenarios, we developed multiple ways to define, manage, and use "costs." The main concept was to associate these costs with traversing each segment of the transportation network, and to provide multiple ways to make the specific route cost depend on the vehicle type, fuel choice, operational and governmental policy in force, and other scenario attributes. Figure 6 illustrates various costs of traversing segments in the network. Different ways to model these

costs serve different modeling needs, and it is important to understand which options are incorporated into a given model and how they are used at run-time to compute transportation costs.

In ArcGIS, these costs are defined as network attributes in the network geodatabase. Some attributes are predefined in the network datasets and have fixed values (such as the distance attribute), some are predefined attributes whose values can change (such as using posted highway speed limits or observed truck speeds for different speed values along different highway segments), and some are attributes added specifically to support GIFT (emissions, speed). The impacts of transportation through intermodal facilities are similarly captured as attribute values on “spokes” created to model intermodal transfers, where attribute values model the impact of freight handling equipment, facility energy use, delays loading and unloading ships, etc.

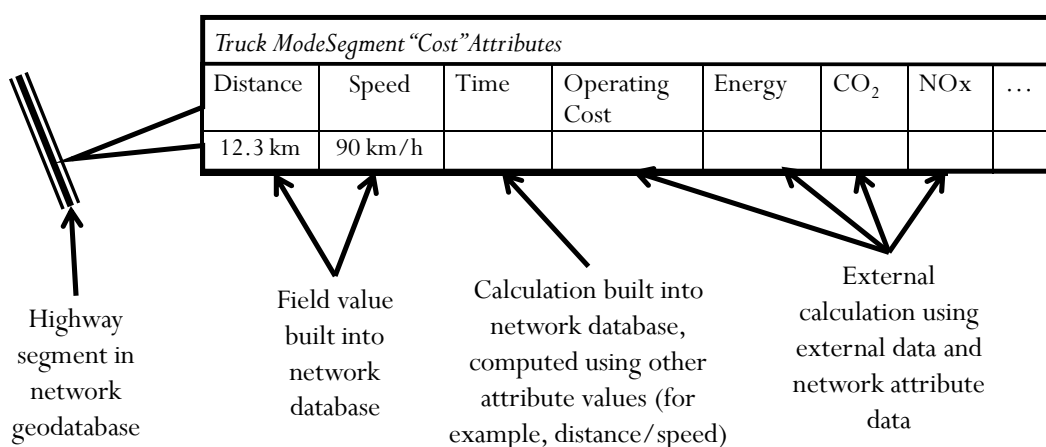


Figure 6. "Cost" attributes associated with transportation network segments

The values for network attributes can be accessed during network analysis run-time (that is, during least-cost optimization or during computations of route data for determined routes) in multiple ways, depending on the data used and their source. Some data are stored statically in the network geodatabase (such as segment distance or posted speed limit), some are computed using Visual Basic scripts embedded into and stored with the database (using ArcCatalog and ArcGIS Network Analyst utilities), and some values are computed using external computations (“custom evaluators” in Network Analyst terminology) that we implemented as C# program components registered in the ArcGIS run-time framework. The embedded computation evaluators can use any data defined as attributes in the network model, whereas the custom evaluators can also access external data and computations. Assigning attribute values or associating evaluators with attributes is performed using ArcCatalog while building the transportation network geodatabase.

Most of the attribute values are computed using custom evaluators that access data that the analyst can modify to reflect differing operational scenarios. The model incorporates a user interaction and data management tool, illustrated in Figure 7, to define and manage cost factors used by the external evaluators. For roadway, waterway, and railway attributes, the custom evaluator simply multiplies the segment distance by the configured cost factor. Values obtained from other sources (e.g., California-specific values and settings) can be entered, saved and reused across multiple analyses.

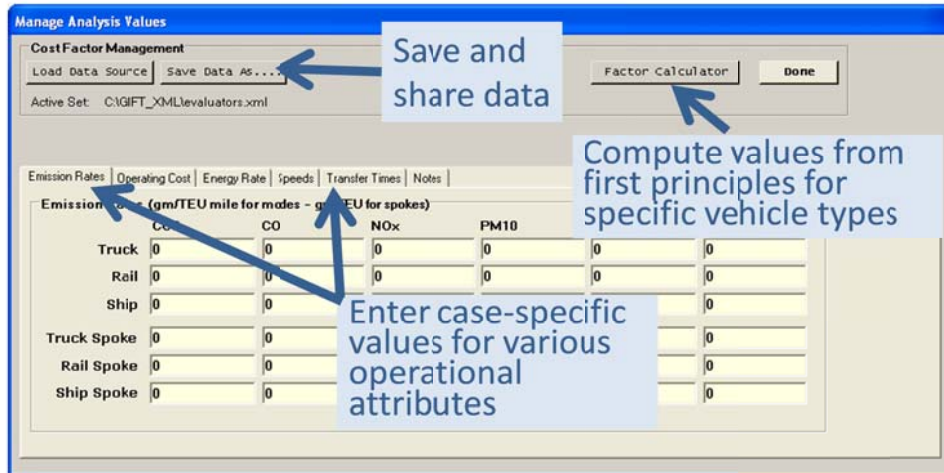


Figure 7. Tool to define and manage case study analysis values.

GIFT also provides a tool to compute the emissions for specific types of trucks, locomotives, and marine vessels, and to manage libraries of these vehicles that the analyst can select when defining a case study scenario (Figure 8). This tool uses first principle models of energy efficiency, fuel content, and other equations to compute energy and emissions. The computed emissions and energy consumption rates are then used in the custom evaluators that Network Analyst uses to determine route optimizations. The computed emissions rates feed the cost factor data that ArcGIS Network Analyst uses to determine the routes that minimize selected emissions, time, and operating costs and accumulates these costs as attributes for each route. For more details on the bottom-up calculation of emissions and energy rates of transportation modes, see *Appendix E*. We also have similar bottom-up tools to characterize freight handling equipment and its operational use for transfer facilities. Emissions values can be entered directly from data obtained elsewhere, or GIFT can use more detailed emission factor calculators to characterize vehicle and facility emissions.

Emissions Calculator

Truck Inputs ☒ Use Truck Calculator

6	MPG	7	Tons per TEU	0.2	g/tp-hr Out NOx
0.86	Carbon Content	0.42	Engine Efficiency	0	NOx Control Efficiency
128450	Energy Dens btu/gal	15	Sulfur Content PPM	0.01	g/tp-hr Out PM10
3167	Mass Dens g/gal	0	SOx Control Efficiency	0	PM10 Control Efficiency
2	TEUs per load				

Load Save Save to Library

-- PredefinedTruck --

Truck Outputs

gCO2 / TEU Mile:	833
btu (in) / TEUMile:	10704
gSOx / TEU Mile:	0.008
gNOx / TEU-mile:	0.353
gPM10 / TEU-mile:	0.018
gCO2 / Ton Mile:	119
btu (in) / Ton Mile:	1529
gSOx / Ton Mile:	0.001
gNOx / Ton Mile:	0.05
gPM10 / Ton Mile:	0.003

Rail Inputs ☒ Use Rail Calculator

8000	Engine HP	0.86	Carbon Content	5.5	g/tp-hr Out NOx
100	# of Container Wets	128450	Energy Dens btu/gal	0	NOx Control Efficiency
4	TEUs per Vwell	3167	Mass Dens g/gal	0.2	g/tp-hr Out PM10
7	Tons per TEU	25	MPH	0	PM10 Control Efficiency
0.4	Engine Efficiency	15	Sulfur Content PPM		
0.7	Load Factor (Engine %)	0	SOx Control Efficiency		

Load Save Save to Library

-- PredefinedLocomotive --

Rail Outputs

gCO2 / TEU Mile:	277
btu (in) / TEUMile:	3562
gSOx / TEU Mile:	0.003
gNOx / TEU Mile:	3.08
gPM10 / TEU Mile:	0.112
gCO2 / Ton Mile:	40
btu (in) / Ton Mile:	509
gSOx / Ton Mile:	0
gNOx / Ton Mile:	0.44
gPM10 / Ton Mile:	0.016

Ship Inputs ☒ Use Ship Calculator

3071	Engine HP	0.86	Carbon Content	5.4	g/tp-hr Out NOx
221	TEUs per Ship	128450	Energy Dens btu/gal	0	NOx Control Efficiency
7	Tons per TEU	3167	Mass Dens g/gal	0.15	g/tp-hr Out PM10
0.4	Engine Efficiency	13.5	MPH	0	PM10 Control Efficiency
0.8	Load factor (Engine %)	15	Sulfur Content PPM		
		0	SOx Control Efficiency		

Load Save Save to Library

-- PredefinedShip --

Ship Outputs

gCO2 / TEU Mile:	408
btu (in) / TEUMile:	5237
gSOx / TEU Mile:	0.004
gNOx / TEU Mile:	4.447
gPM10 / TEUMile:	0.124
gCO2 / Ton Mile:	58
btu (in) / Ton Mile:	748
gSOx / Ton Mile:	0.001
gNOx / Ton Mile:	0.635
gPM10 / Ton Mile:	0.018

Load Values Save Values Done Cancel Reset to Defaults

NOTE: Percentage inputs are entered with a leading zero. Example: 20.5% would be entered 0.205

Figure 8. Computing Emissions and Energy from First Principles

2.3.2 Transportation Network Geospatial Data

The team evaluated over ten different GIS databases for the North America multimodal network (Table 1) for use in the CAL-GIFT project. NTAD, USACE, GeoGratis, Natural Resources Canada, Loadmatch Intermodal, and various company/regional port and railroad directories are open access databases, although several of these were not GIS-ready at the onset of the project. Only NTAD was found to contain all the elements needed to create a fully functional multimodal model. NTAD is built at essentially 1:100,000 scale, and is updated annually, although many of these edits are minor. NTAD lacked assigned speeds on the network segments, resulting in the need to assign estimated speeds based on road class (the FCC variable in NTAD road network). The rail and water segments were assigned a constant speed, based on a class variable for rail and waterway type and distance from a port for water. Web sources, such as Railroad Performance Measures were utilized to help refine track speed.

Upon a visual analysis of the accuracy of the Facilities data provided by NTAD, the team determined that at least 10% of the points are moderately to severely misplaced (over 1 km off). Misplacement was due to the use of mailing addresses instead of the physical location of the transfer facilities and/or incorrect latitude and longitude coordinates for the facilities (data entry errors or reporting errors). Additionally, an unknown number of facilities were not included in the database, but are clearly visible in Google Earth. To address these issues, company and organizational websites, like the Load Match Directory and the related Drayage Directory, were used to recreate the major transfer facilities in North America. More details are discussed in the Intermodal Facilities Geospatial Data section 2.3.3.

Table 1. Databases evaluated for Cal-GIFT Project

DATABASE	ROAD	RAIL	WATER	FACILITIES
National Transportation Atlas Database (NTAD)	Yes	Yes	Yes	Yes
US Army Corps Engineers (USACE)	No	No	Yes	Yes
Streetmap USA (2008 TeleAtlas)	Yes	Yes	No	No
STEEM (University of Delaware)	No	No	Yes	Yes
ALK (ALK Technologies, www.ALK.com)	Yes	No	No	No
GeoGratis/National Resource Canada	Yes	Yes	Yes	No
GeoBase Canada (high detail)	Yes	No	Yes	No
Land Information Ontario (Canada)	Yes	No	Yes	No
Loadmatch Intermodal (www.loadmatch.com)	No	No	No	Yes
The Drayage Directory (www.drayage.com)	No	No	No	Yes
Railroad Performance Measures http://www.railroadpm.org/home/rpm.aspx	No	Yes	No	Yes

The waterway network utilized the STEEM database from the University of Delaware, which is an international shipping database that describes ocean shipping lanes. Close to shore and inland, however, the NTAD and USACE data for waterways are more precise. The GIFT team combined the STEEM, NTAD, and USACE waterways, using STEEM outside of a 20 km buffer from the US coastline. NTAD and USACE data are used near shore and for river networks. The ports database of the USACE and STEEM were used to help determine major intermodal port facilities.

Apart from the open access databases, the proprietary databases that were evaluated included the Streetmap USA (2008) database and the ALK database. The Streetmap USA database includes posted speed limits as an attribute for the road segments, typically assigned by road class. Streetmap USA classifies roads based on a use/volume hierarchy that is independent of the posted speed limit. The proprietary ALK database provides average empirical speed data based on GPS observation records, as opposed to posted speed limits. Additionally, the ALK data contain attribute information on speed by traffic flow direction. Both Streetmap USA and NTAD provide comparable rail networks (there are minor geographic differences between the two), but neither database includes rail speeds by segment. While these proprietary databases contain additional information, they were considered to be too fine-grained for the project purpose, possibly resulting in computing performance problems, and the added detail was deemed not necessary for regional flow studies.

The GIFT transportation network data for highways, railroads, and waterways is thus based largely on the NTAD 2008 data (www.bts.gov/publications/national_transportation_atlas_database/2008/), which is a compilation of data including the National Highway Planning Network, the U.S. Army Corps of Engineers Navigable Waterway Network, and the National Railway Network). These data are at an appropriate level of granularity for regional and national flow studies, they are geo-referenced with the transfer facility data we use, and they have been validated in other GIFT projects.

2.3.3 Intermodal Facilities Geospatial Data

Transfer facility locations and supported mode type data were derived originally from the “Intermodal Terminal Facilities” NTAD 2008 data set. Focusing on California facilities, this data set was validated by visual inspection of the reported location using Google Earth. Google Earth’s bird’s eye view of geographical features allowed visual analysis of each point location to see if it either falls on or is close to something that looks like a facility (Figure 9). If this was found to be the case it was recorded as “verified”. The “TYPE” and “MODE_TYPE” fields in the facilities shapefile metadata indicate the primary transportation mode designated for the facility, and supported modes of traffic respectively. These data acted as clues as to what should be seen in Google Earth for a given facility. For instance, if a facility is a major rail depot that also handles truck traffic, then railroads, railcars, and trucks should be

recognized somewhere close to or on the point representing the facility. If a facility falls on a residential street clearly marked by the rooftops of homes and backyard swimming pools, then something is clearly wrong with the location of the facility. Thus the mode types supported and the facility location were adjusted as necessary, and the data were augmented and further validated with additional facility information derived from publicly available web sites including Loadmatch (www.loadmatch.com) and Railroad Performance Measures (<http://www.railroadpm.org/>), as well as major transportation company websites, such as Union Pacific (<http://www.uprr.com/customers/intermodal/intmap/index.shtml>).

Further details on how the facility data were validated are contained in *Appendix C*.

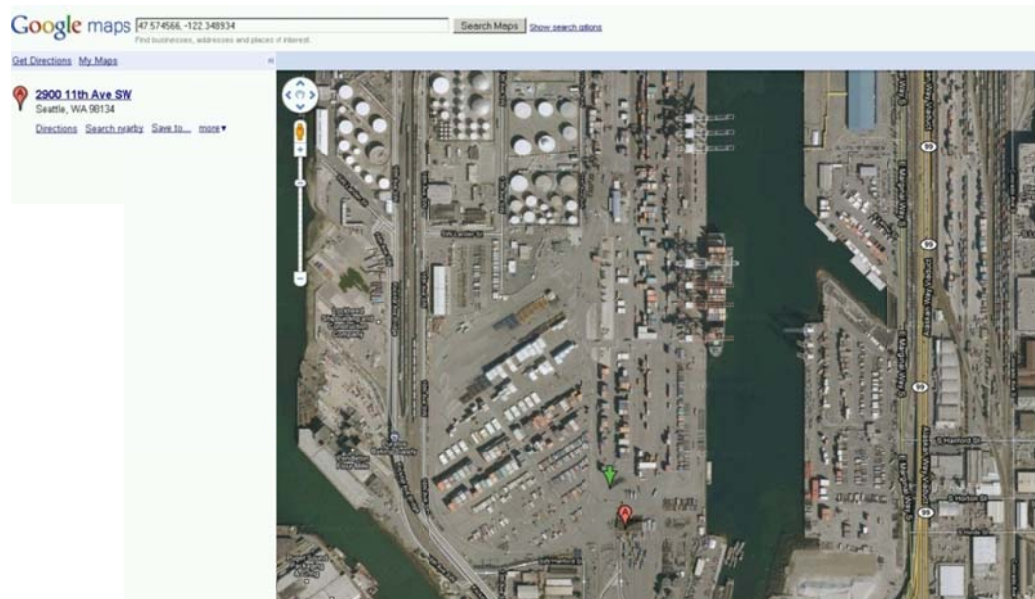


Figure 9. Verifying Facility location using Google Earth

2.3.4 Operational Characteristics

A very wide variation can occur in the operational performance of different vehicles and facilities in the freight transportation system, and the characteristics chosen for a given case study depend on the goals of that case study. Because of this, we have designed GIFT to allow the case study analysts to configure GIFT with the performance characteristics appropriate for their specific case study. Figure 10 illustrates how GIFT allows, through a GUI (graphical user interface), case study analysts to enter operational characteristics specific to a given scenario in their case study that may differ from current default values. Data entered would be derived from sources specific to a case study or from sources identified in Table 10 in Appendix C.

As mentioned before, truck segment speeds are based on the road class from NTAD (U.S.) and Canadian roads. Commercially available road databases have observed speeds, but this project opted to use publicly available data. Rail segment speeds are a constant value across the network, based on the literature, since rail companies have not made available GIS databases with posted or actual speeds. Marine vessel speeds are tied to the vessel characteristics, except near ports where waterway segment speeds are values stored in the waterway geodatabase, derived from the STEEM network for intercoastal and international water segments. One speed is used within 20 km of the shore, and the vessel speed (representing higher sea-speed) is used for off-shore operations.

Vehicle speed data for the highway network starts with the road classification in the NTAD network (the FCC variable) as default values. For train and ship speeds, the analysts can use the tool illustrated in Figure 10 (the “Speeds” tab) to define a speed to use throughout the network. Data from sources such as Railroad Performance Measures (<http://www.railroadpm.org/>) provide default values of speed and transfer/dwell time for GIFT. We seek to extend GIFT to allow segment-specific and locomotive or vessel-specific variations for rail and water modes as is available for on-road networks, but that is beyond the scope of our current research. The methods we develop in related GIFT research to use segment-specific truck speed will inform our future research on using more granular rail and waterway network speed data.

Operating costs can be computed using custom evaluators, with cost per mile or per facility transfer configured using the form shown in Figure 10 (Operating Cost tab). Modal operating costs for each segment can be derived from various studies, typically in \$/TEU-mile or \$/ton-mile. Additionally, intermodal transfer costs can reflect port cost and local drayage costs. No California-specific cost data were provided for the case study in this project, given ARB’s direction to focus this project effort on emissions – particularly CO₂ emissions from goods movement.

Additionally, total hours of travel can be computed for a given route, given that the GIFT model sums travel time on each segment of the route and the time it takes to transfer between modes (if such transfers exist on the route). For transfer facilities, a default penalty for each spoke is currently assumed, and no California-specific times were identified for in-state intermodal transfers. GIFT allows spoke time values to be changed using the form illustrated in Figure 10.

The figure consists of three screenshots of a software interface titled "Manage Analysis Values".

- Top Left Screenshot (Operating Cost tab):** Shows the "CostFactor Management" section with "Load Data Source" and "Save Data As..." buttons. The "Active Set" is "C:\GIFT_XML\evaluators.xml". Below are tabs for "Emission Rates", "Operating Cost", "Energy Rate", "Speeds", "Transfer Times", and "Notes". The "Operating Cost (USDollars/TEU mile for modes - USDollars/TEU for spokes)" section is active, showing a table of costs in US Dollars:

Mode	Cost (USDollars)
Truck	170
Rail	160
Ship	120
Truck Spoke	200
Rail Spoke	200
Ship Spoke	500
- Top Right Screenshot (Speeds tab):** Shows the "Speed (MPH)" section with input fields for:

Truck	50
Rail	25
Ship	20
- Bottom Screenshot (Transfer Times tab):** Shows the "Transfer Times (in hours)" section with input fields for:

Truck Spoke	1
Rail Spoke	1
Ship Spoke	1

Figure 10. Defining Operational Characteristics

2.3.5 Modeling Rail Dwell Times

In a separate project, the GIFT team has begun to characterize potentially significant time penalties associated with dwell times at major intermodal terminals, such as rail terminals, port terminals, and truck terminals – a subset of intermodal connections where in-route freight storage may occur before transfer. Specifically, a U.S. DOT project identified initial dwell conditions generic to rail terminals, although these are not California-specific. According to the Railroad Performance Measures website, maintained by six major US rail freight carriers, “Terminal Dwell is the average time a car resides at the specified terminal location expressed in hours. The measurement begins with a customer release, received interchange, or train arrival event and ends with a customer placement (actual or constructive), delivered or offered in interchange, or train departure event. Cars that move through a terminal on a run-through train are excluded, as are stored, bad ordered, and maintenance of way cars” (<http://www.railroadpm.org/Definitions.aspx>).

Major terminals from each of the major rail freight carriers can be identified from the carriers’ own website maps and positioned using Google Earth coordinates. Dwell times may be assigned to each of these points, e.g., determined from the Railroad Performance Measures website.

Figure 11 illustrates potential dwell points surrounding the Ports of Long Beach and Los Angeles (LA-LB) using overlapping five-mile buffers. In most cases, the dwell time assigned to a point represents half of the total reported dwell time, so that a route accumulates the total dwell penalty after entering and leaving the dwell buffer area. In this LA-LB example, however, total dwell times would be assigned to the dwell points because the rail lines emanate from or terminate at the port. There are no rail lines simply passing through the buffer, as would be the case for a rail line within the interior of the US. To make this approach California-specific, ports should be examined for this characteristic and dwell times adjusted as needed (either being assigned the total dwell penalty if the route only passes through a single dwell point or a half value if the route passes through two points). The case study settings have generic defaults from the U.S. DOT project and therefore time accumulations would be considered prototype and are not reported as results for this case study. Given that rail segment speeds are much lower than road segment speeds on highways, the inclusion of default dwell buffers helps avoid rail in the least-time scenario but does not determine the route differences between least-time and least-CO₂ case study runs.

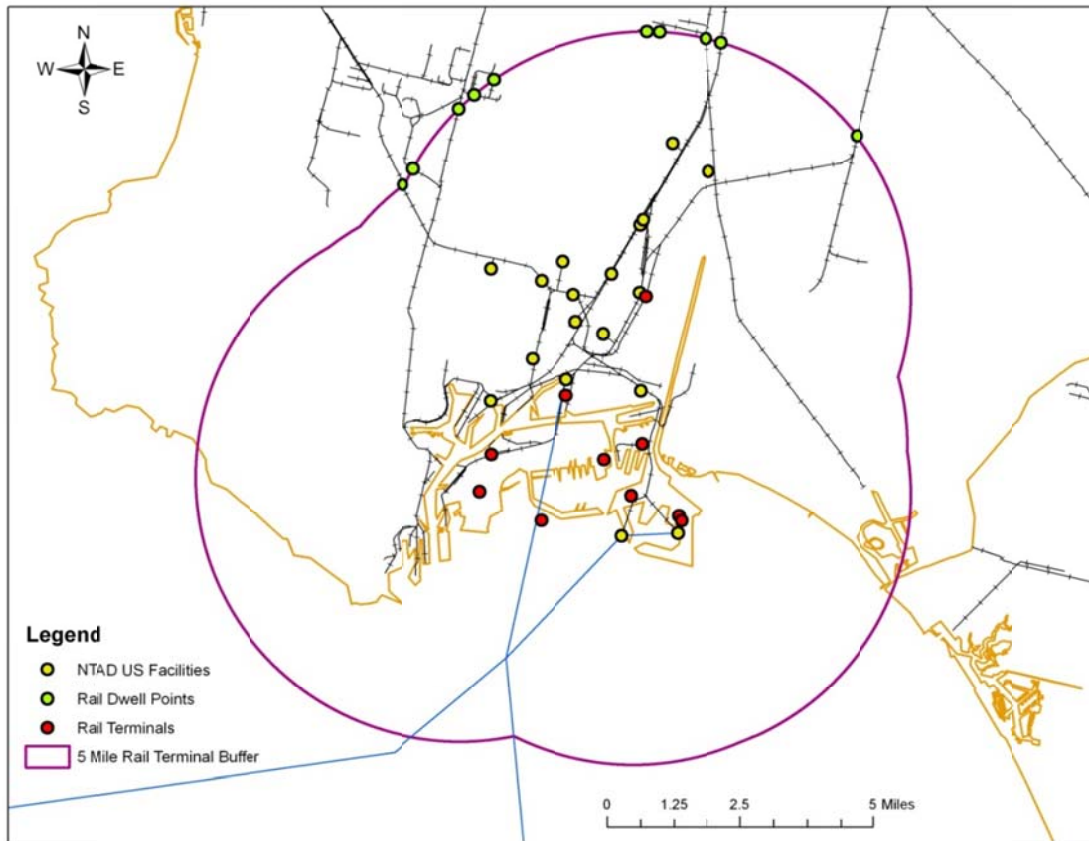


Figure 11. Modeling Dwell for the Port of LA-Long Beach

2.3.6 Origin- Destination Freight Flow Data

An important part of understanding the impacts of port-generated traffic in California is a characterization of the originations and destinations (O/Ds) of freight to and from the California ports, and the volume of freight between those locations. Some of the O/D data represent goods movement within the region of the port, characterizing drayage operations between the port and local truck terminals where the freight is reconfigured for O/Ds beyond the region. Some of the data characterize statewide and nationwide transportation of freight to and from the California ports. Some of the data characterize first drops.

In this project the research team has enhanced GIFT to take as batch input a table of originations, associated destinations, and their freight volume values to compute cost-optimal routes (cost: emissions, time, operating cost, etc.) between those locations and then present cumulative (freight-flow weighted) emissions, energy, and operating cost impacts for these multiple O/D-volume sets. Using this new GIFT capability, case-study analysts can select O/D-volume sets or subsets appropriate to their study.

We also constructed origin-destination data for this project involving cargo flow for California. For details regarding the creation of the freight volume flow, refer to Appendix F. These data have been formatted into event tables for import in the GIFT model. Concurrent with this project, we developed GIFT to process batch origin-destination pairs from O/D input files using Network Analyst in ArcGIS, with routes named for and organized by the port of origin and the destination. These routes contain the emission and cost outputs from the model and can be linked to the freight volumes determined for each O/D pair.

The O-D pair data can be supplemented with the Army Corps of Engineers Entrance and Clearance data based on a vessel's International Maritime Organization (IMO) identification number to quantify the volume of container traffic entering and leaving the port. The Entrance and Clearance data can be linked to vessel-specific data compiled by classification societies such as Lloyd's registry of ships to provide details concerning operational characteristics of these vessels. Eastern Research Group (ERG) linked the two datasets together for other projects and typically can match 90 to 95 percent of vessels to their vessel characteristics. The Entrance and Clearance data also documents the previous and next port of call, which will provide reasonably accurate mapping of international cargo traffic patterns. These data are used to map out individual vessel movements, and this information can be applied to GIS tools to quantify distance between ports. This distance value can be divided by the vessel's speed as noted in the Registry of Ships to calculate hours of operation between ports. These transit times will have to be adjusted to account for operations in reduced speed zones and congestion while approaching and operating within ports.

According to our current data sources, most freight to/from California ports is not originated or destined for the port vicinity, rather, it moves to/from locations throughout California and the U.S. First drop or drayage data in the port region to a transfer facility for reconfiguration or mode change provides one set of O/D-volume data. The Freight Analysis Framework (FAF2) and the Commodity Flow Survey (CFS) data from the U.S. Department of Transportation Bureau of Transportation Statistics (http://www.bts.gov/publications/commodity_flow_survey) provide information on freight flows beyond the port region.

FAF2 and CFS provide data from the LA-LB and other port regions to and from final and original destinations. These locations are both those within the LA-LB Core Based Statistical Area (CBSA) and anywhere in the remaining US either by state, metropolitan area, or other geographic reference. For example, specific metropolitan area data are provided for the San Jose–San Francisco–Oakland, California CBSA, San Diego–Carlsbad–San Marcos, California Metropolitan Statistical Area (MSA), Sacramento–Arden–Arcade–Truckee, CA–NV CBSA (California Part), and Los Angeles–Long Beach–Riverside, California CBSA, with an aggregated entry for “remainder of California.” For locations designated as “remainder of state,” a location was selected as the centroid of the region (state, county), placed at an NTAD transfer facility nearest to that centroid location or at a probable transfer location based on a visual inspection of the road and rail data and Google Earth imagery.

For near-port traffic, ARB has provided a sample of survey data on drayage trips, that is, trips from the ports to the first stop in the LA-LB area. The ARB survey data provided address information for destinations. Many of the addresses provided were to freight company administrative offices and not the warehouse locations. This sample data set has been reviewed and best GIS positional match to actual warehouses was completed as a trial run for the batch mode of the model. As more complete and accurate regional O/D-volume data become available, a similar approach to validating that data and incorporating them into the California GIFT O/D-volume data sets can be performed.

For a given case study, analysts can select the O/D-volume data derived from the FAF2, CFS, and regional data provided in the California configuration of the GIFT model, or the analysts can incorporate other data that may be provided. Combining these data, the research team can model the trip from the port to the first stop and from these drayage points to final destinations.

2.4 Evaluation of the freight flow origination and destination and volume model

Freight flow data are derived from U.S. Commodity Flow Statistics (CFS) and Freight Analysis Framework, Version 2 (FAF2) data. The geographic location of originations and destinations were aligned with intermodal transfer facilities to provide realistic routes and to ensure that route selection did

not favor one mode over another. We evaluated a number of disaggregation methods to provide a refined geographic location for flows. For origination and destination pairs (O/D pairs) outside of California (the “remainder of state” locations of CFS and FAF2), we distributed flow volume to major cities in the state not explicitly identified as Combined Statistical Areas and Metropolitan Statistical Areas (CSAs/MSAs). For O/D pairs with an origination or destination in California, these data were disaggregated based on population. Table 2 summarizes the disaggregation approaches, and Appendix B provides more detail on these disaggregation methods as well as how O/D pair locations are aligned with intermodal transfer facilities.

Table 2. Approaches to disaggregate flow data

Approach	Within CA	Outside CA	Datasets
1	Same as approach for “outside CA”	<u>Distribution</u> from CFS O/D pairs; facilities located in major cities for CSAs; for “remainder of” we distributed to other large cities in the region equally; identification of other cities was somewhat arbitrary; <u>destination</u> at intermodal facilities in the cities OR at retail locations within the city.	CFS
2	<u>Distribution</u> by county in CA based on population of the county; <u>destinations</u> are determined by selecting an intermodal facility that is in the largest city within each county, or a warehouse or retail center within the largest city within each county if no intermodal facility exists.	Same as approach 1	CFS
3	<u>Distribution</u> by incorporated city within the LA/LB region (only) based on population to demonstrate; outside of LA/LB we apply approach #2; <u>destinations</u> in incorporated cities would be at intermodal facilities OR retail locations if no intermodal facilities exist.	Same as approach 1	CFS
4	<u>Distribution</u> from Cambridge Systematics disaggregation of the FAF2 dataset; <u>destinations</u> are identified as in approach #2 to identify destination locations for network modeling.	<u>Distribution</u> from Cambridge Systematics FAF2; <u>destination</u> based on approach 1.	Cambridge Systematics/FAF2

The different methods provide substantially similar results. For the case study, ARB proposed to use approach #4, as it provides the resolution we need with recently-available data outside of California, and appropriate disaggregation within California. As GIFT is data independent, it was straightforward to

incorporate the ARB-provided Cambridge Systematics freight distribution data in a freight flow analysis scenario. The ability to incorporate alternate data is what makes GIFT unique. It can provide accurate estimation of the environmental impacts of freight transport, provided it has accurate data to work upon.

3 Case Study

Using the GIFT model and California-specific model inputs, a detailed Case Study evaluates CO₂ emissions from port-associated goods movement, by focusing on four major West-Coast ports in three regions. The three port regions chosen for the study are:

- **Northern California:** Port of Oakland
- **Southern California:** Port of Los Angeles and Port of Long Beach
- **Northwest:** Port of Seattle

These three port regions accounted for 52 percent of the total container imports to the U.S. for 2008 (Bureau of Transportation Statistics, 2008), making them a natural choice to include in the Case Study to model the effects of containerized freight movement (see Figure 12). The Case Study is concentrated on CO₂ emissions differences between least-travel-time (least-time) v. least-CO₂ routing choices.

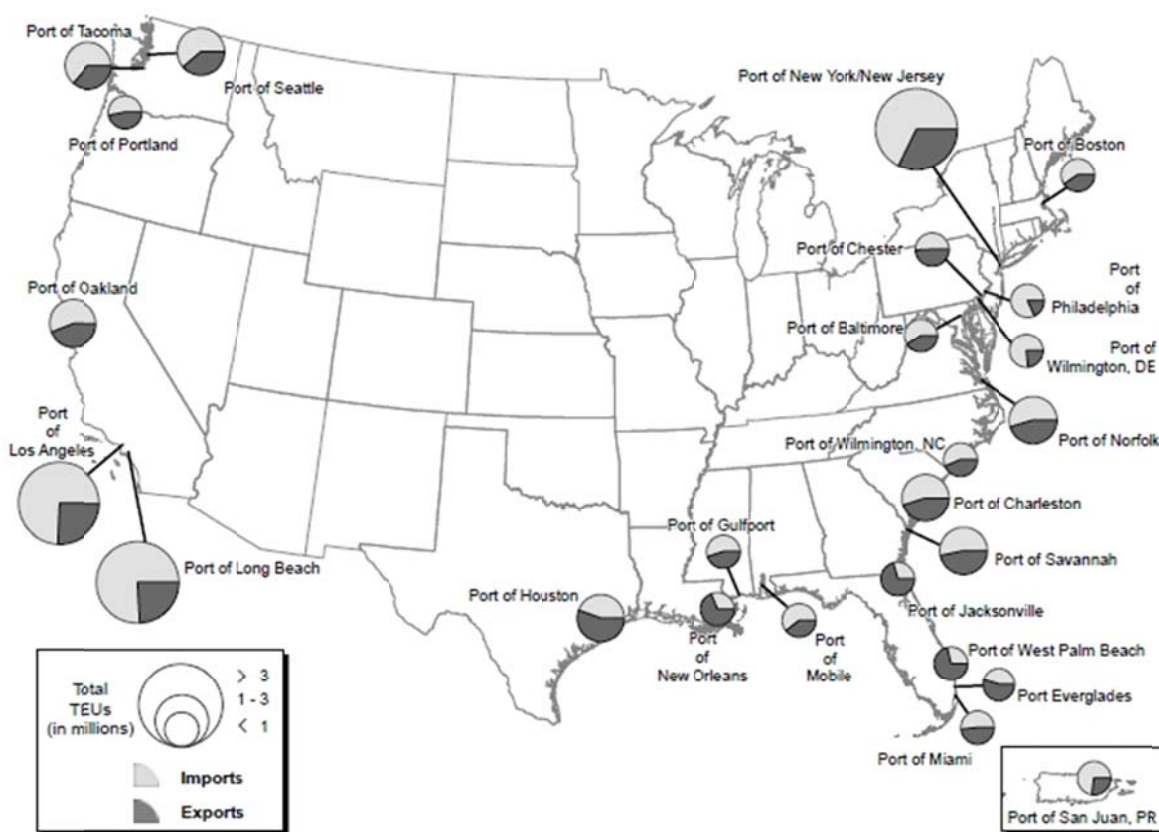


Figure 12. Top 25 Container Ports U.S. 2008 (Source: BTS, US DoT)

3.1 Data Sources

For this Case Study, the international and domestic container traffic associated with each of the three port regions was obtained from two sources. The first source of data was the *California Commodity Origin-Destination Database Disaggregation* technical memorandum produced by Cambridge Systematics, Inc. for the California Department of Transportation and California Air Resources Board (ARB). These data were used to obtain freight distribution patterns for goods movement through California, which was then used as a proxy for the containerized goods movement distribution. This distribution was combined with the second data source -- the inbound and outbound container data for the ports of interest from the Army Corps of Engineers -- to estimate the container traffic associated with the ports. This process of obtaining port generated containerized traffic from freight distribution figures has been explained in detail in *Appendix F: Creation of Origin and Destination and Volume Flow Model*. This section describes data sources used for the Task 5 Case Study.

3.1.1 Cambridge Systematics Origin-Destination Database

The Cambridge Systematics Origin-Destination (O/D) Database disaggregates the Freight Analysis Framework 2.2 (FAF2) data at the county level into a new O/D database. The FAF2 data is a freight database that provides estimates of commodity flows and transportation activity among states, metropolitan regions and international gateways. It is built from publicly available statistics such as the Commodity Flow Survey (CFS) and other sources highlighted on the FAF homepage (http://ops.fhwa.dot.gov/freight/freight_analysis/faf/index.htm).

Cambridge Systematics used principles of regression analysis in disaggregating the freight flow at the regional level to that at the county level. The freight traffic tonnage was estimated at the county level by forming regression models with explanatory variables such as industry employment, population and other factors that affect the production or consumption of a particular commodity in a county. For the counties in California, the tonnage values were adjusted for modal accessibility. The resultant database thus provides freight flow statistics by commodity and by mode, from and to the counties within the state of California. On the recommendation of ARB, the Cambridge Systematics O/D database was used to determine freight movements. The use of this data set also demonstrates the flexibility of GIFT in handling alternate sources of data. For details on CFS and the Cambridge Systematics FAF2 methodology, refer to *Appendix F and Appendix G*.

3.1.2 Port Container Data

The second source of data utilized in the Case Study was the number of containers handled by the ports of interest. Data were obtained from the Waterborne Commerce Statistics Center, maintained by the Army Corps of Engineers (ACE) (Army Corps of Engineers, 2003). Figure 13 shows the freight flow conventions for the Case Study.

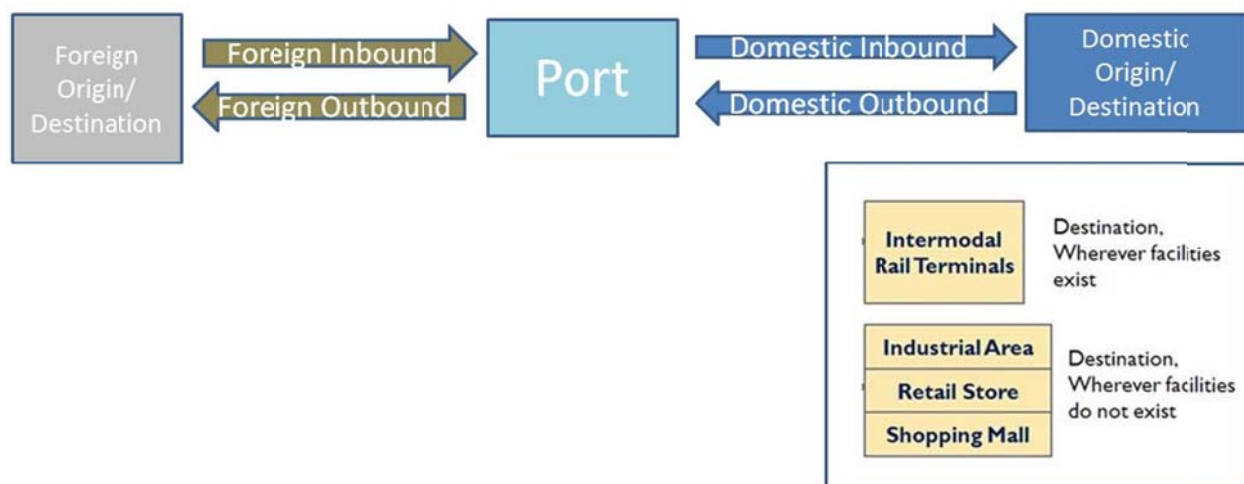


Figure 13. Freight Flow Model

The model assumes that the total outbound freight from the port is the sum of the total Domestic Outbound freight and the total Foreign Outbound freight. Similarly, the total inbound freight to the domestic destinations is the sum of the total Foreign Inbound freight and the total Domestic Inbound freight. The container traffic from and to the port representing the foreign inbound/outbound and the domestic inbound/outbound container data is needed to successfully model the freight movement. These data were obtained from the ACE database. Table 3 lists the container statistics for the three port regions, along with the total inbound and outbound freight calculations. Only loaded containers were considered for this Case Study. The container statistics data used were from 2003, in order to maintain consistency in our analysis of the Case Study.

Table 3. Port Container Statistics

Port Region	Domestic Inbound Loaded TEUs ¹	Domestic Outbound Loaded TEUs ¹	Foreign Inbound Loaded TEUs ¹	Foreign Outbound Loaded TEUs ¹	Total Outbound to Port TEUs ¹	Total Inbound to Destination TEUs ¹
Los Angeles	42,615	131,035	3,106,267	841,980	1,835,519	6,134,033
Long Beach	12,291	24,082	2,972,860	838,422	(Total for LA-LB)	(Total for LA-LB)
Oakland	56,126	139,157	489,742	314,921	454,078	545,868
Seattle	48,412	169,347	516,940	503,624	672,971	565,352

Source: USACE WCSC (http://www.ndc.iwr.usace.army.mil/wscs/by_porttons03.htm).

¹Note: A TEU is a measure of containerized cargo capacity equal to 1 standard 20 ft length by 8 ft width by 8 ft 6 in height container, with a maximum cargo capacity of 48,000 lbs.)

3.2 Assumptions for the Model

GIFT provides environmental attributes for the solved routes from the custom evaluator based on the type of vehicle and vehicle attributes entered by the user. The user can enter into GIFT overall emissions rates (for example, gCO₂/TEU-mile) or the user can use the GIFT emissions calculator to compute emissions

rates for specified fuels, engines, and operating parameters (see *Appendix E* for a description of the calculations) For reference purposes, this report restates vehicle assumptions and the network attributes that existed for Task 4, and were used for the Case Study in this report.

3.2.1 Emission rates

3.2.1.1 Truck Assumptions

A Class 8 heavy-duty vehicle (HDV) that met model year (MY) 1998-2002 emissions standards was assumed to be carrying two TEUs weighing a total of 20 tons. The fuel economy of the vehicle was assumed to be 6.0 miles per gallon. Furthermore, the emission factors associated with the truck operation were assumed to be 6.06 grams of NO_x per brake horsepower-hour (gNO_x/bhp-hr) and 0.139 grams of PM₁₀ per brake horsepower-hour (gPM₁₀/bhp-hr). The emission factor values were sourced from Table B-5 and Table B-8 of Appendix B of the Carl Moyer Program Guidelines Handbook (California Air Resources Board, Part IV- Appendices, 2008).

3.2.1.2 Rail Assumptions

Two Tier-1 locomotives, each powered by a 4,000 hp motor, were assumed to be hauling a 100 well-car load, with each well-car carrying an equivalent of 4 TEUs at 10 tons per TEU. This amounts to a total of 4,000 tons of shipment. An average speed of 25 miles per hour was assumed over the entire rail network. The engines were assumed to be operating at an average efficiency of 35% and an average load factor of 70%. The emission factors associated with the rail were based on Tier 1 levels and assumed to be 6.3 gNO_x/bhp-hr and 0.275 gPM₁₀/bhp-hr. These values were sourced from Table B-18a of Appendix B of the Carl Moyer Program Guidelines Handbook (California Air Resources Board, Part IV- Appendices, 2008).

3.2.1.3 Ship Assumptions

Most of the O/D pairs in the Case Study do not allow for potential water routes, but some could, and the GIFT Model can evaluate the potential for waterways to serve goods movement for coastal regions in so-called "Short-Sea Shipping." The GIFT Model used vessel characteristics for the prototype short-sea vessel "Dutch-Runner" - a 3,070 hp container vessel with a capacity of 221 TEUs, with average payload of 10 tons/TEU (total of 2210 tons of freight). The engine was considered to be operating at 40% efficiency with an average load factor of 80%. Rated speed (i.e., design speed) of the vessel was approximated to be 13.5 statute miles per hour. The ship operates at the maximum allowable emissions standards for NO_x (5.4 g/bhp-hr) and PM₁₀ (0.15 g/bhp-hr) – in other words, meeting current regulations and not adjusted for emissions control standards that are pending.

3.2.1.4 Fuel Assumptions

The assumed fuel for the model evaluation study is on-road diesel fuel with energy content of 128,450 Btu/gallon, a mass density of 3,170 grams/gallon, and a carbon fraction of 86%. We applied this assumption to all modes, acknowledging that residual fuels and various quality distillate fuels vary somewhat. At the scale of this Case Study, the differences are smaller than the variability in other assumptions, but future analyses could use GIFT to model various fuels in terms of a low-carbon fuel standard or other environmentally beneficial fuel alternatives – either by mode or across modes.

The aforementioned figures gave a resultant output of 830 gCO₂/TEU-mile for truck, 320 gCO₂/TEU-mile for rail, and 410 gCO₂/TEU-mile for ship. Thus, the most carbon-intensive mode of freight transport in this case is truck, followed by the container ship, and then rail (Figure 14).

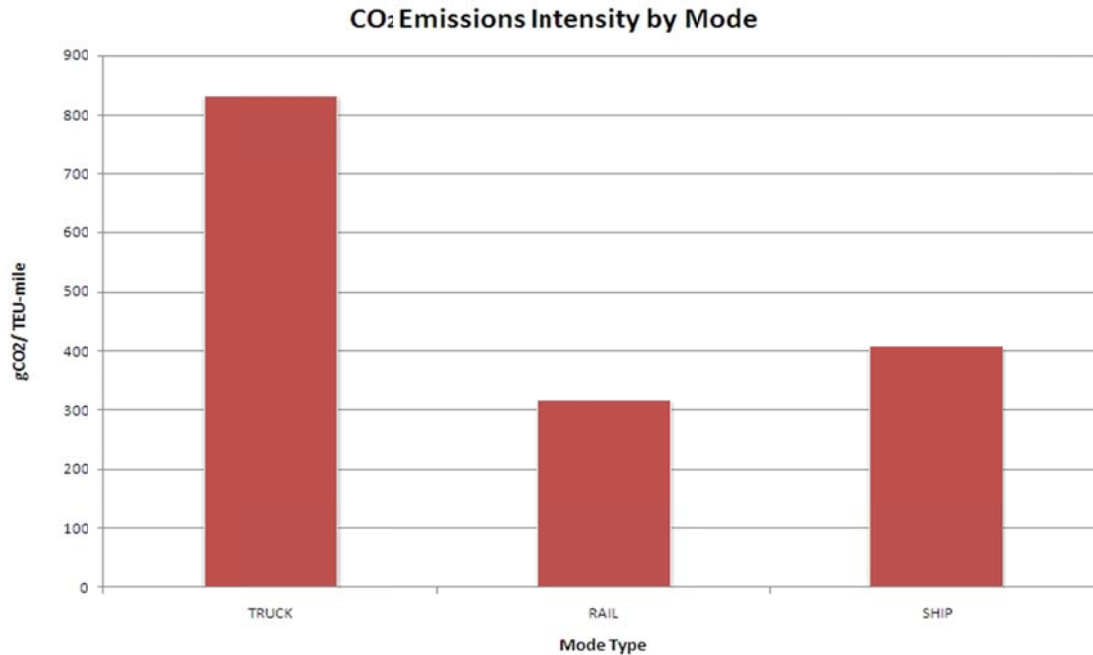


Figure 14. Emissions intensity for different modes

3.2.2 Assumptions for Intermodal Transfers

While the GIFT emissions calculator computes the emissions associated with each of the network segments based on vehicle type, a separate emissions calculator was developed to compute the emissions associated with the movement of container by cargo handling equipment at the ports. The intermodal facilities, represented by a hub-and-spoke model, have environmental attributes similar to those associated with the network segments of the three different modes of transport – road, rail and water (Figure 15).

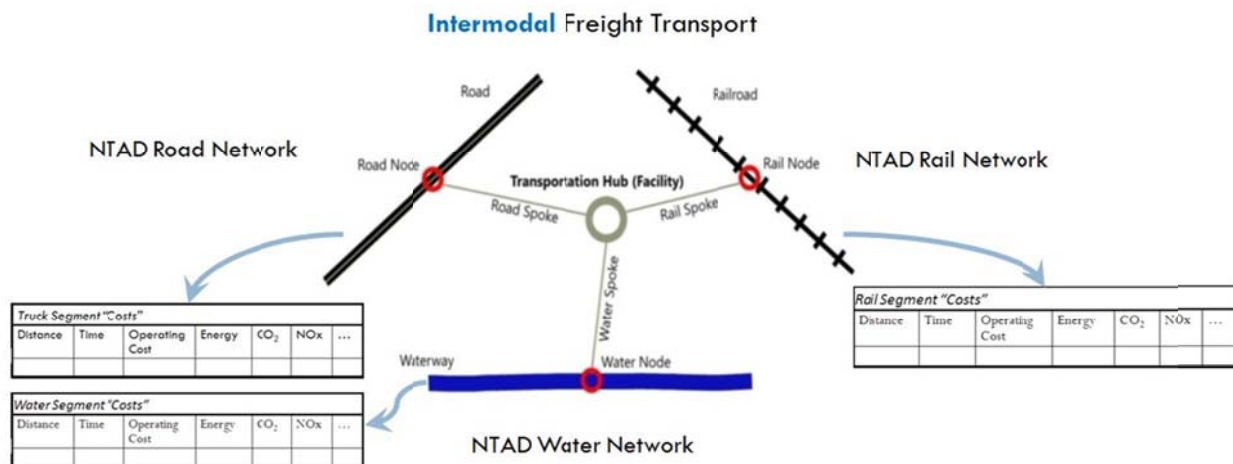


Figure 15. Representing Intermodal Facilities

The principles behind the emissions estimates for cargo handling equipment are the same as those used to calculate emissions from transportation modes. Differences exist in the assumptions regarding the operational attributes of the port equipment. In reality, the transfer of goods from one mode to another occurs at the intermodal facilities and the spokes are a proxy for the movement. In the hub-and-spoke

model, the movement of the containers from one mode to another is modeled through artificial spokes (Figure 15). Thus, the *Road Spoke* represents the transfer of goods between the road network and the intermodal facility. Similarly, the *Rail Spoke* and the *Water Spoke* model the movement of goods between the facility and the rail network, and between the facility and the waterways network, respectively.

When estimating emissions at the facilities, the spokes were assumed to accumulate part of the emissions involved in a mode-to-mode transfer. For example, the total CO₂ emissions generated in moving a container between the road network and the rail network would be spread across the road spoke and the rail spoke. Standard CO₂ emission rates for the road spoke were calculated as the average of the CO₂ emissions accumulated when moving a container from the road network to the rail network and from the road network to the waterway network.

Our assumptions regarding the emissions intensity of the cargo handling activity at the facilities (or ports) led to the approximate estimations listed in Table 4.

Table 4. Intermodal Transfer Emissions

Spoke Type	Grams of CO ₂ per TEU	Grams of NO _x per TEU	Grams of SO _x per TEU	Grams of PM ₁₀ per TEU
Road	9200	1035	6.2	31.5
Rail	4100	53	0.5	1.6
Ship	2500	42	0.3	2

In effect, the total accumulated emissions along a route consisting of an origin point and a destination point can be summarized by the following equation where E_p is the total emissions of pollutant p , $TE_{i,p}$ is the transfer facility emissions penalty at transfer facility i for pollutant p and is summed over all transfers i ; l_j is the length of segment j in miles; and $EF_{j,p}$ is the emissions factor for pollutant p and segment j in grams/TEU-mile.

Equation 1

$$E_p = \sum_i TE_{i,p} + \sum_j l_j \cdot EF_{j,p}$$

The emissions counted on a per TEU-mile basis are obtained for the three different modes depending on the vehicle attributes specified by the user through the emissions calculator or user-entered emissions rates . When optimizing for a particular emission, the travel routes are so selected that the accumulated emissions are minimum.

3.2.3 Travel Time

When solving for routes under various scenarios, the accumulated travel time is calculated based on the allowable speed limits on the road, rail and water network segments. For the road segments, the allowable speed is based on the road class. The common speed values range from 25 mph to 65 mph, with 5 mph intervals. For the rail network, a constant speed of 25 mph is assumed throughout the network. In case of the waterways, a constant speed of 13.5 mph (~12 knots) was assumed for a radius distance of 20 km from the coastline, and 20 mph beyond that.

Apart from the speed being a determinant of the travel time, dwell nodes were included in the rail network to take into account the delays associated with the movement of freight through a rail yard located at a facility or port. For details, refer to the section 2.3.5. Time accumulation is not reported in this Case Study, but it serves as a constraint for the least-time routing solution.

The GIFT emissions calculator calculates emission values based on the assumption of constant average speed for rail and ship. The emissions calculated for truck use average fuel economy assumptions, and are not adjusted for emissions rate variation with speed or engine load. Moreover, this Case Study does not adjust for grade and power relationships in truck or rail, and does not consider localized maneuvering behavior by ships. The travel times calculated in GIFT are based on the speeds associated with the network segments. Thus, the emissions estimated for freight movement are an approximation or best estimate. Under other Case Study designs using the GIFT model, we can define our estimations for environmental, time, cost, and other attributes of freight transportation to meet those purposes.

4 Case Study Results

The freight data on container traffic from/to the three ports on the West coast were imported into ArcGIS. Routes were then solved using GIFT for the origin-destination (O/D) pairs under two different scenarios – least-time and least-CO₂. This section discusses the results of the two scenarios.

4.1 Least-time Route Emissions

As shown in Figure 16 and Figure 17, under the least-time scenario the majority of the container traffic from the ports of Los Angeles-Long Beach, Oakland and Seattle are concentrated along parts of interstates I-5, I-10, I-15, I-40, and I-90. In the least-time case, the freight is routed through the roadway network because of the higher speeds involved. In effect, a total of approximately 2.9 MMT of CO₂ emissions are estimated to occur over the course of the year due to freight moving in and out of these three ports on the West coast. This is under the assumption that all the freight moves by truck. Table 5 lists the estimated emission figures for the various attributes of choice. Of these, the majority of the emissions (~79% of total) are due to traffic moving in and out of the port of Los Angeles-Long Beach. This estimation is supported by the fact that the said port is the biggest on the West coast and one of the biggest in the U.S.

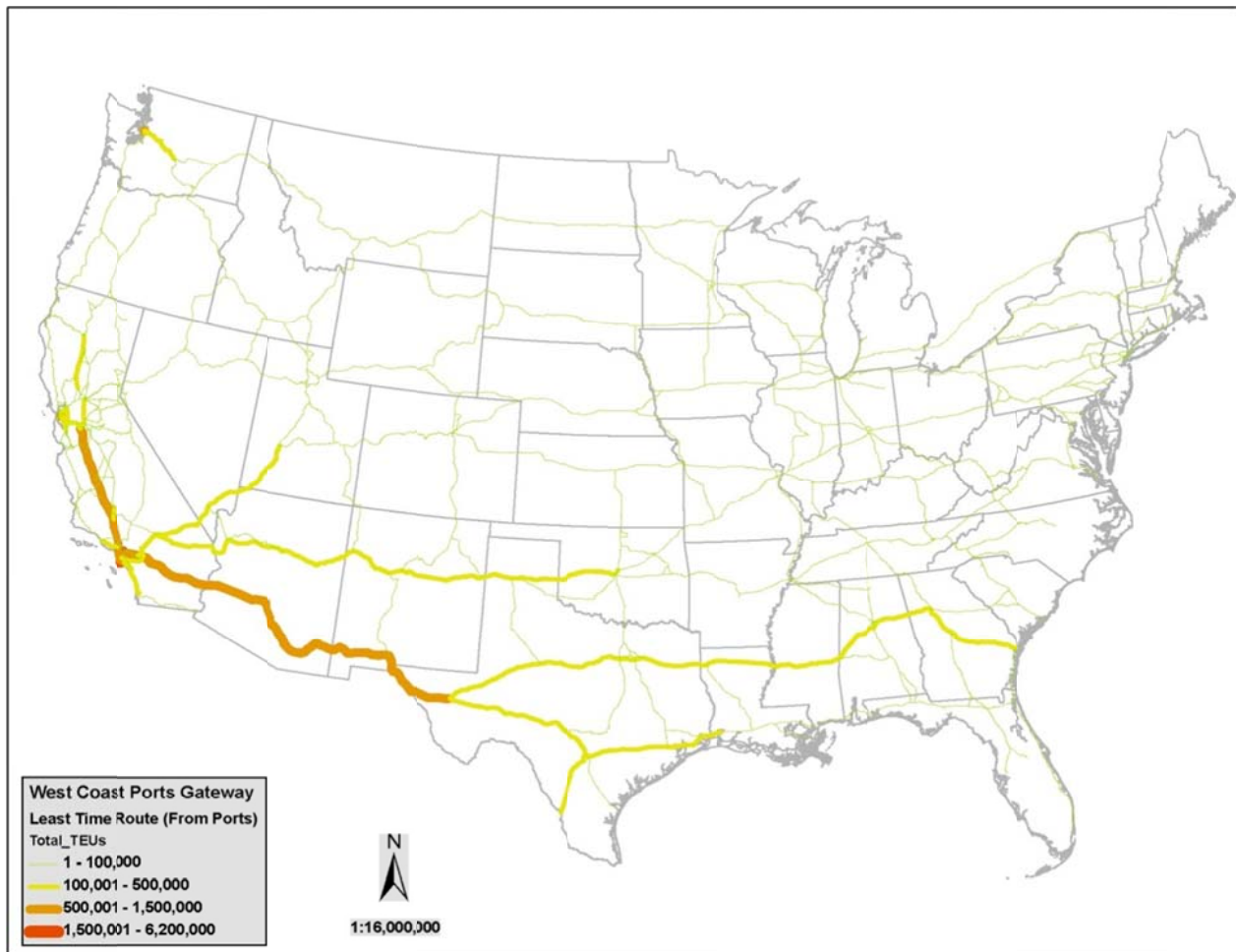


Figure 16. Container Traffic from Ports (Least-time Scenario)



Figure 17. Container Traffic to Ports (Least-time Scenario)

Table 5. Least-time Route Emissions

Emission Attributes	Total Emissions From All port Traffic (MT)	Total Emissions From Traffic from Port (MT)			Total Emissions From Traffic towards Port (MT)		
		Port of LA-LB	Port of OAKLAND	Port of SEATTLE	Port of LA-LB	Port of OAKLAND	Port of SEATTLE
CO ₂	2,885,360	1,707,510	102,759	144,708	597,680	206,560	126,143
NO _x	55,513	33,116	2,277	2,859	11,013	3,798	2,450
SO _x	151	91	7	8	28	10	7
PM ₁₀	1,423	849	60	74	281	96	63

Figure 18 shows the distribution of the freight traffic emissions by air basins, for the least-time scenario. The majority of emissions are concentrated within the South Coast, San Joaquin Valley and the Mojave Desert air basins. This finding is supported by the maps in Figure 16 and Figure 17, which show the majority of the freight traffic to be confined within these regions. Thus, it can be seen that emissions in a region are correlated with the amount of freight traffic moving within that region. While the map in Figure 18 shows estimated CO₂ emissions by air basin, it can be considered as a proxy for the proportional distribution of NO_x, SO_x and PM₁₀ emissions from these goods movements. The complete list of the CO₂ emissions by air basins can be found in Table 8.

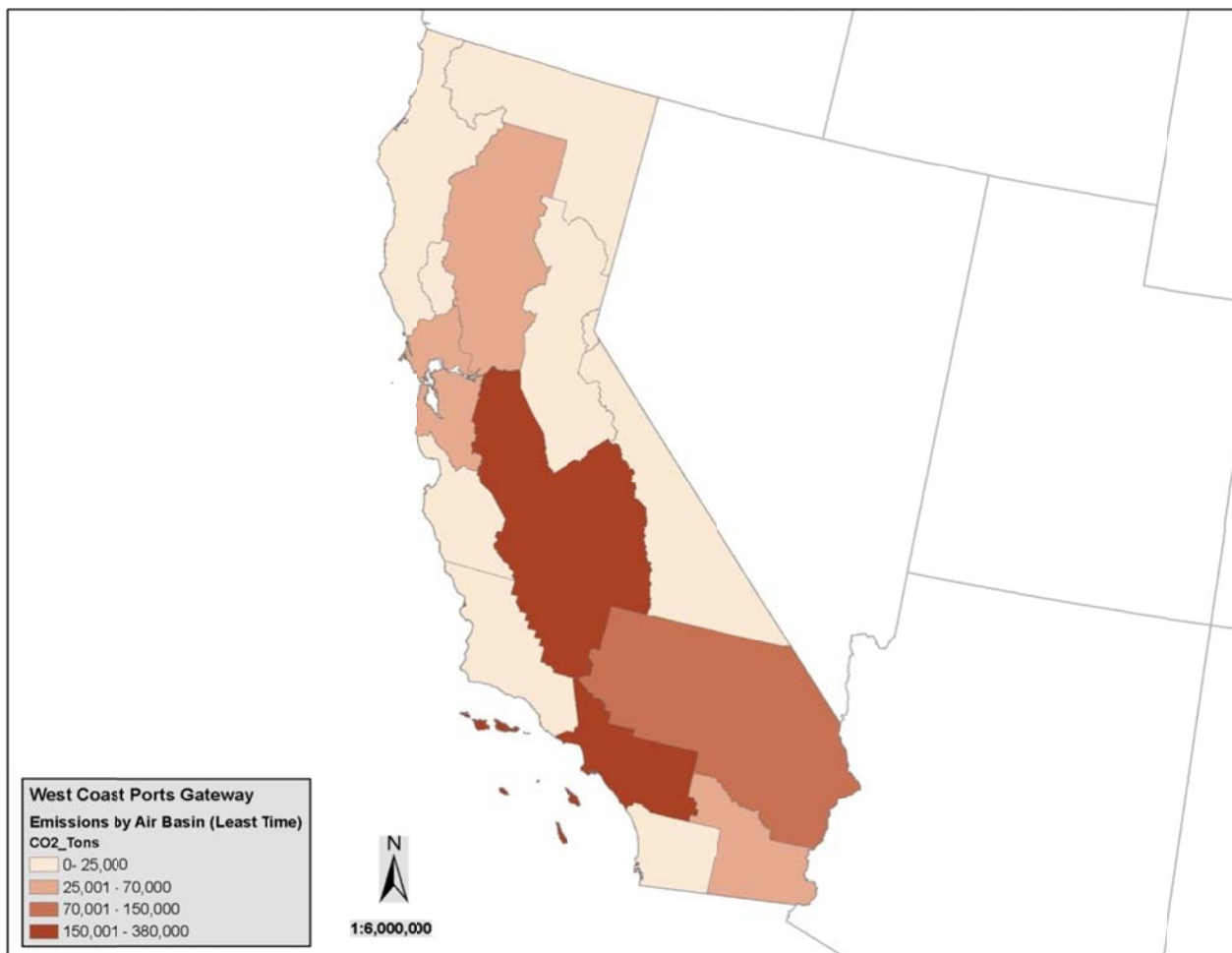


Figure 18. Air Basin Emissions (Least-time scenario)

4.2 Least-CO₂ Route Emissions

In the case of the least-CO₂ scenario, most of the freight was routed through the rail network because of the low emissions involved with moving freight by train (Figure 14). The pattern of the freight distribution is similar to the least-time scenario, as evident by the maps in Figure 19 and Figure 20. In terms of savings in emissions, it is estimated that a total of 59% reduction in CO₂ emissions is achievable by a modal switch from truck to train. (See Table 7 for emissions reduction comparison). This change in emissions can be seen prominently for air basins. Figure 21 shows how the emissions reduce across the air basins in California, when compared with the visualization show in Figure 18.

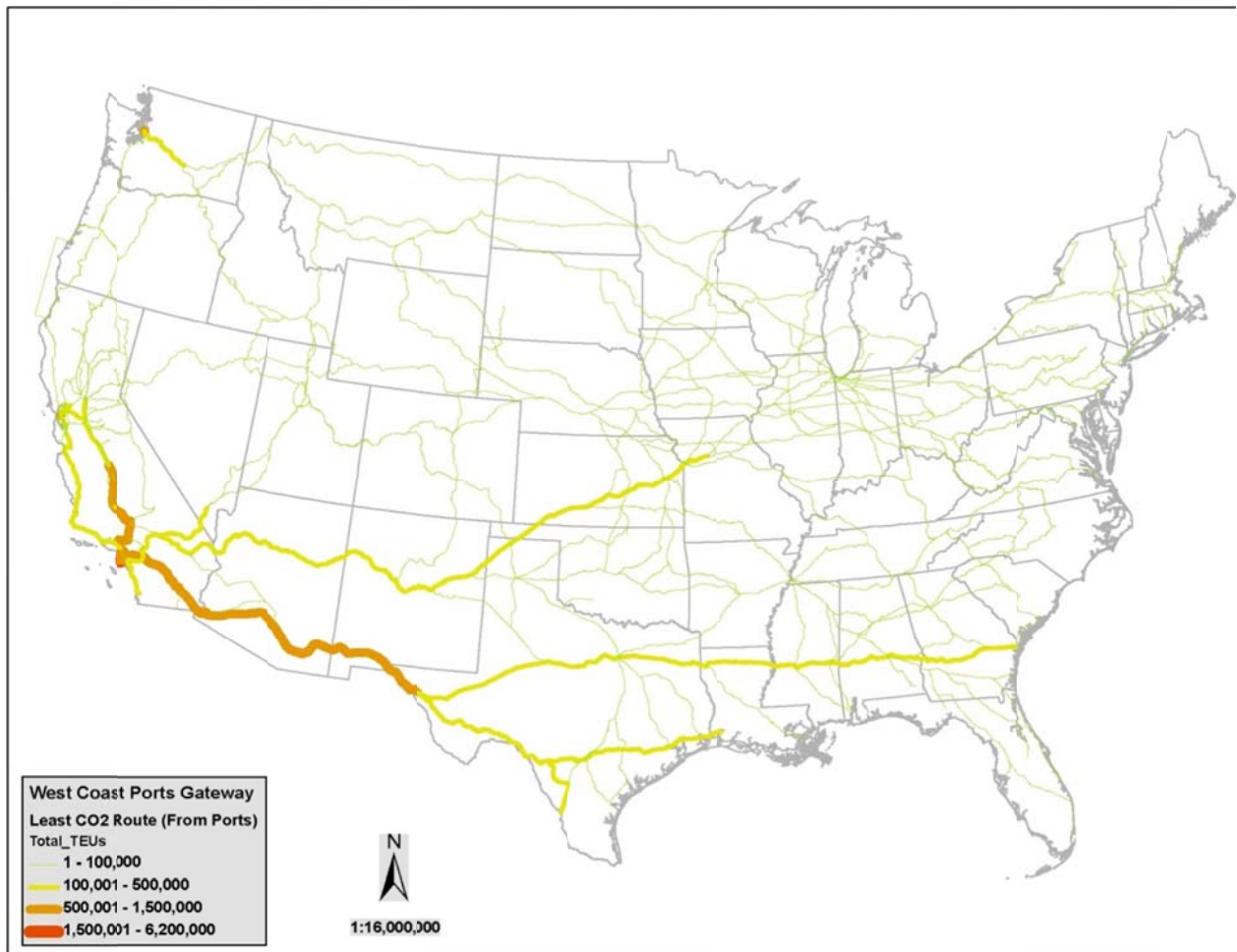


Figure 19. Container Traffic from Ports (Least-CO₂ Scenario)

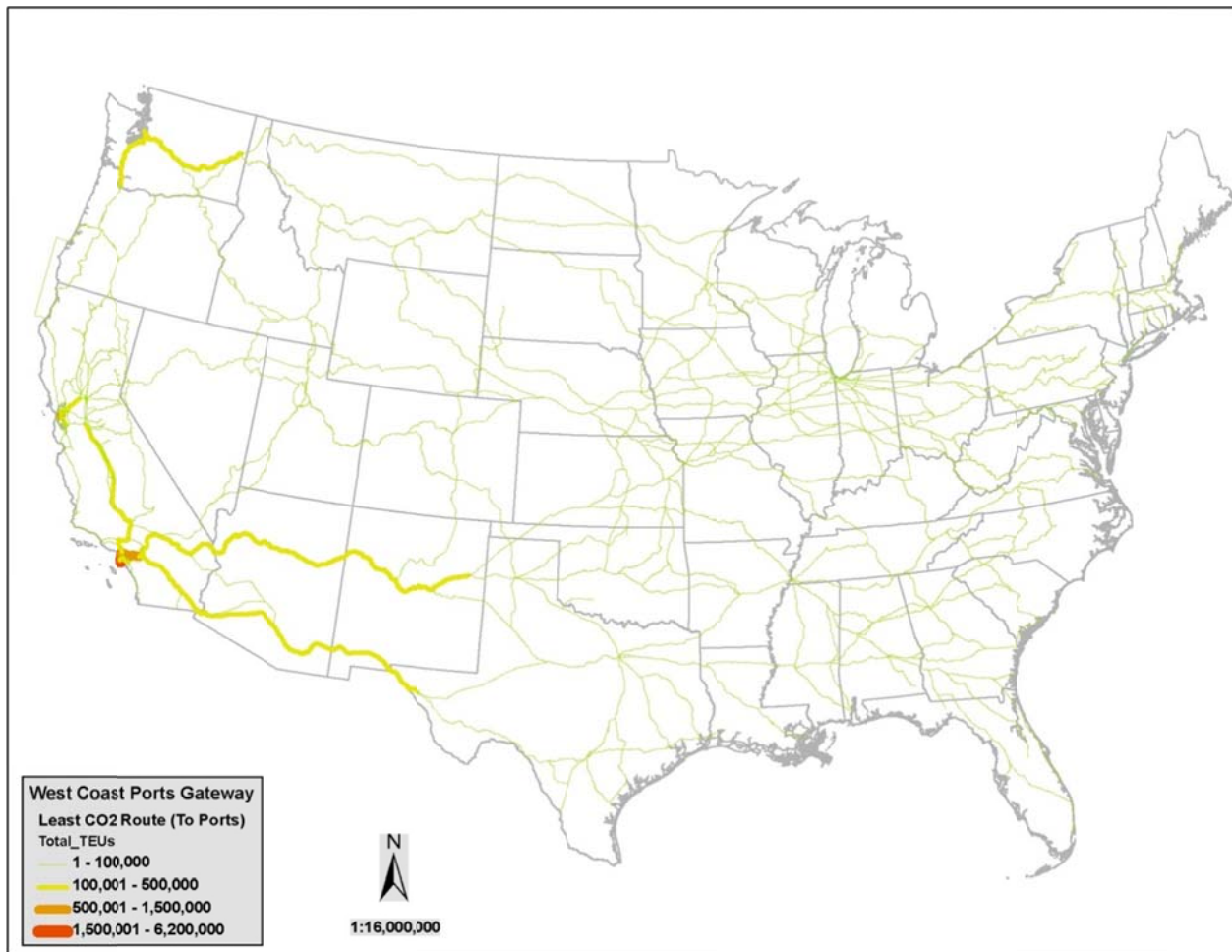


Figure 20. Container Traffic to Ports (Least-CO₂ Scenario)

Table 6. Least-CO₂ Route Emissions

Emission Attributes	Total Emissions From All port Traffic (MT)	Total Emissions From Traffic from Port (MT)			Total Emissions From Traffic towards Port (MT)		
		Port of LA-LB	Port of OAKLAND	Port of SEATTLE	Port of LA-LB	Port of OAKLAND	Port of SEATTLE
CO ₂	1,182,764	694,997	45,337	56,556	248,031	87,227	50,616
NO _x	13,628	7,917	597	640	2,820	1,078	576
SO _x	22	13	1	1	4	2	1
PM ₁₀	574	335	24	27	120	44	24

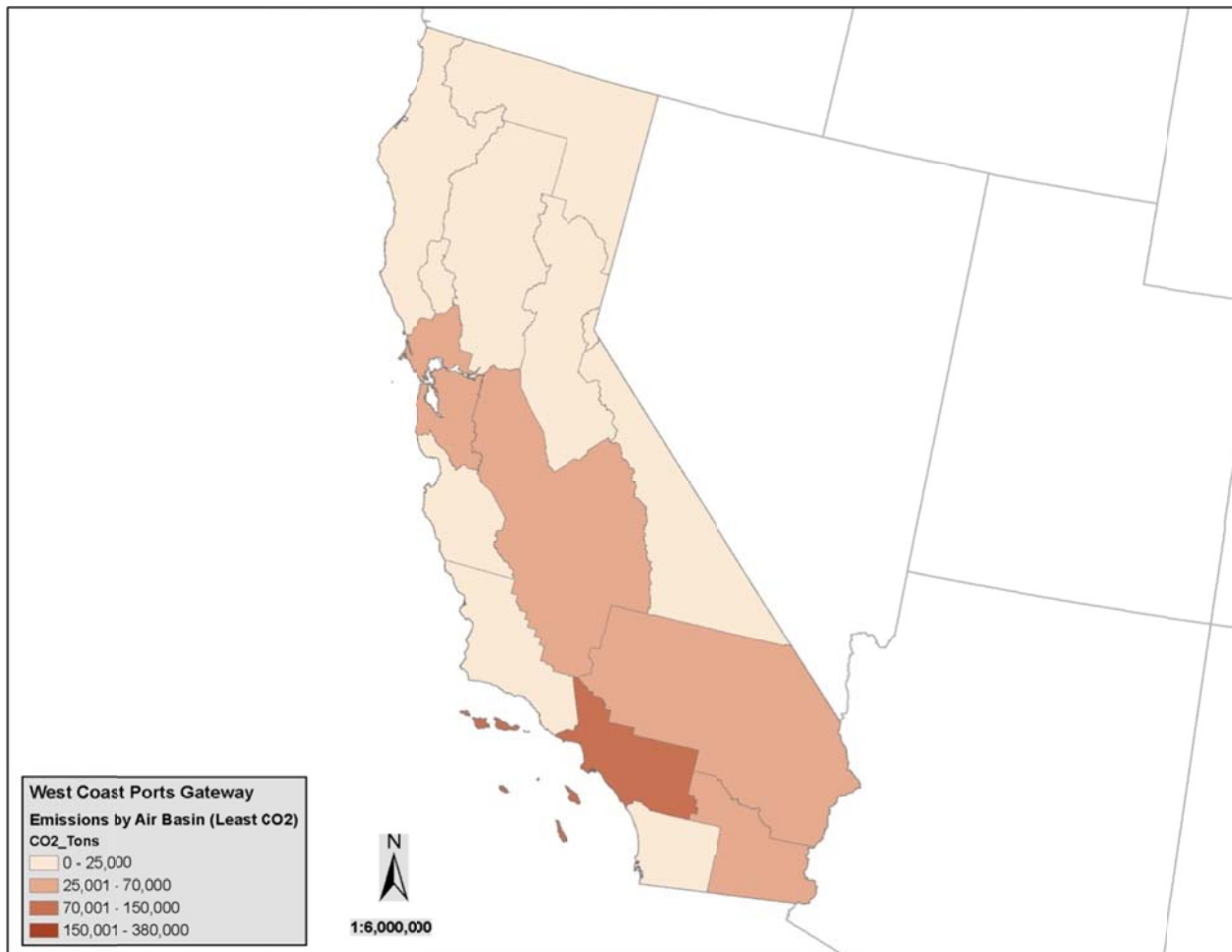


Figure 21. Air Basin Emissions (Least-CO₂ scenario)

4.3 Comparison of Emissions across Scenarios

Figure 22 shows the amount by which the CO₂ emissions reduce across the air basins in California, when moving freight by train instead of truck. Given this Case Study with strict constraints for least-time and least-CO₂ route solutions, this represents an idealized (that is, a, bounded) scenario for potential CO₂ reductions from system improvements. Maximum CO₂ emissions are reduced along the air basins of South Coast, San Joaquin Valley and Mojave Desert. These three regions were also the ones which incurred the most of the freight emissions in the least-time scenario. Thus, a modal shift of freight leads to emissions reduction in the most emissions-intensive regions. Of course, this reduction in emissions may require increased travel time if the railroad network average speed (25 mph) is slower than the road speeds; alternatively, if long-haul trucking with single drivers requires rest hours for every 10 hours of driving time, these differences may be much smaller. Although the difference in travel time is not listed here, GIFT allows the comparison of trade-offs with respect to the travel time when optimizing for emissions. Another point of note is that while the CO₂ emissions are reduced across most of California, the emissions along the North Central Coast and the South Central Coast increase in case of the least-CO₂ scenario because of the increased freight traffic being routed through the railroads within these regions. This finding stresses the importance of geospatial attributes of freight emissions and how it can inform policy decisions.

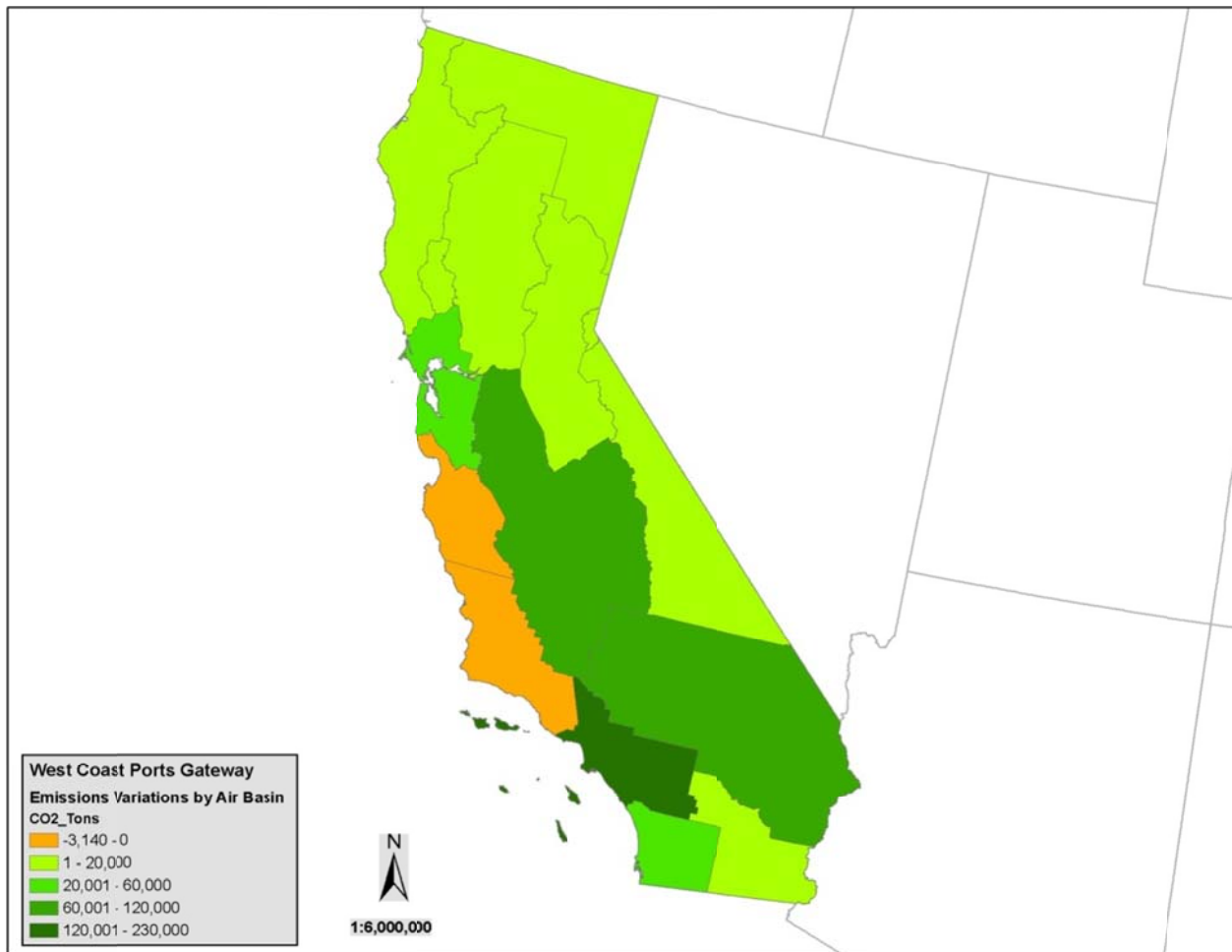


Figure 22. Emission Variations by Air Basin

Table 7. Emissions Comparison for Entire Routes of All O-D Pairs

Emission Attribute	Least-time Scenario Total Emissions (MT)	Least-CO ₂ Scenario Total Emissions (MT)	Total Emission Reduction (MT)	Total Emission Reductions (in percent)
CO ₂	2,885,360	1,182,764	1,702,596	59.01%
NO _x	55,513	13,628	41,885	75.45%
SO _x	151	22	129	85.43%
PM ₁₀	1,423	574	849	59.66%

Table 8. Emissions by Air Basin

Air Basin	Total Least-time Scenario CO₂ Emissions (MT)	Total Least-CO₂ Scenario CO₂ Emissions (MT)	Difference in CO₂ Emissions due to Modal Shift (MT)	Percent Change
South Coast	375,866	149,421	226,445	-60%
San Joaquin Valley	178,572	58,690	119,882	-67%
Mojave Desert	120,951	60,908	60,043	-50%
San Francisco Bay	67,983	31,173	36,810	-54%
Salton Sea	48,900	41,672	7,228	-15%
Sacramento Valley	34,912	16,948	17,964	-51%
San Diego County	24,044	3,471	20,573	-86%
South Central Coast	14,986	17,164	(-2,178)	15%
Northeast Plateau	8,644	3,994	4,650	-54%
Mountain Counties	6,536	3,517	3,019	-46%
North Central Coast	3,100	6,240	(-3,140)	101%
North Coast	814	376	438	-54%
Great Basin Valleys	480	345	135	-28%
Lake County	36	17	19	-53%
Lake Tahoe	23	22	1	-4%
Total in-state	885,847	393,958	491,889	-56%

Note: Positive difference corresponds to negative percent change; both represent CO₂ reductions.

5 Case Study Discussion

The Case Study provides two primary insights. First, the Case Study quantifies port-related intermodal goods movement through the state of California and beyond. Second, the idealized use of least-CO₂ routing constraints illustrates how emissions savings can be achieved through modal shifts. Both of these insights have relevance for consideration of system-wide improvements that may achieve energy savings, CO₂ reductions, and associated benefits for air quality.

The California Greenhouse Gas Emissions Inventory developed by ARB reports that an estimated 26.9 MMT CO₂ were emitted on average from heavy-duty diesel vehicles during the years 2002- 2004. These inventories are available from <http://www.arb.ca.gov/cc/inventory/inventory.htm> and <http://www.arb.ca.gov/cc/inventory/data/forecast.htm>). The Case Study estimates CO₂ emissions to be approximately 2.89 MMT CO₂ from the three West Coast port container traffic using the least-time

scenario (which comprises mostly trucks), for the same period (Table 5). If we assume that onroad heavy-duty diesel activity is primarily devoted to freight transport, the GIFT model estimates in-state CO₂ emissions of port-related goods movement are about 11 percent of California CO₂ from goods movement. This result is expected given that emissions estimated through GIFT only consider (loaded) containerized freight moving in and out of the three major ports on the West coast. Also, as shown in Table 9 our assumption of 10 tons of cargo per TEU means that we are estimating emissions for, on average, about 9 percent (by weight) of the total goods moving in and out of the three port regions. This may be expected given that containerized intermodal payloads are less densely packed than bulk goods. The difference between CO₂ (and energy used) and amount of goods moved could be larger a) if the average weight per TEU is less than 10 tons; and b) if repositioning movements of empty containers were included.

Table 9. Comparing port containers and freight tonnage

		LA-LB	OAKLAND	SEATTLE	Total
Inbound Summary					
Destination Inbound TEUs ¹	A	6,134,033	565,352	545,868	7,245,253
Port TEU tons ²	B(=A*10)	61,340,330	5,653,520	5,458,680	72,452,530
Region Tons From Region ³	C	345,566,070	47,178,970	111,289,750	504,034,790
Percent of total inbound tonnage	D(=B/C)	18%	12%	5%	14%
Outbound Summary					
Destination Outbound TEUs ¹	A	1,835,519	672,971	454,078	2,962,568
Port TEU tons ²	B(=A*10)	18,355,190	6,729,710	4,540,780	29,625,680
Region Tons to Region ³	C	381,499,940	55,553,670	202,376,070	639,429,680
Percent of total outbound tonnage	D(=B/C)	5%	12%	2%	5%
Bidirectional Summary					
Total TEUs (Inbound + Outbound)	A	7,969,552	1,238,323	999,946	10,207,821
Port TEU Tons Total	B(=A*10)	79,695,520	12,383,230	9,999,460	102,078,210
Region Tons Total	C	727,066,010	102,732,640	313,665,820	1,143,464,470
Total TEU Tons as Percent of Region	D(=B/C)	11%	12%	3%	9%

1. Port container data (from US Army Corps of Engineers)
2. Assumed 10 tons per TEU
3. Cambridge Systematics database

Case study findings can also be discussed in the context of the Climate Change Scoping Plan of ARB. The ARB scoping plan recommends in measure T-6 that goods movement can achieve a total reduction of 3.5 MMT CO₂ through adoption of system efficiency improvements (California Air Resources Board, AB 32 Scoping Plan Document, 2010). Our estimation of a total reduction of approximately 1.7 MMT of CO₂ occurs through a nationwide modal shift of West Coast port-generated goods movement; within the state air basins, this reduction is near 0.5 MMT CO₂. Of course, this assumes that all port-related TEUs currently move via truck; this Case Study did not adjust for the amount currently moving via rail, but produced two bounding cases (least-time and least-CO₂). Moreover, the port-related mode shift assumptions in this Case Study could be complemented or substituted by similar mode shifts for goods moving to and from other California destinations and origins. The point is that if goods movement system improvements could facilitate mode shift of this order, then between 14% and ~50% of the T-6 Scoping Plan goal could be achieved.

6 Summary and Conclusions

This project further developed the GIFT model and demonstrated its configuration and use for evaluating tradeoffs among attributes of goods movement in the State of California. The model can be used to

evaluate least ‘cost’ transportation routes for single or multiple origin-destination pairs. The model includes the ability to optimize transportation for energy, environmental, economic, time-of-delivery, distance, and other attributes. This project involved collecting and implementing data obtained specific to the state of California, as well as steps to validate the model.

We demonstrated the model using California-specific inputs through a Case Study focused on CO₂ emissions from goods movement of containers moving through the major California ports. The Case Study concentrated on exploring the least-time v. least-CO₂ emissions of goods movement, but other opportunities exist to expand this tradeoff set in future work. Significant reductions in CO₂ emissions are possible through intermodal changes and other energy-efficiency measures that would support the Air Resources Board goods movement goals. The final results of the case study (discussed in Sections 4 and 5) provide boundaries for potential CO₂ emissions reductions in the goods movement sector for the state.

7 Recommendations

Beyond the Case Study results themselves, this project has demonstrated the feasibility and usefulness of GIFT and its California-specific data and configuration as an important analytical and planning tool for California decision makers. Although the Case Study focused solely on demonstrating emissions tradeoffs between least-time and least-CO₂ routing, we recommend that future work entail analysis based on economic and other California specific attributes.

Future work also can involve migration of GIFT to a web-based environment so that California decision makers would have access to the model through the Internet. Some work related to this migration is ongoing through other project work being conducted by our research team, and leveraging that work with additional California based analyses is conceivable.

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Glossary

ARB	California Air Resources Board
ArcCatalog	A product from ESRI (see http://www.esri.com/) to build and manage geospatial information system databases
ArcGIS	A Geographic Information System (GIS) commercially available from ESRI (see http://www.esri.com/)
ArcToolbox	A set of geospatial data processing and management tools available as part of the ArcGIS product suite.
bhp	Brake horse-power – a unit of measurement of power
BNSF	Burlington Northern Santa Fe Railways
BTS	United States Bureau of Transportation Statistics (http://www.bts.gov/)
BTU	British Thermal Unit – a standard unit of energy
C#	A computer programming language provided by Microsoft and used to customize the ESRI ArcGIS product
CA	California
CARB	California Air Resources Board
CBSA	Core-Based Statistical Area – An area defined by the U.S. Office of Management and Budget to identify core urban areas and adjacent areas
CCD	Census County Division – a subdivision of a county with no minor civil division (MCD) or other governmental boundary (for census purposes)
CDP	Census Designated Place -- concentrations of population that are identifiable by name but are not legally incorporated (see http://www.census.gov/geo/www/cob/pl_metadata.html)
CFS	Commodity Flow Survey (http://www.bts.gov/publications/commodity_flow_survey/)
CN	Canadian National Railway
CO ₂	Carbon dioxide
CP	Canadian Pacific Railway
CSA	Combined Statistical Area – a United States census region combining metropolitan and micropolitan regions linked by commuting ties (see http://www.census.gov/population/www/metroareas/metrodef.html)
CSX	A United States-based rail transportation company
DOT	United States Department of Transportation
ERG	Eastern Research Group, a collaborator in the GIFT research projects
FAF and FAF2	Freight Analysis Framework versions 1 and 2 (http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/)
FEC	Florida East Coast Railway
g	Grams
GATX	A United States-based rail transportation company – often referred to as General American Transportation
Geodatabase	A file system for storing and managing geospatial information (from ArcGIS)
GIFT	Geospatial Intermodal Freight Transportation model
hp	Horsepower – a unit of measurement of power (see bhp)
IMO	International Maritime Organization
km	Kilometers

KCS	Kansas City Southern Railway
KWh	Kilowatt-hour
LA	Los Angeles, California
LA/LB	Los Angeles/Long Beach – referring to the port complex near San Pedro, California
m	meters
MCD	Minor Civil Division. A census area defining a subcounty area such as a town or township
MSA	Metropolitan or Micropolitan Statistical Area– a county or region census area containing a substantial urban area and its adjacent communities (see http://www.census.gov/population/www/metroareas/aboutmetro.html)
mol	Mole – a unit of measure of the physical quantity of a gas
MY	Model Year
NS	Norfolk Southern Railway
NTAD	National Transportation Atlas Database (available from the United States Bureau of Transportation Statistics at http://www.bts.gov/help/national_transportation_atlas_database.html)
O/D or O-D	Origination / Destination – points marking the beginning and end of a transportation route
ObjectID	A number uniquely identifying a segment in a transportation network file of ArcGIS
ppm	Parts per million
RIT	Rochester Institute of Technology
SOx	Sulfur oxides
Shapefile	A file format for representing geospatial points, polylines, and polygons
SourceID	I number identifying a portion of a geospatial information system’s file set (identifies a shapefile in a geodatabase in the ArcGIS system)
STEEM	Ship, Traffic, Energy and Environmental Model, a characterization of international ocean-going ship traffic (see http://coast.cms.udel.edu/NorthAmericanSTEEM/)
TEU	Twenty-foot equivalent unit – a standard measure for shipping containers A measure of capacity for shipping containers
TRANSFLO	An intermodal transloading provider in the United States – A subsidiary of CSX Corporation
UD	University of Delaware
UP	Union Pacific Railway
U.S.	United States
USACE	United States Army Corps of Engineers
Visual Basic	A computer programming language provided by Microsoft and used to customize the ESRI ArcGIS product
VOC	Volatile organic compounds
WCSC	Waterborne Commerce Statistics Center (see http://www.iwr.usace.army.mil/ndc/wcsc/pdf/wcusnatl04.pdf)

APPENDIX A: Data Summary Sheets for Mobile Sources

Data Summary Sheets

General data category: **Highway Vehicle Fleet**

Data title: **Review of the US DOE Heavy Vehicle Technologies Program-Summary**

Data source: **National Academy of Sciences**

Year released: **2000**

Brief summary of the value of the data for the Cal GIFT Model: **Lists truck fuel use at 4mil bbl/day for cars, 4.5 mil bbl/day for Class 1 & 2 trucks, and 3 mil bbl/day for Class 3-8 trucks. Estimates that trucks will consume twice as much fuel as cars by 2020.**

Recommends implementation of a program to introduce technologies for trucks in order to reduce emissions and become more fuel efficient. Fuel efficiency improvement methods such as improving aerodynamics, use of lightweight materials, and decreasing roll resistance on trucks are recommended.

Limitations: **No tangible data is provided in this document for use in the model.**

Data Summary Sheets

General data: **Yard Trucks**

Data title: **Cargo Handling Equipment Yard Truck Off-Road Emission Testing**

Data source: **CARB**

Year released: **N/A**

Brief summary of the value of the data for the Cal GIFT Model: **CARB has a program to obtain information on baseline emissions and control strategies for port and intermodal rail yard trucks. Tested six yard trucks: 3 in use mechanically controlled off-road engines (1997, 2000, 2001 MY), 1 electronically controlled off-road engine (2004 MY), 1 electronically controlled on-road engine (2004 MY) and 1 LPG engine. All were Cummins 8 mode test cycle 5.9L or 8.3L. Emission control strategies suggested are yard trucks with on-road certified engines, use of alternative fuels such as propane or natural gas, use of emulsified diesel, or installments of after-treatments.**

- **Emission testing performed using constant volume sampling for PM emissions.**
- **Weighting factors applied are listed in the document**
- **Yard truck test matrix developed to represent the makeup of the existing fleet, evaluate effectiveness of using emulsified diesel, compare currently available and certified on and off-road engines, and test alternatively fueled propane yard trucks.**
- **Results of testing on emissions for NOX, PM and THC are discussed**
- **Provides modal data**

Limitations: **Data limited to yard trucks for Port of Los Angeles and Port of Long Beach**

Data Summary Sheets

General data category: **Truck / Rail**

Data title: **Evaluating the public investment mix in US Freight Transportation Infrastructure**

Data source: **Michael F. Gorman, Elsevier**

Year released: **2005, 2007**

Brief summary of the value of the data for the Cal GIFT Model: **Discusses how 25% of the truck freight could be handled at 25% lower cost if rail infrastructure to support it existed. An additional 80% reduction in social costs could be achieved through this modal conversion. Discusses modal efficiency comparison and shipper modal choice behavior. Looks at both private and social costs. Provides intermodal rail operating costs on a per ton mile basis, and truck operating costs. Estimates costs for infrastructure investment costs. Discusses variables such as congestion costs, social costs, pollution. Provides data to support these discussions.**

Limitations: **Does not discuss specific locations.**

Data Summary Sheets

General data category: **Highway vehicle fleet**

Data title: **Institute for Trade and Transportation Studies, Volume I, Issue 5**

Data source: **Institute for Trade and Transportation Studies (ITTS)**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **ITTS is working with the American Transportation Research Institute (ATRI) is developing truck speed performance measurements along the Alliance Region's major corridors, and ATRI, in cooperation with the Federal Highway Administration (FHA), is developing a database of average truck speeds along the nations highway system.**

Limitations: **This document is more of a newsletter, and is discussing the I-10 corridor specifically.**

Data Summary Sheets

General data category: **Highway vehicles, rail, transfer facilities**

Data title: **A Geographic Information System Framework for Transportation Data Sharing**

Data source: **Kenneth Ducker, Allison Butler, Center for Urban Studies, Portland State University**

Year released: **2000**

Brief summary of the value of the data for the Cal GIFT Model: **This paper develops a framework and principles for sharing transportation data to achieve more accurate presentation of transportation data. Paper talks about the Geographic Information Systems Transportation (GIS-T) model. This is an intermediate form from which databases to support applications can be generated.**

Limitations: **Differences in definitions of basic transportation entities in data models could result in obstacles in sharing data.**

Data Summary Sheets

General data category: **Cargo handling equipment**

Data title: **Preliminary Analysis of GHG Emissions from Cargo Handling Equipment at Ports During Extended Idling**

Data source: **CARB**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **Discuss fuel consumption, fuel costs, emissions. Idling time was estimated and then used to calculate the associated emissions and fuel consumption due to idling. This was then projected to annual emission estimates for PM, NOX and CO2 for year 2007.**

Limitations: Exhaust temperature data gathered from port terminals only. Data was not collected for yard trucks. A very small sample was used, would need a larger sample in order to be more representative of the fleet.

Data Summary Sheets

General data category: **Highway Vehicle Fleet**

Data title: **Assessment of Out of State Truck Activity in California**

Data source: **Nicholas Lutsey, Institute of Transportation Studies, University of California at Davis**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model:

- **Data collected on truck activity in California:**
 - **Trips/year into California**
 - **Days spent in California**
 - **Amount of fuel trucks are carrying**
 - **Travel patterns such as point of entry into California**
- **General Truck sample statistics were collected:**
 - **Type of truck**
 - **Registration**
 - **Days of operation**
 - **Miles driven/year**
 - **Fuel capacity**

Limitations: **Since data is not kept on interstate trucks' activity while in California, results from truck activity registered outside California collected during a survey were extrapolated to estimate California's in-state truck activity.**

Data Summary Sheets

General data category: **Marine, rail, and highway**

Data title: **Annual Energy Outlook, 2008**

Data source: **Department of Energy, Energy Information Administration**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **Provides national level energy/fuel usage and fuel cost data.**

Limitations: **Little information that is specific to California.**

Data Summary Sheets

General data category: **Railroad and highway vehicles**

Data title: **GREET**

Data source: **Argonne National Laboratory**

Year released: **data downloaded October 2009**

Brief summary of the value of the data for the Cal GIFT Model: **Provides generic emission factors**

Limitations: **Emission factors from GREET need to be adjust to better match locomotives (line-haul and yard) and to account for the introduction of California-specific emission and fuel standards .**

Data Summary Sheets

General data category: **Railway**

Data title: **Class 1 Railroad Statistics**

Data source: **Association of American Railroads (AAR).**

Year released: **November 18, 2008.**

Brief summary of the value of the data for the Cal GIFT Model: **Provides excellent general information about Class 1 railway that can be used to quality check operational assumptions made for the CalGift model.**

Limitations: **The information is aggregated to the national level, California specific data are not provided. For interstate railroad shipment, this data source may be useful to quantify fuel consumption rates, mileage, and some information about the composition of the national line-haul fleet.**

Data Summary Sheets

General data category: **Railroad and highway activities**

Data title: **Analysis of Transportation Options to Improve Fuel Efficiency and Increase the Use of Alternative Fuels in Freight and Cargo Movement in the California/Mexico Border Region**

Data source: **California Energy Commission**

Year released: **August 2008**

Brief summary of the value of the data for the Cal GIFT Model: **Provides insight into cross border freight shipments with Mexico, including information about existing highway vehicle activities and emission factors. Issue related to infrastructure limitations and appropriate potential control options are also present which can be incorporated into the model limit projected activity and emissions.**

Limitations: **The study focused on crossborder shipments with Mexico, and did not consider freight originating in other states. Also because Mexican ports currently have a limited amount of containership traffic and the rail links with California are few and traffic is limited, most of the intermodal freight is associated with highway truck transfers.**

Data Summary Sheets

General data category: **Facility highway, locomotive and nonroad**

Data title: **Statewide Strategies to Reduce Locomotive and Associated Rail Yard Emissions.**

Data source: **California Environmental Protection Agency, Air Resources Board (CARB)**

Year released: **December, 2006; and updated in September 2009.**

Brief summary of the value of the data for the Cal GIFT Model: **This reference provides detail insight into appropriate control options that can be specifically applied to California intermodal facilities to reduce risk from yard related emission sources. Some of the information provided is also useful for port facilities.**

Limitations: **The study only provides recommended control options, while actual penetration and control effectiveness are needed to adjust facility emissions to accurately represent actual emissions.**

Data Summary Sheets

General data category: **Railway, marine vessel, and highway-trucks**

Data title: **FY 2004-2006 Carl Moyer Program, Multi District Projects**

Data source: **California Environmental Protection Agency, Air Resources Board (CARB),**

Year released: **March 22, 2008**

Brief summary of the value of the data for the Cal GIFT Model: **The information provided in the Carl Moyer Program summaries is important to ensure that transfer and port facility emissions are appropriate adjusted to reflect re-engining of vessels, application of idle reduction devices, and use of electric, hybrid and alternative fuel yard and cargo handling equipment.**

Limitations: **In order to account for control options promoted by initiatives such as the Carl Moyer Program data is required for multiple years to accurately assess changes in the equipment fleet.**

Data Summary Sheets

General data category: **Railway**

Data title: **Rail Short Haul Intermodal Corridor Case Studies**

Data source: **Casgar, C. S., DeBoer, D. J. et al.**

Year released: **2003**

Brief summary of the value of the data for the Cal GIFT Model: **The Federal Railroad Administration's Office of Policy and Program Development sponsored the development of this document in the interest of information exchange. The objective of this report is to provide an industry context for public officials who are interested in rail short haul intermodal corridors and to offer a template for analyzing related costs and benefits. The cost data included in this study may of value for the model to assess costs associated with construction of corridors that speed up short haul operations. The study also includes many actual case studies that can be used to calibrate the model.**

Limitations: **The case studies provided include only cities on the east coast and need to be assessed carefully to determine their suitability for west coast corridors.**

Data Summary Sheets

General data category: **Railway**

Data title: **Railroad and Locomotive Technology Roadmap**

Data source: **Argonne National Laboratory, Center for Transportation Research (CTR)**

Year released: **December 2002**

Brief summary of the value of the data for the Cal GIFT Model: **Report provides excellent summary information concerning viable emission reduction approaches. Report also includes considerable amount of information about the national railroad fleet that can be used as surrogate data or to validate assumptions made in the model.**

Limitations: **Some of the data needs to be updated to more accurately reflect recent economic changes. The study does not include data specific to California.**

Data Summary Sheets

General data category: **Marine vessel**

Data title: **Modal Comparison of Domestic Freight Transportation Effects on The General Public**

Data source: **Center for Ports and Waterways, Texas Transportation Institute (TTI)**

Year released: **March 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides excellent summary information about inland waterway traffic.**

Limitations: **Because very little containerized shipment are associated with barge operations, most of this report have little value to the model.**

Data Summary Sheets

General data category: **Marine vessel and railways**

Data title: **Air Pollution Emission Inventory Guidebook-2009**

Data source: **CORINAIR, European Monitoring and Evaluation Programme / European Environmental Agency**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **This report provides emission factors and fuel consumption information for marine vessels and railway operations. These data may be useful to develop validate assumptions made in the model.**

Limitations: **None of the emission factor or fuel consumption data is specific for California emission sources.**

Data Summary Sheets

General data category: **Railways**

Data title: ***Energy Efficiency Technology for Railroads***

Data source: **International Union of Railways (IUR)**

Year released: **Continually being updated**

Brief summary of the value of the data for the Cal GIFT Model: **This data set provides one of the most comprehensive inventories of control options for railways. It includes data on anticipated emission reductions, fuel savings, economic and social costs and benefits.**

Limitations: **Much of the information provided is highly technical and will require considerable amount of work to incorporate into any model. The data provided does not indicate technologies that are currently in use in California, additional research will be needed to accurately assess the penetration of these control options in the states**

Data Summary Sheets

General data category: **Railways**

Data title: **Impact of Technology on Rail Network Capacity**

Data source: **TTCI**

Year released: **April 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This study evaluates the impact that car ordering has on intermodal shipments .**

Limitations: **The information provided in this report is not appropriate for use in the model**

Data Summary Sheets

General data category: **Railway- highway drayage trucking**

Data title: **Exploring a Green Alternative for Container Transport**

Data source: **Presentation provided to the Port of Los Angeles Harbor Commission by S. Roop and J. Lavish**

Year released: **2006**

Brief summary of the value of the data for the Cal GIFT Model: **This presentation provides operational details related to implementation of maglev shuttle service as a replacement for drayage trucks**

Limitations: **At this stage the data provided in this presentation is not relevant for inclusion into the model.**

Data Summary Sheets

General data category: **on-road and railway**

Data title: **Annual Energy Outlook 2008**

Data source: **Annual Energy Outlook 2008**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **This data set includes energy consumption and cost data for current and projected years.**

Limitations: **The data provided does not differentiate fuel consumption or cost specific for the state of California. The cost data would have to be adjusted to account for the fuels that are specifically used in the state. The other data elements may have value to quality check assumption made about fuel usage.**

Data Summary Sheets

General data category: **On-road and railway**

Data title: **North American Transborder Freight Data**

Data source: **U.S. Department of Transportation, Bureau of Transportation Statistics.**

Year released: **August 2009.**

Brief summary of the value of the data for the Cal GIFT Model: **These data quantify cross border activities between Mexico and California. The data set is particularly useful to evaluate commodity exchanges.**

Limitations: **The study focused on crossborder shipments with Mexico, and did not consider freight originating in other states. Also because Mexican ports currently have a limited amount of containership traffic and the rail links with California are few and traffic is limited, most of the intermodal freight is associated with highway truck transfers.**

Data Summary Sheets

General data category: **On-road, marine, and railway**

Data title: **North American Freight Transportation: Trade with Canada and Mexico**

Data source: **U.S. Department of Transportation. Bureau of Transportation Statistics**

Year released: **2006**

Brief summary of the value of the data for the Cal GIFT Model: **This study provided useful data concerning trading patterns between the U.S. , Mexico and Canada.**

Limitations: **The information provided in this report does not traffic through California ports of entry, but these data are dated, while *Transborder Freight Data*, noted above provides similar details and is frequently updated.**

Data Summary Sheets

General data category: **Railroad, marine vessel, and on-road trucks**

Data title: **Transportation Statistics Annual Report, 2008,**

Data source: **U.S. Department of Transportation. Bureau of Transportation Statistics,**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **The study includes national fuel price data, emissions data and fuel consumption data by mode, which may be of value to the model if data are need to gap fill missing data elements.**

Limitations: **The fuel price data may be useful, but other data sources may be more recent, for example the latest railroad fuel cost data is 2006, no data were available for 2007or 2008. There is some information about intermodal transfer in the study, but nothing specific for California**

Data Summary Sheets

General data category: **On-road, marine, and railway**

Data title: **State Transportation Statistics 2008.**

Data source: **U.S. Department of Transportation. Bureau of Transportation Statistics,**

Year released: **2008**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides California specific freight data that can be used to calibrate the model to insure that the traffic patterns reported by the model are similar to those found in this DOT report.**

Limitations: **The data used in the study range between 2004 and 2006 and it is not always easy to differentiate what port of the on-road and rail data relate to intermodal shipments.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Particulate emissions from commercial shipping: Chemical, physical, and optical properties.**

Data source: **Lack, D. A., J. J. Corbett, et al. J. Geophys. Res. 114(D00F04).**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model:.

This report characterizes particulate emissions on the basis of chemical, physical, and optical properties from commercial vessels. Observations during the Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study 2006 field campaign provide chemical and physical characteristics including sulfate (SO₄) mass, organic matter (OM) mass, black carbon (BC) mass, particulate matter (PM) mass, number concentrations (condensation nuclei (CN) > 5 nm), and cloud condensation nuclei (CCN). Optical characterization included multiple wavelength visible light absorption and extinction, extinction relative humidity dependence, and single scatter albedo (SSA). The global contribution of shipping PM was calculated to be 0.90 Tg a⁻¹, in good agreement with previous inventories (0.91 and 1.13 Tg a⁻¹ from Eyring et al. (2005a) and Wang et al. [2008]). Observed PM composition was 46% SO₄, 39% OM, and 15% BC and differs from inventories that used 81%, 14%, and 5% and 31%, 63%, and 6% SO₄, OM, and BC, respectively. SO₄ and OM mass were found to be dependent on fuel sulfur content as were SSA, hygroscopicity, and CCN concentrations. BC mass was dependent on engine type and combustion efficiency. A plume evolution study conducted on one vessel showed conservation of particle light absorption, decrease in CN > 5 nm, increase in particle hygroscopicity, and an increase in average particle size with distance from emission. These results suggest emission of small nucleation mode particles that subsequently coagulate/condense onto larger BC and OM. This work contributes to an improved understanding of the impacts of ship emissions on climate and air quality and will also assist in determining potential effects of altering fuel standards.

Limitations: **Though the study does not focus on California vessels, the data can be used to update and supplement the marine vessel emission factor data.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **The effect of Mg-based additive on aerosol characteristics in medium-speed diesel engines operating with residual fuel oils**

Data source: **Lyrranen, J., J. Jokiniemi, et al. Journal of Aerosol Science 33: 967-981**

Year released: **2002**

Brief summary of the value of the data for the Cal GIFT Model:.

Aerosol measurements were carried out to determine particle formation and characteristics produced in a 4-stroke, turbo-charged 1 MW diesel engine operating with high ash-content heavy fuel oil with and without a Mg-based additive. The mass size distributions are bimodal (modes at 0.1 and 10 μm , aerodynamic size) without additive and have three modes (additional mode at 2 μm) with the additive. It was found that the 2 μm mode was generated by magnesium together with some vanadium, nickel and sulfur. The primary particles are formed by nucleation of the volatilized fuel oil ash species that further grow by condensation and agglomeration. The 10 μm mode particles are mainly re-entrained from deposits and fuel residue particles of different sizes. Primary particle size is about 40–100 nm as observed in the SEM and TEM micrographs. It appears that the 9ne particles (0:1 μm mode) are more spheroidal and catenulate with the additive than without.

Limitations: **Though the study does not focus on California vessels, the data can be used to update and supplement the marine vessel emission factor data.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Aerosol Characterisation In Medium-Speed Diesel Engines Operating With Heavy Fuel Oils.**

Data source: **Lyrranen, J., J. Jokiniemi, et al. Journal of Aerosol Science 30(6): 771-784.**

Year released: **1999**

Brief summary of the value of the data for the Cal GIFT Model:.

Aerosol measurements were carried out in medium-speed diesel engines to determine the aerosol characteristics and formation in four-stroke diesel engines equipped with turbocharger(s) burning heavy fuel and high ash-content heavy fuel oil. The mass size distributions are bimodal with a main mode at 600-90 nm and a second mode at 700-1000 nm. The small mode particles are formed by nucleation of volatilized fuel oil ash species, which further grow by condensation and agglomeration. The large mode particles are mainly agglomerates of different sizes consisting of the small particles. The number size distributions peak at 400-600 nm, as also observed in the SEM micrographs. Agglomerates consisting of these primary spherical particles are also found. The TEM micrographs reveal that these particles consist of even smaller structures. Based on the mass and elemental size distributions evidence of high volatility of the fuel oil ash was found. The main effect on the aerosol size distributions was caused by the engine type and fuel oil properties.

Limitations: **Though the study does not focus on California vessels, the data can be used to update and supplement the marine vessel emission factor data.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **A Critical Review of Ocean-Going Vessel Particulate Matter Emission Factors**

Data source: **Sax, T. and A. Alexis**

Year released: **2007**

Brief summary of the value of the data for the Cal GIFT Model: **California Air Resources Board staff has conducted an exhaustive evaluation of available data to assess ocean-going vessel particulate matter (PM) emission factors. The goals of this assessment were to compile available testing data, analyze potential confounding relationships in the data, and assess emission factors. Our analysis identified no significant difference between emission factors for auxiliary and main engines and between emission factors and load factor, installed power, or model year. CARB found PM emission factors for vessels operating on heavy fuel oil at 2.5% sulfur content were statistically significantly higher (1.5 g/KW-hr) than vessels operating on distillate fuel (0.3 g/KW-hr). While they expected to identify a clear relationship between fuel sulfur content and PM emission factors, our analysis identified only a weak relationship. A future sulfur emission control area may be defined across North America with a 1.5% fuel oil sulfur content limit. Based on the weak relationship between PM emission factors and fuel sulfur content identified in this paper, they estimate the PM emission factor at 1.5% fuel sulfur would be reduced by about 30% to 1 g/KW-hr. Future research and additional testing is necessary to improve PM emission factor measurements from large vessel engines, and to better assess the relationship between PM emission factors and fuel sulfur content.**

Data Summary Sheets

General data category: **Railway**

Data title: **Class I Railway Company R-1 Reporting Forms, 2009.**

Data source: **U.S. Department of Transportation, Federal Railroad Administration**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **These data are reported to the FRA by individual railway companies, including details about their fleet of locomotives, cars, fuel consumption, and national cargo traffic. These data are useful to characterize the national fleet of individual locomotives and can be used to gap fill missing line haul data or to validate data used to populate the state line haul operations.**

Limitations: **The data are not disaggregated at the state level, such that the data are only useful for the GIFT model where it is appropriate to gap fill with national level data, such as with long haul operations. The data also has some value as a reference point for quality assurance checks on the data used to populate the model to ensure that the State data are similar to the national data.**

Data Summary Sheets

General data category: **Railway**

Data title: **Technical Highlights: Emission Factors for Locomotives (EPA420-F-09-025).**

Data source: **U.S. Environmental Protection Agency, Air and Radiation, Office of Transportation and Air Quality.**

Year released: **April 2009.**

Brief summary of the value of the data for the Cal GIFT Model: **The data in this report quantify the regulatory emission standards for locomotives. These standards vary by year of original manufacture and whether the locomotive has been remanufactured. The study clearly shows assumptions that were made in developing the emission factors associated with these locomotive standards. The factors included in this report can be used directly in the GIFT model or they can be used as validation checks on more detailed locomotive specific factors to ensure that the factors used are compliant with the appropriate standard.**

Limitations: **These standards do not reflect changes to the fleet that operate in California - for example California probably has the largest population of hybrid and genset locomotives operating relative to other states. These locomotives significantly out perform the EPA standards.**

Data Summary Sheets

General data category: **Railway**

Data title: **Characteristics of the Existing U.S. Locomotive Fleet**

Data source: **U.S. Environmental Protection Agency, National Vehicle and Fuel Emissions Laboratory,**

Year released: **28 February 2007**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides summary information about the national fleet of locomotives. Some of the data are useful to quantify general characteristics such as typical horsepower ranges.**

Limitations: **The information in this study do not represent individual state fleets, such that the data are only useful for the GIFT model where it is appropriate to gap fill with national level data, such as with long haul operations. The data also has some value as a reference point for quality assurance checks on the data used to populate the model to ensure that the State data are reasonable relative to available national data.**

Data Summary Sheets

General data category: **Railway and Marine vessel**

Data title: **Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder (EPA420-R-08-001a)**

Data source: **U.S. Environmental Protection Agency/ Assessment and Standards Division, Office of Transportation and Air Quality**

Year released: **May 2008**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides considerable information about the national marine and locomotive fleet, including details about fleet composition and, fuel consumption, and cargo traffic patterns. These data are useful to characterize the national fleet of individual locomotives and can be used to gap fill missing line haul data or to validate data used to populate the state line haul operations.**

Limitations: **It should be noted that vast majority of containerships involved in California's intermodal cargo traffic are equipped with category 3 propulsion engines (cylinder volume great than 30 liters) and are therefore not included in this evaluation.**

The locomotive data included in this study are not disaggregated at the state level, such that the data are only useful for the GIFT model where it is appropriate to gap fill with national level data, such as with long haul operations. The data also has some value as a reference point for quality assurance checks on the data used to populate the model to ensure that the State data are similar to the national data.

Data Summary Sheets

General data category: **Railways and Marine vessels**

Data title: **The State of U.S. Railroads, Rand Corporation Technical Report, 2008.**

Data source: **Weatherford, Brian; Willis, H.H.; and Ortiz, D.S., Rand Corporation**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **This Study includes summary data about the current state of the railroad sector focusing on existing fleet of locomotives, rail cars and infrastructure relative to growing demand. This study includes some unusual but useful data such as:**

- **Ton-mile per track mile**
- **Miles of track per locomotive**
- **Track maintenance costs**
- **Social cost associated with congestion**
- **Average tons per train**
- **Average length of haul**
- **Average speed for intermodal traffic by railway company**
- **Average dwell time per company**

These data may be useful in gap filling missing data in the model or to calibrate the model to ensure that the operational components are reasonable.

Limitations: The information included in this study is not disaggregated at the state level, such that the data are only useful for the GIFT model where it is appropriate to gap fill with national level data. The data also has some value as a reference point for quality assurance checks on the data used to populate the model to ensure that the State data are similar to the national data.

Data Summary Sheets

General data category: **Marine, Railway, On-road trucking.**

Data title: **Great Lakes Maritime Research Institute, Intermodal Freight Transport in the Great Lakes: Development and Application of a Great Lakes Geographic Intermodal Freight Transport Model,**

Data source: **Winebrake, J. J.; Corbett, J.J.; Hawker, S; and Kormacher, K. for the Great Lakes Maritime Research Institute.**

Year released: **October 31, 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This is a recent version of the GIFT model that was developed for the Great Lakes Area and includes a lot of functionality that would be appropriate for the Cal GIFT model.**

Limitations: **This version of the model has been created for the Great Lakes area and therefore the data it contains would have to be adjusted to accurately reflect operations in California.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: [In-use gaseous and particulate matter emissions from a modern ocean going container vessel](#)

Data source: **Agrawal, Harshit; Malloy, Quentin G.J.; Welch, William A.; Miller, J. Wayne; Cocker, David R. III; Atmospheric Environment, Volume 42, Issue 21,**

Year released: **July 2008**

Brief summary of the value of the data for the Cal GIFT Model: **This paper provides the emission measurements of gases, particulate matter (PM), metals, ions, elemental and organic carbon, conducted from the main engine of an ocean going PanaMax class container vessel, at certification cycle and at vessel speed reduction mode, during actual operation at sea. The composition of PM, from main engine is dominated by sulfate and water bound with sulfate (about 80% of total PM) and organic carbon constitutes about 15% of the PM. Sulfur, vanadium and nickel are the significant elements in the exhaust from the engine running on the HFO. At the point of sampling 3.7–5.0% of the fuel sulfur was converted to sulfate. These results can be incorporated into the Cal GIFT marine vessels emission factors directly as they relate to vessel directly involved in intermodal shipments.**

Data Summary Sheets

General data category: **Marine Vessel**

Data title: **Characterization of particulate matter and gaseous emissions from a large ship diesel engine**

Data source: **Jana Moldanova, Erik Fridell, Olga Popovicheva, Benjamin Demirdjian, Victoria Tishkova, Alessandro Faccinetto, and Cristian Focsa**

Year released: **2008**

Brief summary of the value of the data for the Cal GIFT Model: **In this study, the composition of exhaust from a ship diesel engine using heavy fuel oil (HFO) was investigated onboard a large cargo vessel. The emitted particulate matter (PM) properties related to environmental and health impacts were investigated along with composition of the gas-phase emissions. Mass, size distribution, chemical composition and microphysical structure of the PM were investigated. The PM composition was dominated by organic carbon (OC), ash and sulphate while the elemental carbon (EC) composed only a few percent of the total PM. Increase of the PM in exhaust upon cooling was associated with increase of OC and sulphate. Hazardous constituents from the combustion of heavy fuel oil such as transitional and alkali earth metals (V, Ni, Ca, Fe) were observed in the PM samples. Measurements of gaseous composition in the exhaust of this particular ship showed emission factors that are on the low side of the interval of global emission factors published in literature for NO_x, hydrocarbons (HC) and CO. These results need to be evaluate to determine if they should be incorporated into the Cal GIFT marine vessels emission factors.**

Limitations: **The study focus on heavy oils, which may be appropriate for the operations on the open seas, but may not be appropriate for operations in California state waters. Further evaluation is needed to determine how best to use these data.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Emission measurements from a crude oil tanker at sea**

Data source: **Agrawal, H., W. A. Welch, et al.; Environmental Science and Technology 42(19): 7098-7103**

Year released: **2008**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides emission factors for the main propulsion engine (ME), auxiliary engine (AE) and an auxiliary boiler on a Suezmax class tanker while operating at sea. The data include criteria pollutants (carbon monoxide, nitrogen oxides, sulfur oxides, and particulate matter), a greenhouse gas (carbon dioxide), speciated hydrocarbons, and a detailed analysis of the PM into its primary constituents (ions, elements, organic, and elemental carbon). The vessel burned two fuels: a heavy fuel oil in the ME and boiler and a distillate fuel in the AE. This article also provides emission factors for selected polycyclic aromatic hydrocarbons, heavy alkanes, carbonyls, light hydrocarbon species, metals, and ions for the ME, AE, and the boiler. These results need to be evaluated to determine if they should be incorporated into the Cal GIFT marine vessels emission factors.**

Limitations: **The study focus on heavy oils, which maybe appropriate for the operations on the open seas, but may not be appropriate for operations in California state waters. Furthermore tanker operations may be significantly different than containership operations. Additional evaluation is needed to determine how best to use these data.**

Data Summary Sheets

General data category: **Marine Vessel**

Data title: **North American Port Container Traffic 2006.**

Data source: **American Association of Port Authorities**

Year released: **2007**

Brief summary of the value of the data for the Cal GIFT Model: **This report provides a summary of container traffic for all major ports in North America.**

Limitations: **The data only covers 2006, U.S. Army Corps of Engineers entrance and clearance data provides more detailed information about California ports**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Airborne Toxic Control Measure For Auxiliary Diesel Engines and Diesel-Electric Engines Operated On Ocean-Going Vessels with in California Waters and 24 Nautical miles Of The California Baseline**

Data source: **California Air Resources Board**

Year released: **June 29, 2009**

Brief summary of the value of the data for the Cal GIFT Model: **The model should be adjusted to reflect the application of this regulation on container ships that operate with in 24 nautical miles of the California coast.**

Data Summary Sheets

General data category: **Marine Vessel**

Data title: **Fuel Sulfur and Other Operational Requirements for Ocean-Going Vessels Within California Waters and 24 Nautical Miles of the California Baseline**

Data source: **California Air Resources Board**

Year released: **June 29, 2009**

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Data Summary Sheets

General data category: **Marine vessels**

Data title: **Ocean Going Vessel Emission Control, Technology Matrix,**

Data source: **California Air Resource Board**

Year released: **October 2002**

Brief summary of the value of the data for the Cal GIFT Model: **This matrix provides a comprehensive summary of available emission control options and provides a percent reduction for PM and NO_x. These data can be easily incorporated in to the GIFT model to estimate emission reductions associated with the application of these technologies on container ships.**

Limitations: **The study only includes PM and NO_x, additional data will be needed to account for reductions of other pollutants and impacts on fuel usage.**

Also control technologies that do reduce emissions from other pollutants were not included in the matrix.

This assessment evaluated individual control technologies, Additional research will be needed to account for emission impacts of application of multiple control technologies.

Data Summary Sheets

General data category: **Marine Vessel**

Data title: Analysis of Transportation Options to Improve Fuel Efficiency and Increase the Use of Alternative Fuels in Freight and Cargo Movement in the California/Mexico Border Region.

Data source: **California Energy Commission**

Year released: **August 2008**

Brief summary of the value of the data for the Cal GIFT Model: **This report, which is part of a larger California Energy Commission project on energy issues in the California/Mexico border region, discusses opportunities to reduce energy consumption and emissions associated with the movement of goods across the border. The study includes a description of the transportation infrastructure, trade patterns, and mode shares in the border region. Opportunities to use alternative and reformulated fuels and advanced vehicle technologies for highway, rail, marine, and aviation modes are discussed as well. Information in this study may be of value to account for cross border cargo flow and define technologies that are appropriate for this unique component of California cargo traffic.**

Limitations: **The data presented in this study are specific for the California/Mexico border regional and may have limited value for the rest of the state.**

Data Summary Sheets

General data category: **Marine vessel, railway, and on-road trucks**

Data title: Modal Comparison of Domestic Freight Transportation Effects on The General Public

Data source: **Center for Ports and Waterways, Texas Transportation Institute (TTI),**

Year released: **March 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides summary data for a wide range of intermodal components, which can be used to validate assumptions made in the model. These data elements included, highway truck trailer capacity and fuel efficiencies for highway trucks and railways.**

Limitations: **Because the focus is on barge activities - some of the data are not meaningful for**

Data Summary Sheets

General data category: **Marine vessel**

Data title: **2005-2006 British Columbia Ocean-Going Vessel Emission Inventory.**

Data source: **Chamber of Shipping**

Year released: **January 2007**

Brief summary of the value of the data for the Cal GIFT Model: **This report presents the results from the emissions inventory of ocean-going (deep-sea) vessels in B.C. waters, for the period from April 1, 2005 to March 31, 2006. Emission estimates are provided for ten criteria air contaminants and for greenhouses gases (GHGs). The report also contains a variety of compiled statistics on vessel behaviour. This study relied on two key data sources: (1) high-resolution Coast Guard VTOSS Track data with detailed information on vessel location and speed, sampled on a 3-7 minute interval, (2) survey data on vessel characteristics for each vessel making a port call in B.C. during the study period. Emissions estimates were compiled for the entire study area, which includes all inland and territorial waters along the B.C. coast, the US and Canadian portions of the Strait of Juan de Fuca, and oceanic waters extending 50 nautical miles offshore. There is little data in this study that would directly relate to California ports, but it does provide information that would be useful to validate assumptions made in the GIFT model.**

Limitations: **This study does not include information related to California ports.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Ship Emissions Inventory - Mediterranean Sea: Final Report**

Data source: **CONCAWE (implemented by Entec UK, Limited)**

Year released: **2007**

Brief summary of the value of the data for the Cal GIFT Model: **This emission inventory of marine vessel activities in the Mediterranean does include containerships. The value of this data set for GIFT is limited and there are other studies that are more relevant for California, which should be preferred over this study.**

Limitations: **This study does not contain information directly related to California intermodal ship traffic. The emission factors included in this study are similar to those found in other sources.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: Allocation and Forecasting of Global Ship Emissions

Data source: **Corbett, James; Wang, C.; Winebrake, J.J.; and Green, E.**

Year released: **January 11, 2007.**

Brief summary of the value of the data for the Cal GIFT Model: **This report presents global inventories of emissions from international shipping. The study provides a clear summary of recent work, evaluates growth in international shipping, includes a spatially allocated global ship emission inventory (0.1 X 0.1 degree lat/long) and evaluates BAU forecast of fleet energy and emissions trends. The insight provided in this study can be used in the GIFT model to quantify or validate eastern trade routes.**

Limitations: **The projections data presented in this report were developed prior to the current economic down turn and need to be revised with revised growth projections if needed.**

The study also lays out procedures to adjust the ICOADS vessel to address sampling bias, by trimming over-reported vessels, using multiple year data and by weighting ship observations with ship installed power.

Data Summary Sheets

General data category: **Marine Vessel**

Data title: **Air Pollution Emission Inventory Guidebook-2009.**

Data source: **CORINAIR, European Monitoring and Evaluation Programme / European Environmental Agency,**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **The Guide summarizes recommended criteria, metal HAPs and PAH emission factors and provides emission reduction for commercially available control devices.**

Limitations: **The data in this report is appears to be an aggregation of data provided in the ENTEC and SEPA marine vessel emission factor studies. The SEPA data is preferred as it provides more disaggregated emission factors that can be more easily tailored to account for the types of containerships that operate in California waters.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Quantification of Emissions from Ships Associated with Ship Movements between Ports in the European Community: Final Report**

Data source: **European Commission developed by Entec UK Limited**

Year released: **July 2002**

Brief summary of the value of the data for the Cal GIFT Model: **This study has been conducted by Entec UK Ltd on behalf of the European Commission, with sub-consultants IVL of Sweden, to address the following key tasks:**

- **Quantify ship emissions of SO₂, NO_x, CO₂ and hydrocarbons in the North Sea,**
- **Irish Sea, English Channel, Baltic Sea, Black Sea and Mediterranean, as well as**
- **quantify in-port emissions of these pollutants plus particulate matter;**
- **Determine emissions for all vessels as well as separately for each vessel type and flag state (Registered in the European Community or outside)**
- **Estimation of the effects of the MARPOL Agreement and additional future scenarios upon emissions, principally sulphur dioxide and particles, in the North**
- **Sea and Baltic Sea and other European seas;**
- **Undertake a market survey of low sulphur marine distillates; and**
- **Investigate the feasibility of ships storing and using multiple grades of marine distillates.**

The main value of this study for the GIFT model are the emission factors used in this study. The authors have done an excellent job compiling the most recent test data of marine vessel data and converting these data into usable emission factors.

Limitations: The SEPA factors appear to be an update and expansion of the EC/Entec factors which includes metal HAPs, dioxin, HCB, and GHG pollutants and would therefore be preferred.

Data Summary Sheets

General data category: **Marine vessel**

Data title: **Assessment of Transport Impacts on Climate and Ozone: Shipping, Atmospheric Environment**

Data source: **Eyring, V., I. S. A. Isaksen, et al.**

Year released: **2009 (in press)**

Brief summary of the value of the data for the Cal GIFT Model: **This study presents an assessment of the contribution of gaseous and particulate emissions from oceangoing shipping to anthropogenic emissions and air quality. Using the global temperature change potential (GTP) metric indicates that after 50 years, the net global mean effect of current emissions is close to zero through cancellation of warming by CO₂ and cooling by sulfate and nitrogen oxides. The study includes a variety useful data about fuel consumption that can be used to calibrate the model or QA the models fuel consumption data.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Lloyd's Registry of Ships**

Data source: **Fairplay**

Year released: **2009 (updated quarterly)**

Brief summary of the value of the data for the Cal GIFT Model: **Lloyds printed the first *Register of Ships* in 1764 in order to give both underwriters and merchants an idea of the condition of the vessels they insured and chartered: Since 1880, the Register, with information on all sea-going, self-propelled [merchant ships](#) of 100 [gross tonnes](#) or greater. Currently the registry is updated quarterly by the joint venture company of [Lloyd's Register - Fairplay](#) which was formed in July 2001 by the merger of Lloyd's Register's Maritime Information Publishing Group and Prime Publications Limited. The registry provides vessel specific characteristics data including: IMO identification number, call sign, vessel type, draft, length, dead weight tonnage, net tonnage, propulsion and auxiliary engine type, engine kW rating, stroke, cylinder diameter, engine speed, vessel maximum speed, etc. Individual vessels identified by AIS or US ACE entrance and clearance data can be linked to Lloyds data based on the vessels IMO numbers. Many of the other data elements (i.e., fuel type, propulsion and auxiliary engine type, engine kW rating, and engine speed) are critical for developing vessel specific emission factors using data sources such as SEPA. The cylinder volume can be calculated using the engine stroke and cylinder diameter, in order to determine which EPA regulatory group the vessel is associated with.**

Limitations: **Some of the data fields related to auxiliary engines is not well populated, and surrogates would have to be developed to fill missing data.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **A Comparative Evaluation of Greenhouse Gas Emission Reduction Strategies for the Maritime Shipping and Aviation Sectors.**

Data source: **Hansen, Mark; Smirti, M.; and Zou, B.,**

Year released: **July 27, 2008**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides a useful summary of strategies which can control GHG emissions from marine vessels. These strategies can be incorporated in to the GIFT model to evaluate the air quality impacts of different control scenarios relative to changes in traffic patterns.**

Limitations: **The control options evaluated in this study needed to be evaluated to identify those that specifically relate to the types of containerships that frequent California ports.**

Data Summary Sheets

General data category: **On-road trucking**

Data title: **Supply Chain Bottlenecks: Border Crossing Inefficiencies between Mexico and the United States; International Journal of Transport Economics XXXI(No.2).**

Data source: **Haralambides, H. E. and Londono-Kent, M. P.**

Year released: **2004**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides detailed insight into the process of moving cargo across the California/Mexico border. Such information can be incorporated into the GIFT model to quantify delays at the border.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Updated Study on Greenhouse Gas Emissions from Ships: Final Report Covering Phase 1 and Phase 2**

Data source: **International Maritime Organization (IMO)**

Year released: **9 April 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This study provides estimates of present and future emissions from shipping. Emissions from water-borne navigation into two primary categories: domestic and international, where “international waterborne navigation” is defined as navigation between ports of different countries. Emission estimates from domestic shipping and emissions from fishing are also included in this report. The study addresses greenhouse gases (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆) and other relevant substances (NO_x, NMVOC, CO, PM, SO_x) that are defined in the terms of reference for this study. Annual inventories of emissions of greenhouse gases and other relevant emissions are provided for the study period of 1990 to 2007. The report also included an analysis of the progress in reducing emissions from shipping through implementation of MARPOL Annex VI. An analysis of technical and operational measures to reduce emissions in also include in this report along with analysis of policy options to reduce emissions. Scenarios for future emissions from international shipping are also evaluated in this study. There is also a section of the report that analysis the effect of emissions from shipping on the global climate. Lastly the study provides a comparison of the energy efficiency and CO₂ efficiency of shipping compared to other modes of transport. The GHG and criteria emission factors presented in this report are the most comprehensive and update and should be used directly in the GIFT model.**

Limitations: **Some of the emission factor data is aggregated and does not account for containerships that operate in California state waters. In order to develop a comprehensive data set of emission factors, data from other studies will be needed to supplement the IMO emission factors for missing pollutants.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Particulate emissions from commercial shipping: Chemical, physical, and optical properties. J. Geophys. Res. 114(D00F04).**

Data source: **Lack, D. A., J. J. Corbett, et al.**

Year released: **25 February 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This study characterizes particulate emissions on the basis of chemical, physical, and optical properties from commercial vessels. Observations during the Texas Air Quality Study/Gulf of Mexico Atmospheric Composition and Climate Study 2006 field campaign provide chemical and physical characteristics including sulfate (SO_4^{2-}) mass, organic matter (OM) mass, black carbon (BC) mass, particulate matter (PM) mass, number concentrations (condensation nuclei (CN) > 5 nm), and cloud condensation nuclei (CCN). The emission factors provided in this study should be evaluated for inclusion into the GIFT model.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **The effect of Mg-based additive on aerosol characteristics in medium-speed diesel engines operating with residual fuel oils; Journal of Aerosol Science 33: 967-981.**

Data source: **Lyyranen, J., J. Jokiniemi, et al.**

Year released: **2002.**

Brief summary of the value of the data for the Cal GIFT Model: **In this study aerosol measurements were carried out to determine particle formation and characteristics produced in a 4-stroke, turbo-charged 1 MW diesel engine operating with high ash-content heavy fuel oil with and without a Mg-based additive. The primary particles were formed by nucleation of the volatilized fuel oil ash species that further grew by condensation and agglomeration. The 10 µm mode particles were mainly re-entrained from deposits and fuel residue particles of different sizes. Fractionated PM emission factors provided in this study should be evaluated for inclusion into the GIFT model.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Particle Formation in Medium Speed Diesel Engines Operating With Heavy Fuel Oils; Journal of Aerosol Science 29(Supplement 1): S1003-S1004**

Data source: **Lyyranen, J., J. Jokiniemi, et al.**

Year released: **1998.**

Brief summary of the value of the data for the Cal GIFT Model: **Aerosol measurements were carried out in this study of medium-speed diesel engines to determine the aerosol characteristics and formation in four-stroke diesel engines equipped with turbocharger(s) burning heavy fuel and high ash-content heavy fuel oil. The main effect on the aerosol size distributions was caused by the engine type and fuel oil properties. Fractionated PM emission factors provided in this study should be evaluated for inclusion into the GIFT model.**

Data Summary Sheets

General data category: **Marine Vessel**

Data title: [Comprehensive Simultaneous Shipboard and Airborne Characterization of Exhaust from a Modern Container Ship at Sea](#); **Environmental Science and Technology**,

Data source: **Murphy, Shane M.; Agrawal, Harshit; Sorooshian, Armin; Padr, Luz T.; Gates, Harmony; Hersey, Scott; Welch, W.A.; Jung, H.; Miller, J. W.; Cocker, David R. III; Nenes, Athanasios; Jonsson, Hafliði H.; Flagan, Richard C. and Seinfeld, John H.**

Year released: **February 4, 2009**

Brief summary of the value of the data for the Cal GIFT Model: **This report focused on the chemical composition of particulate ship emissions. Emissions testing was implemented on the main propulsion engine of a Post-Panamax class container ship cruising off the central coast of California and burning heavy fuel oil. The mass spectrum of the organic fraction of the exhaust aerosol strongly resembled emissions from other diesel sources and appeared to be predominantly hydrocarbon-like organic (HOA) material. Emission test results provided in this study should be evaluated for inclusion into the GIFT model.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **The present State of Marine Transports and Environmental Countermeasures in Japan; OECD/ITF Global Forum on Sustainable Development: Transportation and Environment in Globalizing World.**

Data source: **Okada, Hiroshi**

Year released: **November 22, 2008.**

Brief summary of the value of the data for the Cal GIFT Model: **This presentation included a selection of control technologies being implemented or being considered for implementation to address ship emissions in Japan. The technologies presented in this study would be appropriate for California marine vessel activities. This information could be included in the GIFT model to evaluate the air quality impact of different control scenerios.**

Limitations: **Some of the options presented here do not relate specifically to container ships, and the observations noted in this presentation may have to be evaluated for California ports and container ships that operate in California waters.**

This assessment evaluated individual control technologies, additional research will be needed to account for emission impacts of application of multiple control technologies.

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Exploring a Green Alternative for Container Transport, Presented to the Port of Los Angeles Harbor Commission.**

Data source: **Roop, S. and Lavish, J.**

Year released: **2006**

Brief summary of the value of the data for the Cal GIFT Model: **This presentation includes a variety of control options specific to the Port of Los Angeles which could be included in the model to evaluate air quality impacts of different control scenarios.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Swedish Methodology for Environmental Data, Methodology for Calculating Emissions from Ships**

Data source: **Swedish Environmental Protection Agency (SEPA)**

Year released: **2 February 2004**

Brief summary of the value of the data for the Cal GIFT Model: **This report derived emission factors for ships (> 100 Gross Register Tonnage). The study has focused on 28 different air pollutants, where the emission factors have been proposed as a function of engine and fuel type. For year 2002, the factors cover three operational modes (“at sea”, “maneuvering” and “in port”) and thereby take into account main engine and auxiliary engine emissions. In order to obtain representative and up-to-date emission factors for this application, “in-house” emission data and also published literature emission factor databases were assessed. Thus emission factors were derived from a database consisting of exhaust measurements from 62 ships involving 180 marine engines. The emission factors have been weighted to account for the proportion of the fleet using exhaust gas cleaning measures, age factors for fuel consumption and increased use of low-sulphur fuels. Since the number of measurement data available for the different pollutant emission factors varies considerably, an attempt was made to classify the factors after estimated uncertainty.**

Limitations: **These factors should be supplemented with more recently developed factors discussed in this report; specifically speciated PM factors.**

Data Summary Sheets

General data category:

Data title: **Evaluation of Low Sulfur Fuel Availability- Pacific Rim.**

Data source: **Starcrest for the Ports of Los Angeles and Long Beach**

Year released: **July 2005.**

Brief summary of the value of the data for the Cal GIFT Model: **This report evaluates the availability of lower sulfur fuels use in containerships calling on the Ports of Los Angeles and Long Beach, as well as operational issues, emissions benefits, and emission reduction costs associated with their use. Data in this study should be evaluated to better estimate the sulfur concentration of the fuel currently used by containerships that visit California ports to ensure that GIFT mode provides the most accurate sulfur emission estimates. The report also discusses the availability in the pacific of low sulfur fuels. This information is critical in order to adjust the sulfur emission in the model to better reflect compliance with international SECA regulations. Fuel sulfur concentration is also import in evaluating different control scenarios as high sulfur fuels can poison catalytic system.**

Limitations: **The data in this study is helpful to evaluate potential sulfur levels of fuel, but given the international nature of global cargo shipments and fuel cost constraints it is sometimes very difficult to predict fuel sulfur levels. It is recommended that this study we reviewed along with EPA fuel usage studies developed by RTI for the EPA's recent Category 3 vessel regulations.**

Data Summary Sheets

General data category: **Marine Vessels**

Data title: **Waterborne Commerce Statistics Center.**

Data source: **U.S. Army Corp of Engineers**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **The Waterborne Commerce Statistics Center's standard publications, *Waterborne Commerce of the United States*. Domestic and foreign vessel trips and tonnages by commodity for ports and waterways are covered in the Report. Foreign waterborne commerce between the U.S. and foreign countries are summarized by U.S. port, foreign port, foreign country, commodity group, and tonnage. Data summaries include origin to destination information of foreign and domestic waterborne cargo movements by region and state, and also waterborne tonnage for principal ports and state and territories. Internal waterway tonnage indicators are updated monthly on the NDC website. The report is issued in five parts (one to cover each coast and a national summary). Also available is The Public Domain Database which contains aggregated information of foreign and domestic waterborne cargo movements. Transportation Lines of the United States contains listings of domestic vessel operators, details their equipment and references their service areas. Most data are available in both hard copy and electronic form. Specialized data processing requests are considered on a case-by-case basis and are charged accordingly**

Limitations: **At this time, the Army Corps of Engineers are initiating a new electronic system of reporting system and there may be delays in getting 2009 data.**

Data Summary Sheets

General data category: **Marine vessel, railway, and on-road trucking**

Data title: **National Energy Modeling System. Annual Energy Outlook 2008: Report #:DOE/EIA-0383**

Data source: **U.S. Department of Energy, Energy Information Administration**

Year released: **April 2009.**

Brief summary of the value of the data for the Cal GIFT Model: **The Annual Energy Outlook 2009 (AEO2009) presents projections and analysis of US energy supply, demand, and prices through 2030. The projections are based on results from the Energy Information Administration's National Energy Modeling System. The AEO2009 includes the reference case which was updated this spring to reflect the provisions of the American Recovery and Reinvestment Act (ARRA) that were enacted in mid-February 2009. The need to develop an updated reference case following the passage of ARRA also provided the Energy Information Administration (EIA) with an opportunity to update the macroeconomic outlook for the United States and global economies, which has been changing at an unusually rapid rate in recent months. These data can be used in the GIFT model to project future fuel demand and baseline control scenerios.**

Limitations: **It should be noted that the data included in the AEO is national level data and may not reflect projected fuel demand or control levels specifically for California.**

Data Summary Sheets

General data category: **On-road trucking, rail and marine vessel traffic**

Data title: **Transborder Freight Data.**

Data source: **U.S. Department of Transportation, Bureau of Transportation Statistics.**

Year released: **Retrieved June, 2007**

Brief summary of the value of the data for the Cal GIFT Model: **The North American Transborder Freight Database, has been available since April 1993, and contains freight flow data by commodity type and by mode of transportation (rail, truck, pipeline, air, vessel, and other) for U.S. exports to and imports from Canada and Mexico. The database includes two sets of tables; one is commodity based while the other provides geographic detail. The purpose of the database is to provide transportation information on North American trade flows. This type of information is being used to monitor freight flows and changes to these since the signing of the North American Free Trade Agreement (NAFTA) by the United States, Canada and Mexico in December 1992 and its entry into force on January 1, 1994. The database is also being used for trade corridor studies, transportation infrastructure planning, marketing and logistics plans and other purposes. These data, specifically the Mexico/California data should be evaluated for incorporation into the GIFT model, this would allow the users to analyze cross-border movement of merchandise by all land modes and waterborne vessels.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Final Regulatory Support Document: Control of Emissions from New Marine Compression-Ignition Engines at or above 30 Liters per Cylinder, EPA420-R-03-004.**

Data source: **United States Environmental Protection Agency (2003),**

Year released: **January 2003.**

Brief summary of the value of the data for the Cal GIFT Model: **This document includes multiple other studies that quantify large vessel operations including underway and in-port activities, fuel usage, and emissions. The studies disaggregate vessel types to include containerships relative to five different dead weight tonnage size categories. There is a lot of information in this study that can be used directly in the model to gap fill missing data or as a reference point to quality check data used to populate the model.**

Limitations: **These documents primarily focus on national level activity, though California ports are specifically included in the in- and near- port components of this study; care should be taken in extrapolating the national data to represent California vessels and activities. Because the data is presented in a disaggregated format, it is possible to extract data appropriate for California.**

Data Summary Sheets

General data category: **On-road trucking**

Data title: **Onroad Mobile Sources T6/T7 Heavy Duty Diesel Emission Factors for Calendar Year 2020**

Data source: **EMFAC 2009, Version 2.50.7a (EMFAC 2009)**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **The Emission FACtors (EMFAC) model is developed by the California Air Resources Board and used to calculate emission rates at the state, air district, air basin, or county level from on-road motor vehicles. EMFAC models six criteria pollutants (CO, NO_x, TOG, SO_x, Lead, and PM (either as PM_{2.5} or PM₁₀); six priority mobile source air toxics (benzene, 1,3-butadiene, acetaldehyde, formaldehyde, acrolein, DPM) and CO₂ emission factors. Emissions are calculated for twenty one different vehicles classes comprised of passenger cars, various types of trucks and buses, motorcycles, and motor homes. EMFAC contains default vehicle activity data, and the option of modifying that data, so it can be used to estimate a motor vehicle emission inventory in tons/day for a specific year, month, or season, and as a function of ambient temperature, relative humidity, vehicle population, mileage accrual, miles of travel and speeds. EMFAC2009 includes new data and methodologies regarding calculation of motor vehicle emissions and revisions to implementation data for control measures. EMFAC2009 includes updated data supporting new emission factors and speed correction factors for estimating emissions from heavy-heavy duty diesel trucks. The model includes modifications to the algorithms for inspection and maintenance as well as corrections for heavy-duty truck gas cap benefits from the inspection and maintenance program. Impacts of ethanol permeation and updates to fuel correction factors are included as well as revisions to particulate brake wear emissions. EMFAC2007 incorporates new temperature and humidity profiles. In addition to these changes, which impact emission factors for each area in California, EMFAC incorporates new mileage accrual rates and speed distributions, a redistribution of heavy-duty diesel truck vehicle miles traveled (VMT) and updated VMT for all vehicle classes.**

Limitations: **The Air Resource Board has not approved EMFAC 2009 for public release. ARB will be revising the EMFAC later this year, at which time updated factors can be provided.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **International Maritime Organization Adopts Program to Control Emissions from Oceangoing Vessels, EPA-420-F-08-033.**

Data source: **U.S. Environmental Protection Agency**

Year released: **October 2008**

Brief summary of the value of the data for the Cal GIFT Model: **Currently the EPA is proposing rules that would comply with the IMO's Sulfur Emission Control Area (specifically regulations 13 and 14 and Appendix III of MARPOL Annex VI). It is important to track these developments to insure that the GIFT model accounts for the implementation of these fuel emission standards guidelines.**

Limitations: **Currently the EPA is setting forth a proposal to designate as an Emission Control Area specific portions of the coastal waters of the United States and Canada, in accordance with MARPOL Annex VI. Until the rule is promulgated, it is difficult to anticipate how this may affect containerships operating in California waters.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Boosting Energy Efficiency, Energy Efficiency Catalogue, Ship Power Research and Development.**

Data source: **Wartsila**

Year released: **February 3, 2009.**

Brief summary of the value of the data for the Cal GIFT Model: **Wartsila is one of the largest ship manufacturing firms in the world and this presentation provides a comprehensive summary of available and near-future marine control options. The presentation is provided in a format to clearly identify those technologies that apply to containerships. The fuel and emission reductions noted in the presentation can be applied to the GIFT model to evaluate the impact of different control scenarios.**

Limitations: **This assessment evaluated individual control technologies, additional research will be needed to account for emission impacts of application of multiple control technologies.**

Data Summary Sheets

General data category: **Marine vessels**

Data title: **Energy Use and Emissions from Marine Vessels: A Total Fuel Life Cycle Approach.**
Journal of the Air and Waste Management Association 2007, 57, 102-110.

Data source: **Winebrake, J. J.; Corbett, J. J.; Meyer, P.,**

Year released: **2007**

Brief summary of the value of the data for the Cal GIFT Model: **This study described the Total Energy & Emissions Analysis for Marine Systems (TEAMS) model. TEAMS can be used to analyze total fuel life cycle emissions and energy use from marine vessels. TEAMS captures "well-to-hull" emissions, that is, emissions along the entire fuel pathway, including extraction, processing, distribution, and use in vessels. TEAMS conducts analyses for six fuel pathways: (1) petroleum to residual oil, (2) petroleum to conventional diesel, (3) petroleum to low-sulfur diesel, (4) natural gas to compressed natural gas, (5) natural gas to Fischer-Tropsch diesel, and (6) soybeans to biodiesel. TEAMS calculates total fuel-cycle emissions of three greenhouse gases (carbon dioxide, nitrous oxide, and methane) and five criteria pollutants (volatile organic compounds, carbon monoxide, nitrogen oxides, particulate matter with aerodynamic diameters of 10 µm or less, and sulfur oxides). TEAMS also calculates total energy consumption, fossil fuel consumption, and petroleum consumption associated with each of its six fuel cycles. TEAMS can be used to study emissions from a variety of user-defined vessels. This paper provides example modeling results for three case studies using alternative fuels including a container ship. TEAMS data could be incorporated in the GIFT model to adjust the emissions factors to account for upstream emissions associated with the different fuel marine vessel used. The inclusion of such data would allow for a more comprehensive air quality impact assessment of different control strategies.**

Data Summary Sheets

General data category: **On-road trucking**

Data title: **MOVES Versus EMFAC: Comparison of Greenhouse Gas Emissions Using Los Angeles County**

Data source: **Bai, Song; Eisinger, Douglas S; and Niemeier, Debbie**

Year released: **2009**

Brief summary of the value of the data for the Cal GIFT Model: **The U.S. Environmental Protection Agency is developing a new generation emission model, MOVES (Motor Vehicle Emission Simulator), to replace MOBILE6. MOVES changes the basis for mobile source emissions estimation from average speed to modal activity. This study examines differences in features, methods, and results between MOVES and EMFAC. Using a Los Angeles County, California application; two greenhouse gases, carbon dioxide (CO₂) and methane (CH₄); and two analysis years, 2002 and 2030 were considered. At the county level, for 2002 MOVES produced similar CO₂ emissions, but only 42% of the CH₄ emissions estimated by EMFAC; for 2030, MOVES produced 40% higher CO₂ emissions and CH₄ emissions were nearly double the estimates provided by EMFAC. Important contributing factors to these differences are the activity data and emission rates embedded in MOVES. The default vehicle activities indicated a younger fleet and higher miles traveled for light-duty trucks by 2030. The CO₂ emissions differences between the two models appear to be mainly affected by the magnitude of forecasted vehicle miles traveled; CH₄ emissions results tended to be most effected by the emission rates. EPA considers the underlying MOVES database for CO₂ and CH₄ emissions to be a draft and emissions results will likely change with upcoming model releases. Such studies further re-enforce the position that EMFAC data should be used in the GIFT model.**

APPENDIX B: Using the Model in Case Study

This appendix describes how to use the model in a case study. It describes specific steps to configure the model, determine freight flow based on differing optimization settings, and example results.

How to Run a Multiple OD-Pair Route Analysis in ArcGIS Network Analyst

The model uses ArcGIS Network Analyst to solve routing problems for OD pairs across a multi-modal network and provides solutions as polyline features (routes). The resulting route solutions are represented by single polylines that include, for example, total time and total distance attributes associated with specific OD pairs but do not include the time and/or distance traveled on any given mode. By default, there is no way to determine how much of a solved route was traveled by ship, rail or road, which is crucial to understanding and assessing route solutions. To address this shortcoming, separate time and distance fields were added to the network dataset for each of the component feature classes and modes of transportation. The following fields were added to the eleven feature classes making up the network.

- Rail_Miles
- Rail_Kilometers
- Rail_Hours
- Ship_Miles
- Ship_Kilometers
- Ship_Hours
- Road_Miles
- Road_Kilometers
- Road_Hours

The network dataset was then re-constructed adding the above fields as additional evaluator attributes to be accumulated when routes are solved. Using the enhanced network, time and distances are accumulated by mode for route solutions. The resulting routes have nine additional fields representing the accumulated time and distance traveled for each mode for all segments traversed by a given route. Summing the time and distance of each mode equals the total time and distance of the route.

The enhanced network provides total time and distance for each mode which collectively make up a specific route solution allowing for quick identification of the modes making up a route and their associated time and distance.

Further processing is required to determine the specific locations where any given mode is traversed and where mode changes occur. The solution developed to create unique IDs for each network segment for the dissolve process described below also allows for the mode of each segment to be identified by a numeric code contained in the DissolveID, making it possible to identify the mode of each segment making up a route. Thus, the DissolveID can be used to create visual representations of the modes traveled by any given route.

Importing Multiple OD Sets into Network Analyst (METHOD 1)

We have developed two ways of importing lists of OD points for use in Network Analyst. The first involves creating an Excel spreadsheet with the following fields for each origin port.

Name	Lat	Long	RouteName	Sequence
PORT OF LONG BEACH	33.7395700	118.2095000	- Albany_Schenectady_Amsterdam NY CSA	1
Albany_Schenectady_Amsterdam NY CSA	42.6427100	-73.7481600	Albany_Schenectady_Amsterdam NY CSA	2
PORT OF LONG BEACH	33.7395700	118.2095000	- Anchorage_Alaska	1
Anchorage_Alaska	61.2224600	149.8879300	- Anchorage_Alaska	2
PORT OF LONG BEACH	33.7395700	118.2095000	- Arkansas_Little Rock	1
Arkansas_Little Rock	34.6900700	-92.3261700	Arkansas_Little Rock	2

Within ArcGIS, click on Tools-Add XY Data to create an events theme of the OD Point data

- Navigate to your Excel file and select the correct spreadsheet
- X and Y fields should load correctly (LONG and LAT)
- Edit the Coordinate System – Select – Geographic Coordinate System – North America – North American Datum 1983 (or whatever your XY coordinate units are)
- Click OK

Select OK again to acknowledge the pop-up message. To create a shapefile or feature class from this events theme, right click and choose data export.

Activate the Network Analyst extension

- Click on Network Analyst – New Route
- Open the Network Analyst Window
- Right click on Stops
- Click Load Locations
- Navigate to your XY Events theme (e.g., LALB) – Name and RouteName should fill in automatically
- Click OK

The OD Pairs will load into separate two-point route sets, with the origin port listed first. This will result in a route originating from the port and ending at the paired destination.

Importing Multiple OD Sets into Network Analyst (METHOD 2)

The second method involves creating separate Excel spreadsheets for origins and destinations with the following fields for each file.

DESTINATIONS File			ORIGINS File		
Name	Lat	Long	Name	Lat	Long

Albany_Schenectady_Amsterdam NY CSA	42.6427100	-73.7481600	PORT OF LONG BEACH	33.7395700	-118.2095000
Anchorage_Alaska	61.2224600	-149.8879300	PORT OF SEATTLE	47.5877110	-122.3592180
Arkansas_Little Rock	34.6900700	-92.3261700	PORT OF OAKLAND	37.8215200	-122.3081000

Within ArcGIS, click on Tools-Add XY Data to create an events theme of the OD Point data

- Navigate to your Excel file and select the correct spreadsheet
- X and Y fields should load correctly (LONG and LAT)
- Edit the Coordinate System – Select – Geographic Coordinate System – North America – North American Datum 1983 (or whatever your XY coordinate units are)
- Click OK

Select OK again to acknowledge the pop-up message. Repeat these steps for the other spreadsheet, resulting in two events themes (origins and destinations). To create shapefiles or feature classes for these events themes, right click on each and choose data export.

Activate the Network Analyst extension

- Click on Network Analyst – New Closest Facility
- Open the Network Analyst Window
- Right click on Facilities
- Click Load Locations
- Navigate to your XY Events theme for Origins (e.g., LALB) – Port name should fill in automatically
- Click OK
- Right Click on Incidents
- Click Load Locations
- Navigate to your XY Events theme for Destinations (e.g., Albany_Schenectady_Amsterdam NY CSA) – Destination name should fill in automatically
- Click OK
- Right Click on the Closest Facility Layer in the ArcMap Table of Contents
- Select Layer Properties
- Click the Analysis Settings Tab
- Select "Travel From:" as Facility to Incident

Routes will be generated from Facilities (Origins) to Incidents (Destinations) with the resulting route names including both Origin and Destination in one concatenated field when solved.

Creating Routes Optimizing on Various Impedance Attributes

To run a set of routes, click on the Route Properties icon located in the Network Analyst window

- Under the General Tab, change the layer name (e.g. LALB HOURS) and add a description
- Under the Analysis Settings Tab, select the impedance attribute (e.g. HOURS)
- Under the Accumulation Tab, check the network accumulation attributes you wish to generate
- Click Apply and OK
- Click the Solve icon in the Network Analysts Toolbar

NOTE: All GIFT Evaluator parameters are entered via the GIFT cost factor management and calculator tools except HOURS, KILOMETERS, and MILES. HOURS is an attribute field in each polyline network features and the DWELL TIME junction features. For linear features, HOURS is calculated by dividing the MILES attribute by the SPEED attribute for the road, rail, and waterway features. The transfer facility spoke features (road_spoke, rail_spoke, water_spoke) for the US and Canadian databases use a default value of one hour to represent a transfer time for switching travel modes. Because the spokes are simply artificial bridges between the facilities and the transport networks, length is an unreliable estimate of the distance a TEU must travel if it is transferred from one mode to another at a facility, so HOURS becomes a constant value, or a facility specific transfer time value if the data are available. DWELL TIME nodes are assigned HOURS values based on published railroad industry values for dwell times at each major station, with industry averages used at minor or unreported stations.

By default, a File Geodatabase creates and updates a SHAPE_LENGTH Attribute for each polyline feature class. With an Equidistant Conic projection, the unit of measure is the meter. KILOMETERS are calculated by dividing SHAPE_LENGTH by 1000, and MILES are calculated by multiplying SHAPE_LENGTH by 0.000621371192.

The values used in the SPEED attribute are derived differently for each polyline feature. While the GIFT cost factor management and calculator allows the user to specify an average speed for a given mode (which is reported in the TIME attribute), SPEED is entered directly into the feature class database. For NTAD and Canadian roads, typical or posted speeds for road class are used, based on published government estimates. Commercial road databases often have “real time” speeds reported, but this project opted to use the publicly available NTAD database for roads and rail network features. Rail speeds are a constant value from the literature, since rail companies have not made available GIS databases with posted or actual speeds. The waterways, derived from the STEEM database from the University of Delaware, have two speeds – near shore and off shore. A 20 km buffer was used to split and assign waterway segments the appropriate speed.

Adding in CFS Freight Totals, Weights, and Destination Estimated TEUs

For this type of analysis, the first OD pair import methods works best.

- The spread sheet with the port calculations for distributing TEUs to specific destinations is joined to the stops using the Name attribute field, rather than the RouteName attribute. This prevents double counting totals by automatically assigning the origin port default values of zero.
- Solve for the Routes.
- Run the Network Analyst Traversal Result to ArcMap Script (see details in the next section)
- Open the Edges attribute table
- Join the Edges attribute table (RouteID) with the Routes Attribute Table (ObjectID)
- Export edges
- Create a unique ID field (DISSOLVEID) for use in a dissolve application (see section **Creating Unique IDs for the Edge Features**)

Add Network Analyst Traversal Result To ArcMap

Since the model generates multiple routes over the network from a single port, it can be difficult to identify where and how often routes overlap. Including additional origin ports, such as Oakland and Seattle, further complicates this assessment, since routes originating from those ports will also use some network segments from the initial port (LALB). Overlapping routes are a possible indicator of transport volume, congestion, and usage in freight movement. The following script is provided to allow the user to convert individual routes into segments (edges). The edges can then be combined through the DISSOLVE command (ArcToolbox – Data Management Tools – Generalization – Dissolve), counting segments by unique ID to determine how often a given segment of a network is used in the routing analysis. Knowing freight flow to each destination, multiplied by the number of times a given route segment is used when moving TEUs from a port to a destination, allows the user to estimate truck counts and possibly congestion. It also allows the user to accumulate pollutants for a given segment used in multiple routes.

Script AddNATraversalResultToArcMap.txt (provided by Jay Sandhu, ESRI)

```
Public Sub AddNATraversalResultToArcMap()  
  
    Dim pMxDoc As IMxDocument  
  
    Dim pNetworkAnalystExtension As INetworkAnalystExtension  
  
    Dim pNALayer As INALayer  
  
    Dim pFLayer As IFeatureLayer  
  
    Dim pTraversalResultQuery As INATraversalResultQuery  
  
    Dim pNATraversalResultEdit As INATraversalResultEdit  
  
  
    Set pMxDoc = ThisDocument  
  
    Set pNetworkAnalystExtension = Application.FindExtensionByName("Network Analyst")  
  
    Set pNALayer = pNetworkAnalystExtension.NAWindow.ActiveAnalysis  
  
    Set pTraversalResultQuery = pNALayer.Context.Result  
  
    Set pNATraversalResultEdit = pTraversalResultQuery  
  
  
    'Infer Geometry  
  
    pNATraversalResultEdit.InferGeometry "", Nothing, New CancelTracker  
  
  
    'Get the Edges and add as a layer  
  
    Set pFLayer = New FeatureLayer
```

```
Set pFLayer.FeatureClass = pTraversalResultQuery.FeatureClass(esriNETEdge)
```

```
pFLayer.Name = pFLayer.FeatureClass.AliasName
```

```
pMxDoc.FocusMap.AddLayer pFLayer
```

```
'Get the Junctions and add as a layer
```

```
Set pFLayer = New FeatureLayer
```

```
Set pFLayer.FeatureClass = pTraversalResultQuery.FeatureClass(esriNETJunction)
```

```
pFLayer.Name = pFLayer.FeatureClass.AliasName
```

```
pMxDoc.FocusMap.AddLayer pFLayer
```

```
End Sub
```

To use this script in a network analysis, it needs to be loaded into the map document BEFORE the routes are solved

- Click Tools – Macros – Visual Basic Editor
- In Visual Basic Editor, click File – Import File
- Navigate to the directory with the script, change file type to allow for All Files and select AddNATraversalResultToArcMap.txt (note - macro will load but may not display in Visual Basic Editor)
- Click File – Close and Return to ArcMap

For a previously solved route, simply resolve to load the current OD route analysis into memory

Run the macro on the active route set –

- Click Tools-Macros-Macros
- Highlight the macro AddNATraversalResultToArcMap
- Click Run

The macro will not show a status bar as it runs, but will generate two memory feature class layers when complete, (junctions and edges). Edges are the routes broken down into simple two-point segment sets (based on junctions), with new unique IDs for each segment, but retaining the route unique ID as SOURCEID and the unique feature layer ID as SOURCEID. These edges are not permanent features and will be erased once you close the map document, even the map document is saved. To create permanent features, either in the feature database or as a new shapefile, you will need to export the data.

- Right click on the layer you want to export (e.g., Edges)
- Select Data – Export Data, navigate to the folder of feature dataset you want to use, and save the file

Creating Unique IDs for the Edge Features

Because the network dataset is comprised of different transportation networks, there is an issue involving the unique IDs generated by the edge extraction of the original route features. Canadian roads and US roads, for example, each have Object IDs ranging from 1 to n, but are separate features classes. Therefore, if the dissolve process is used on SOURCEOID attribute in the edges feature class to generate counts, it is possible to include a count of Canadian road segments with US road segments if both sets have edges with SOURCEOID values of 5, for example. To generate a truly unique ID to edges within a given route, a new, unique attribute needs to be created for the dissolve analysis that combines SOURCEID with SOURCEOID.

- Right click on Edges and Open the Attribute Table
- On the table, click Options – Add Field
 - DISSOLVEID
 - Long Integer
 - 12
- Right click on DISSOLVEID and click Field Calculator
 - [SourceID] * 1000000 + [SourceOID]
 - OK

DISSOLVEID is now unique and allows the user to know what network feature class a given edge is from (the first one or two digits) and the unique ObjectID of the original network feature (the last six digits).

Calculating the Number of Times a Network Segment is Used for a Given Port Analysis

To create a count statistic for the number of times a given network segment is used in a multiple route analysis from a port and the number of TEUs that move over a given route segment, run dissolve, making sure the output name describes the port and impedance attribute used in the network analysis.

- ArcToolbox – Data Management Tools – Generalization – Dissolve
 - LALB_EDGES_HOURS (the input features)
 - LALB_EDGES_HOURS DISSOLVE (the output features)
 - DISSOLVEID (the dissolve field)
 - From the Statistics Field dropdown menu, choose DISSOLVEID
 - Select COUNT as the Statistics Type
 - From the Statistics Field dropdown menu, choose LALB_DTEUs
 - Select SUM as the Statistics Type
 - Add in other attributes and statistical summaries as desired
 - Uncheck the box for multipart features
 - Click OK

Use the resulting shapefile to create thematic maps that illustrate route counts and TEU totals by network segment. The following figures illustrate sample analysis results.

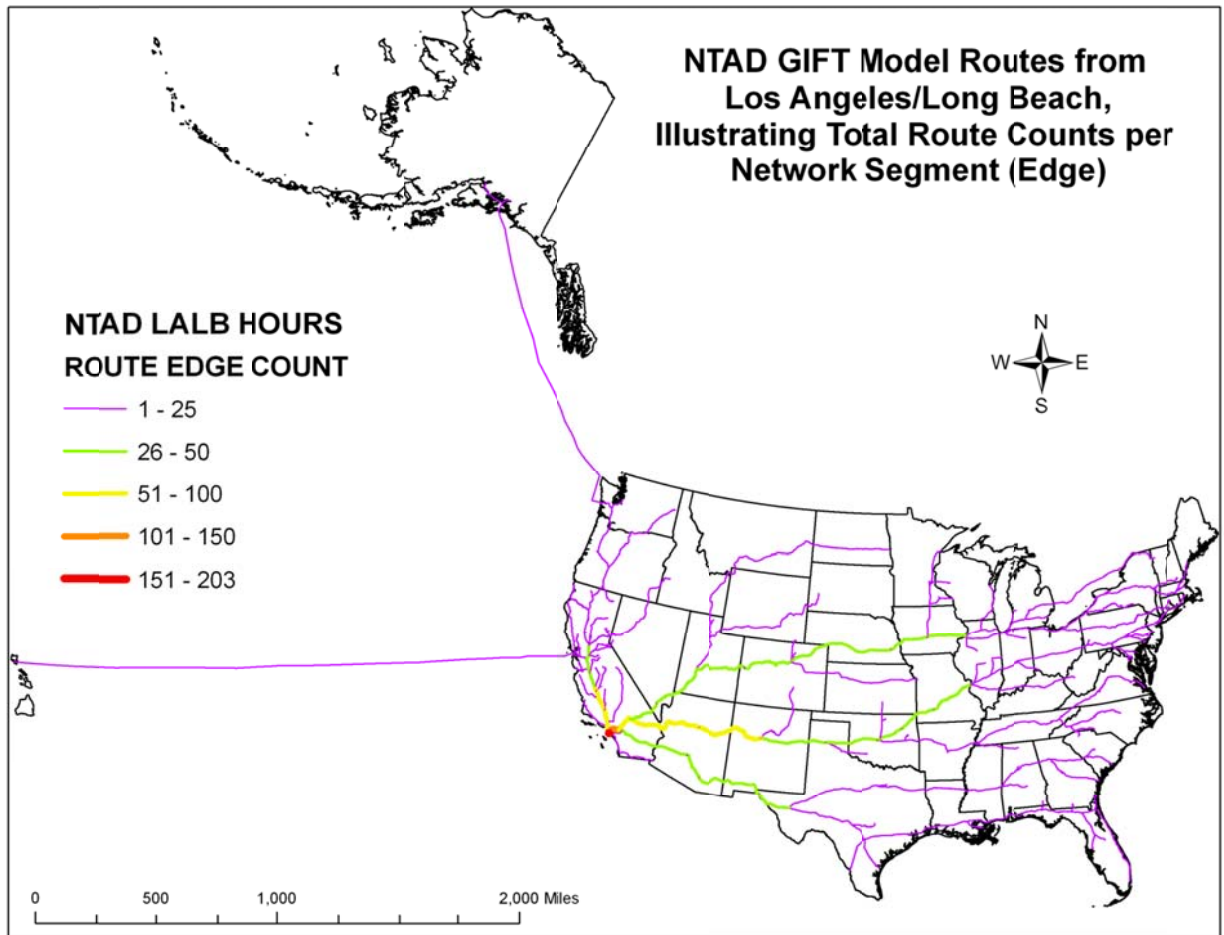


Figure 23. LA-Long Beach total route counts per network segment (edge)

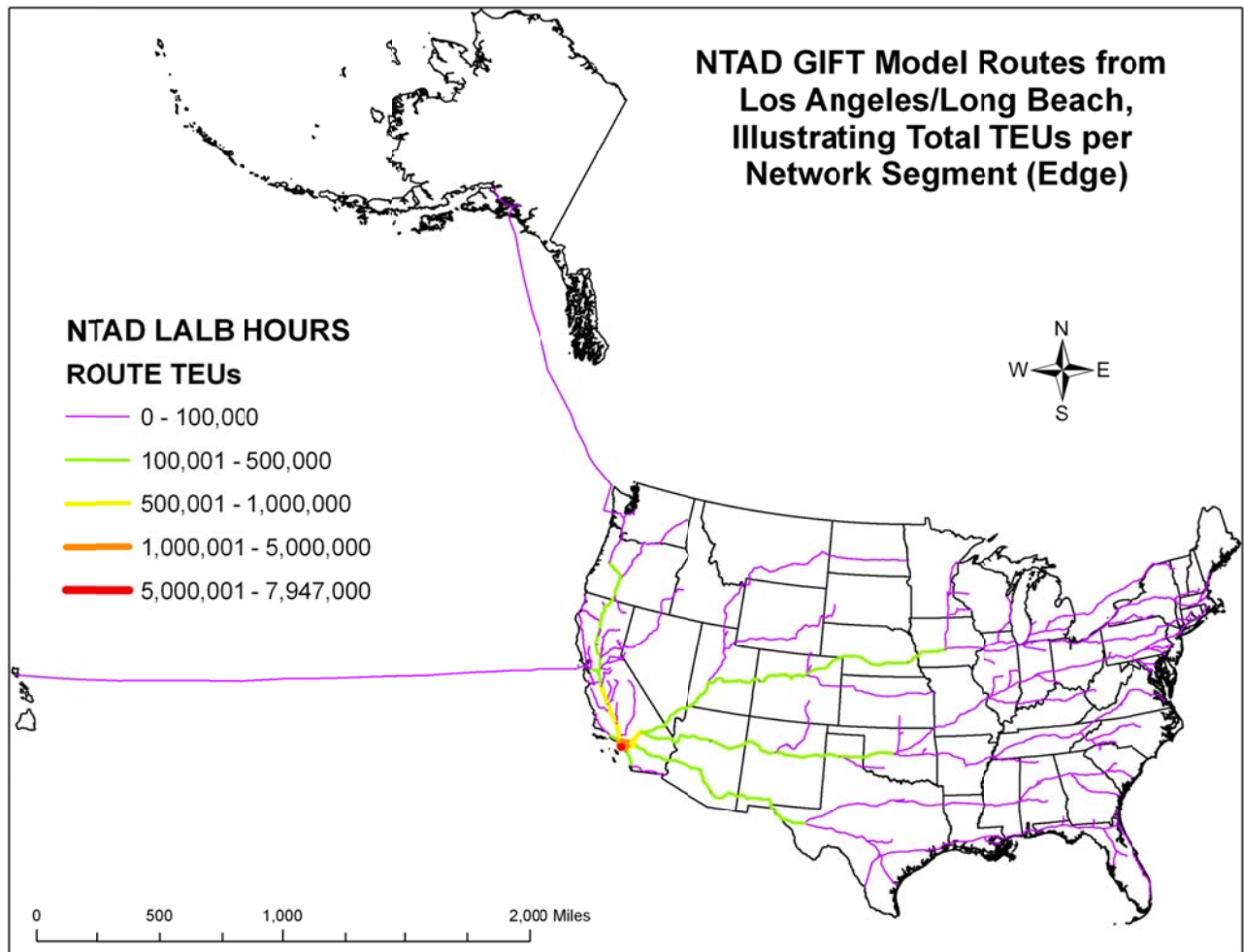


Figure 24. LA-Long Beach total TEUs per network segment (edge)

APPENDIX C: Recommended Emissions, Cost and Energy Data Sources

Table 10. Recommended emissions, cost, and energy data sources

Mode	Parameter	California Specific Data	National / International Default Data
On road	Emissions	EMFAC emission factors by California county and segment vehicle speed (grams of pollutant/mile)	No additional data are required
	Cost	California Energy Commission highway fuel cost assumption (\$/gallon)	No additional data are required
	Energy	"Burden" mode for EMFAC provides fuel consumption (gallons) which can be applied to VMT to calculate miles/gal	No additional data are required
Rail	Emissions	Obtain Segment level load factor (notch setting) data from California Department of Transportation (% of max) - currently trying to track down these data	National default NOx, PM, HC, SOx and CO2 emission factors from recent (April 2009) EPA regulatory background documents. These criteria factors can be speciated into HAP components using NEI data.(g of pollutants/hp-hr or gal).
	Cost	California Energy Commission railway fuel cost assumption (\$/gal)	AEO data can be used as a quality check to insure that the IMO and CEC data are reasonable, also national fuel price data provided in the R-1 submittals made by individual rail companies that operate in the state can also be used as a check on the railway
	Energy	California specific locomotive fuel consumption data are not readily available	The EPA regulatory background documents noted above include fuel factors for line-haul, short-haul and yard locomotives that can be used (gallons of fuel/hp-hr). Typical line-haul and yard HP ratings can be obtained from other EPA documents to derive fu
Marine vessel	Emissions	Identify containerships that frequent California ports using army Corps of Engineers <i>Entrance and Clearance</i> data in conjunction with Lloyds data to quantify vessel characteristics (kW)	Apply California vessel characteristics data to IMO GHG factors and SEPA criteria and HAP factors (g of pollutant/kW-hr) - These baseline emission factors will be updated with more recent and more specific factors developed by ARB, CE-CERT, and IVL.
	Cost	IMO (inbound vessel) Marine vessel fuel cost adjusted for California bunkered marine fuel costs as reported by the California Energy Commission (outbound) (\$/tons of fuel)	AEO data and fuel price data compiled in support of recent EPA marine vessel regulations can be used as a quality check to insure that the IMO and CEC data are reasonable.
	Energy	Identify containerships that frequent California ports using Army Corps of Engineers <i>Entrance and Clearance</i> data in conjunction with Lloyds data to quantify vessel characteristics (kW)	Apply California vessel characteristics data to SEPA fuel factors (g of fuel/kW-hr)
Facility Port	Emissions	Emission factor data included in the LA/Long Beach emission inventories.	Other port inventories and studies of port-based non-road mobile and stationary equipment.
	Cost	California Energy Commission marine vessel and highway fuel cost assumptions	
	Energy	Energy use data included in the LA/Long Beach emission inventories or derived from CO ₂ factors.	Other port inventories and studies of port-based non-road mobile and stationary equipment.
Facility Rail Yard	Emissions	Emission factor data included in the Yard emission inventories developed for ARB by the Rail companies that operate in the state	Other rail yard inventories and studies of rail terminal non-road mobile and stationary equipment.

Mode	Parameter	California Specific Data	National / International Default Data
	Cost	California Energy Commission railway and highway fuel cost assumptions	
	Energy	Energy use data included in the Yard emission inventories developed for ARB by the Rail companies that operate in the state or derived from CO ₂ factors.	Other rail yard inventories and studies of rail terminal non-road mobile and stationary equipment.
Facility Truck Transfer	Emissions	Emission factor data included in the truck-stop emission inventories (sources to be identified). Use EMFAC emission factors for idling, but will need typical idling times from other idle reduction studies.	Other truck yard inventories and studies of truck terminal non-road mobile and stationary equipment. Look at Dray Fleet model developed by TIOGA for Ken Adler at EPA
	Cost	California Energy Commission highway fuel cost assumption	
	Energy	Energy use data included in the truck-stop emission inventories or derived from CO ₂ factors (sources to be identified) Use EMFAC fuel consumption factors for idling, but will need typical idling times from other idle reduction studies.	Other truck yard inventories and studies of truck terminal non-road mobile and stationary equipment.

APPENDIX D: Validating Intermodal Facilities

Below is the procedure for creating a spreadsheet of verified rail carrier facilities. Figure 25 illustrates this spreadsheet and Figure 26 illustrates the facilities imported into ArcGIS as a shapefile.. This procedure can be repeated as additional facility data becomes available.

Major Carrier	ObjectID	Status	Distance
TRANSFLO	91	?	?
BNSF	371	Good	504 m
BNSF	381	Good	584 m
BNSF	310	Good	533 m
BNSF	311	Good	930 m
CSX	485	Good	665 m
CSX	611	Good	695 m
CSX	598	Good	688 m
CSX	481	Good	718 m
CSX	512	Good	785 m
FEC	838	Good	896 m
KCS	444	Good	564 m
KCS	522	Good	766 m
NS	228	Good	828 m
NS	229	Good	672 m
NS	1647	Good	572 m
NS	198	Good	565 m
NS	138	Good	891 m
NS	227	Good	588 m
NS	211	Good	608 m
NS	214	Good	609 m
NS	222	Good	840 m
TRANSFLO	107	?	?
TRANSFLO	838	Good	?
TRANSFLO	1035	Good	?
TRANSFLO	1159	Good	?
TRANSFLO	1410	Good	?
TRANSFLO	1517	Good	?
TRANSFLO	2285	Good	?
TRANSFLO	2667	Good	?
UP	254	Good	798 m
UP	1777	Good	524 m
UP	598	Good	679 m
UP	520	Good	709 m
UP	571	Good	739 m
BNSF	388	Good	141 m
BNSF	385	Good	13 m
BNSF	1673	Good	25 m
BNSF	395	Good	34 m
BNSF	428	Good	35 m
BNSF	381	Good	39 m
BNSF	1669	Good	478 m
BNSF	311	Good	7 m
BNSF	1667	Good	84 m
BNSF	385	Good	95 m
BNSF	371	Good	183 m
BNSF	271	Good	184 m
BNSF	311	Good	203 m
BNSF	1668	Good	243 m
BNSF	388	Good	248 m
BNSF	385	Good	39 m
BNSF	389	Good	61 m
BNSF	303	Good	69 m
BNSF	1673	Good	185 m
BNSF	388	Good	223 m
BNSF	395	Good	254 m

Figure 25. Rail carrier facility spreadsheet

The spreadsheet consist of three field names: Major Carrier, ObjectID, and Status

- **Major Carrier:** This attribute represents a list of the different major rail carriers: BNSF (Burlington Northern Santa Fe), CN (Canadian National), CP (Canadian Pacific), CSX, FEC (Florida East Coast), KCS (Kansas City Southern), UP (Union Pacific), GATX (General American), TRANSFLO (a CSX subsidiary providing intermodal transloading), and NS (Norfolk Southern).
- **ObjectID:** This uniquely identifies specific terminal facilities and its location.
- **Status:**
 - **Missing** - This status represents facilities that are nonexistent from Garth_RR3 source
 - **Not on rail spoke** - This status represents facilities that are close to but not on the rail spoke of the NTAD facilities.
 - **Way off**- This status represents facilities from the facilities file that are marginally off from NTAD facilities.
 - **Good** - This status represents facilities from the facilities file source that are linked to the corresponding NTAD facilities and that they are close by to each other.
 - **"?"** - This status represents the facilities file facilities in question. Further investigation is needed.

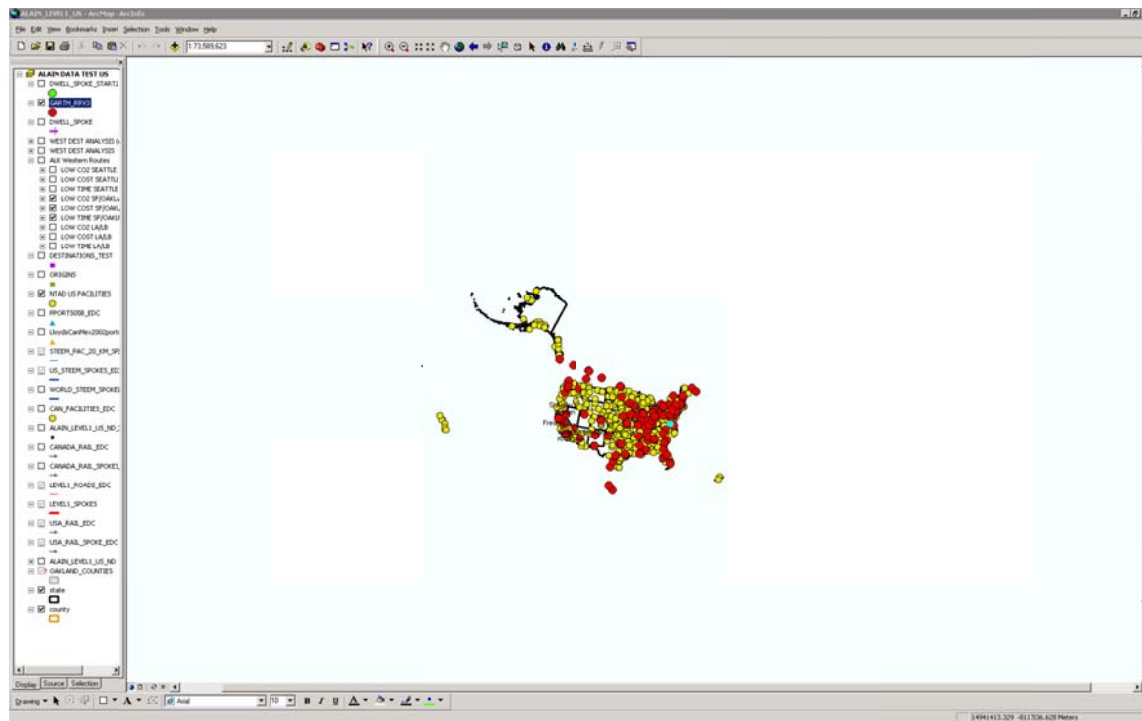


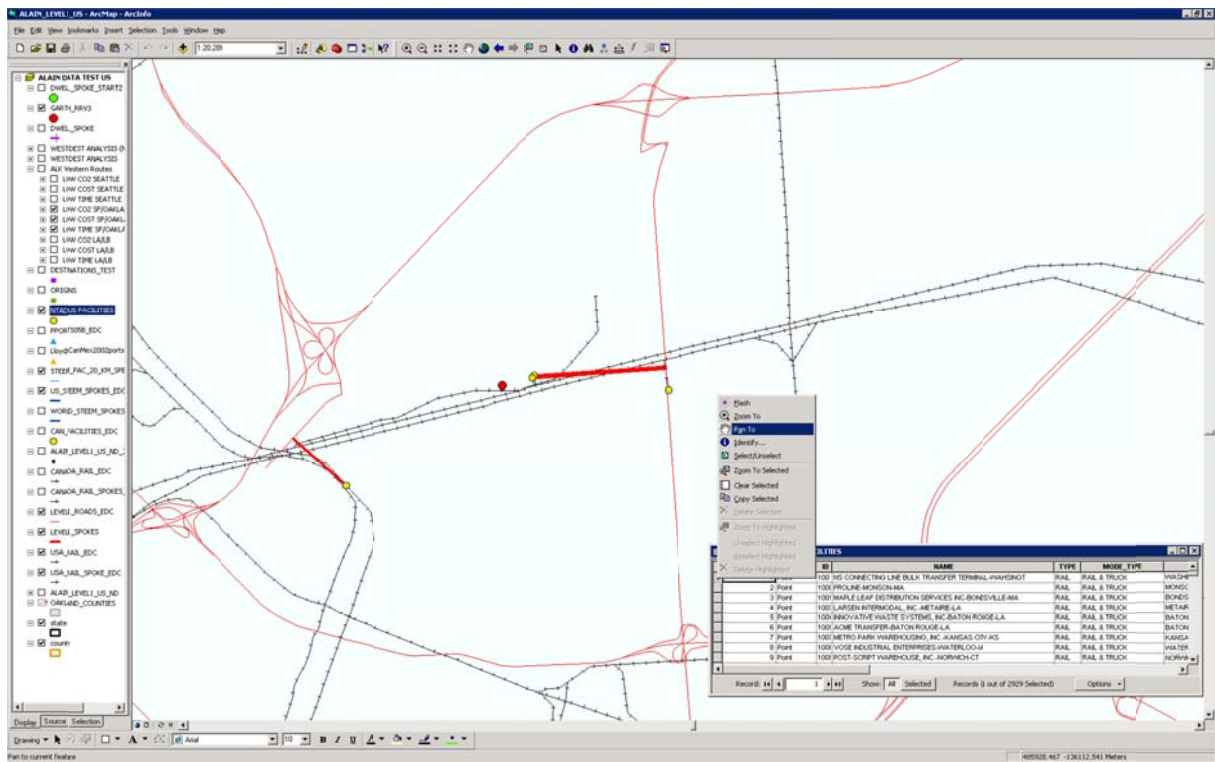
Figure 26. Facilities spreadsheet as an imported shapefile

Procedure

1. Import facilities spreadsheet into ArcGIS as a shapefile
2. NTAD US Roadway shapefile opened using ArcGIS
3. Imported facilities and NTAD US FACILITIES layers are selected/checked
4. Open Attribute Table of NTAD US FACILITIES (See Figure 27)
5. Highlight Name attribute
6. Sort by Ascending
7. List all major carriers and their respective ObjectID
8. Record the major carriers list into the spreadsheet
9. For each major carriers in the NTAD US FACILITIES table, pan to the terminal facilities' location by right-clicking on the selected record (See Figure 28).
10. Verify that there is a terminal facility from NTAD (represented by yellow dot symbol)
11. Verify if there are any facilities listed from imported facilities (represented by red dot)
12. Verify both NTAD and imported facilities by using status attributesRecord into the spreadsheet

Attributes of NTA0 US FACILITIES																			
OBJECTID	Shape	ID	NAME	TYPE	MODE TYPE	CITY	STATE	FIPS	ZIP	ZIP2	PARCEL	LATITUDE	LONGITUDE	GEOSOURCE	CREATEDATE	CREATOR	MODDATE	VERSION	REF. NO. TERRA
1	Point	1000	PROLINE-MONSON,MA	RAIL	RAIL & TRUCK	MONSON	MA	25	01057			42 1089	-72 31 265 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
2	Point	1001	MAPLE LEAF DISTRIBUTION SERVICES INC-BONEVILLE,MA	RAIL	RAIL & TRUCK	BONEVILLE	MA	25	01069			42 34202	-71 05485 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
3	Point	1002	LARSEN INTERNATIONAL, INC-METABE,LA	RAIL	RAIL & TRUCK	METABE	LA	22	70051			29 67628	-92 29471 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
4	Point	1003	ANNOVATIVE WASTE SYSTEMS, INC-BATON ROUGE,LA	RAIL	RAIL & TRUCK	BATON ROUGE,LA	LA	22	70807			30 5545	-91 1991 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
5	Point	1004	ACHIE TRANSFER-BATON ROUGE,LA	RAIL	RAIL & TRUCK	BATON ROUGE,LA	LA	22	70807			30 5545	-91 1991 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
6	Point	1005	METRO PARK WAREHOUSE, INC-KANSAS CITY,KS	RAIL	RAIL & TRUCK	KANSAS CITY	KS	20	66106			39 0579	-94 68441 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
7	Point	1006	VOSE INDUSTRIAL ENTERPRISES-WATERLOO,IA	RAIL	RAIL & TRUCK	WATERLOO	IA	19	50700			42 31488	-90 40864 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
8	Point	1007	POST SCRIPT WAREHOUSE, INC-NORTHCH,CT	RAIL	RAIL & TRUCK	NORTHCH	CT	09	06360			41 12611	-72 08792 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
9	Point	1008	DELTA AND PARKER-TUCULOGUA,IL	RAIL	RAIL & TRUCK	TUCULOGUA	IL	01	56401			33 01182	-87 6261 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
10	Point	1009	GLOBAL MATERIALS SERVICES-MEMPHIS,TN	RAIL	RAIL & TRUCK	MEMPHIS	TN	47				35 08972	-90 10944 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
11	Point	1010	COMMERCIAL TRANSLAD OF MINNESOTA-FRISLEY,MN	RAIL	RAIL & TRUCK	FRISLEY	MN	27	55432			45 30705	-93 26334 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
12	Point	1011	SHREWSBURY INDUSTRIAL ENTERPRISES-UK-ROU,IL	RAIL	RAIL & TRUCK	SHREWSBURY (DETROIT)	IL	17	60132			42 08419	-87 23275 540	2000 STREETS	480003	INDUS	-#n/a-	01	CN
13	Point	1012	SOUTH TEC DEVELOPMENT CORP-KANKAKEE,IL	RAIL	RAIL & TRUCK	KANKAKEE	IL	17	60901			41 37213	-87 88918 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
14	Point	1013	STELLAR-CHICAGO,IL	RAIL	RAIL & TRUCK	CHICAGO	IL	17	60632			41 82261	-87 70891 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
15	Point	1014	TRANSLOAD SERVICES, LLC-HARVEY,LA	RAIL	RAIL & TRUCK	HARVEY	LA	17				41 12601	-87 68006 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
16	Point	1015	AUTOMATED PRODUCTS-AUTOMATED PRODUCTS-MARSHFIELD,WI	RAIL	RAIL & TRUCK	MARSHFIELD	WI	55	54449	4607		44 05479	-89 15304 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
17	Point	1016	PORT ARTHUR, TX	RAIL	RAIL & TRUCK	PORT ARTHUR	TX	48	77641			29 56504	-95 50947 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
18	Point	1017	INTERNATIONAL LARDO, TX	RAIL	RAIL & TRUCK	LARDO	TX	48	78044			2 5628	-99 50172 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
19	Point	1018	DALLAS WAREHOUSE AND RELOAD, LLC-DALLAS, TX	RAIL	RAIL & TRUCK	DALLAS	TX	48	75218			32 80181	-96 67223 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
20	Point	1019	SHIP INDUSTRIAL SALVAGE CORPUS CHRISTI, TX	RAIL	RAIL & TRUCK	CORPUS CHRISTI	TX	48	78405			27 05589	-97 45389 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
21	Point	1020	GREATER SOUTH TRANSPORTATION-MEMPHIS,TN	RAIL	RAIL & TRUCK	MEMPHIS	TN	47	38109	2408		35 36594	-90 07698 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
22	Point	1021	TER ONE DISTRIBUTION-SPRINGFIELD, OH	RAIL	RAIL & TRUCK	SPRINGFIELD	OH	39	45501			39 3132	-83 7792 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
23	Point	1022	SOUTH BUFFALO DISTRIBUTION CENTER-LACKAWANNA,NY	RAIL	RAIL & TRUCK	LACKAWANNA	NY	39	14218			42 52375	-78 85011 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
24	Point	1023	RELOAD, INC. ST. LOUIS, MO	RAIL	RAIL & TRUCK	ST. LOUIS	MO	20	63110	2533		38 52481	-90 24295 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
25	Point	1024	CENTRAL MISSOURI RELOAD-KANSAS CITY, MO	RAIL	RAIL & TRUCK	KANSAS CITY	MO	20	64123	1989		39 17288	-94 50439 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
26	Point	1025	EFFLUENT PAPER COMPANY, LLC	RAIL	RAIL & TRUCK	WATCHEE	MS	28	39218			32 28432	-90 18943 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
27	Point	1026	INTERSTATE MERCHANDISE WAREHOUSE, INC.	RAIL	RAIL & TRUCK	MERIDIAN	MS	28	39301			32 36619	-89 69918 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
28	Point	1027	IND-AMERICAN DISTRIBUTION COMPANIES	RAIL	RAIL & TRUCK	MOBILE	MS	28	39640			31 2474	-90 45129 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
29	Point	1028	LAW SUPERIOR WAREHOUSE-LOUISIANA	RAIL	RAIL & TRUCK	SULLY	MS	21	56682	2609		48 78613	-92 10139 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
30	Point	1029	K & W WAREHOUSE-MEMPHIS, TN	RAIL	RAIL & TRUCK	MEMPHIS	MS	26	48958			48 01975	-97 60776 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
31	Point	1030	LEVELS CHICAGO, IL	RAIL	RAIL & TRUCK	KALAMAZOO	MI	26	49001			42 2638	-85 57219 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
32	Point	1031	NEWEST TOWER	RAIL	RAIL & TRUCK	EDWARDSBURG	MI	26				41 8579	-84 65389 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
33	Point	1032	LOUMBER RELOAD DETROIT, MI	RAIL	RAIL & TRUCK	DETROIT	MI	26	48234			42 44155	-83 01384 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
34	Point	1033	MURPHY BOKER WAREHOUSE	RAIL	RAIL & TRUCK	SHREVEPORT	LA	22	71108			32 03638	-93 77982 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
35	Point	1034	MOORE WAREHOUSE	RAIL	RAIL & TRUCK	MOORE	LA	22	71202			32 89465	-92 11962 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
36	Point	1035	ADWAY SYSTEMS, INC.	RAIL	RAIL & TRUCK	BATON ROUGE, LA	LA	22	70807	1519		30 56561	-91 17448 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
37	Point	1036	ROBERTS AND CYRIL, INC.	RAIL	RAIL & TRUCK	WATERLOO, IA	IA	19	50703	2528		42 52118	-92 35912 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
38	Point	1037	TRANSFER SERVICES	RAIL	RAIL & TRUCK	CEAR RAPIDS	IA	19	52404			41 80513	-91 69008 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
39	Point	1038	THE INDIANA RAIL, ROAD CO.	RAIL	RAIL & TRUCK	INDIANAPOLIS	IN	18	45206			39 87463	-86 18499 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
40	Point	1039	C.W.P., INC.	RAIL	RAIL & TRUCK	VERDE	IL	17	62000	1028		38 38213	-90 17473 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
41	Point	1040	ST LOUIS RELOAD, INC.	RAIL	RAIL & TRUCK	MASSON	IL	17				38 08267	-90 16245 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
42	Point	1041	PREMIER RELOAD	RAIL	RAIL & TRUCK	FRANKLIN PARK	IL	17	60131	3004		41 82243	-87 85785 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
43	Point	1042	AND VY DISTRIBUTION	RAIL	RAIL & TRUCK	EFFINGHAM	IL	17	62401	2833		38 05019	-89 5474 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
44	Point	1043	LOUMBER RELOAD	RAIL	RAIL & TRUCK	CHICAGO	IL	17	60632			41 80063	-87 71262 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
45	Point	1044	C.C. LOUGHERY, INC.	RAIL	RAIL & TRUCK	WILLMANTIC	CT	09	06026			41 71731	-72 24423 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
46	Point	1045	MOORE MOVING AND STORAGE	RAIL	RAIL & TRUCK	MOBILE	AL	01	36655			30 54614	-88 07348 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
47	Point	1046	INDEPENDENT BLK TRANSFER TERMINAL-DETROIT, MI	RAIL	RAIL & TRUCK	DETROIT	MI	26	48209			42 30586	-83 09073 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
48	Point	1047	WAREHOUSING OF INDOCHINA GREEN BAY-VA-2275 CENTU	RAIL	RAIL & TRUCK	GREEN BAY	WI	55	54307			44 15425	-88 00536 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
49	Point	1048	WAREHOUSING OF INDOCHINA GREEN BAY-VA-2275 CENTU	RAIL	RAIL & TRUCK	GREEN BAY	WI	55	54307			44 15425	-88 00536 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
50	Point	1049	AND D WAREHOUSE	RAIL	RAIL & TRUCK	GREEN BAY	WI	55	54307			44 15425	-88 00536 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
51	Point	1050	IND-AMERICAN	RAIL	RAIL & TRUCK	WHITE RIVER CT	VT	30	05601			43 04168	-72 35134 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
52	Point	1051	NEW RAIN DISTRIBUTION	RAIL	RAIL & TRUCK	CINCINNATI	OH	39	45227			39 14795	-84 40468 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
53	Point	1052	DEKATED LOGISTICS INC.	RAIL	RAIL & TRUCK	ROSELLE	IN	27	55113			40 51581	-83 20505 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
54	Point	1053	MURPHY WAREHOUSE COMPANY-FRANKLIN-7033 CEDAR	RAIL	RAIL & TRUCK	FRANKLIN	IN	27	55144			40 49411	-83 2472 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
55	Point	1054	NEW WAREHOUSE	RAIL	RAIL & TRUCK	BATTLE CREEK	MI	26	49016	2102		42 11688	-86 18171 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
56	Point	1055	NEW ENGLAND AND PUBLIC WAREHOUSE-SOUTH PARIS,ME	RAIL	RAIL & TRUCK	SOUTH PARIS	ME	23	04281			44 22292	-70 51301 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
57	Point	1056	THE HOUSE CORPORATIONS WEST BLOOMFIELD, MI	RAIL	RAIL & TRUCK	WEST BLOOMFIELD	MI	26	48102			42 54205	-83 36224 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
58	Point	1057	NEW ENGLAND PUBLIC WAREHOUSE-MECHANIC FALLS,ME	RAIL	RAIL & TRUCK	MECHANIC FALLS	ME	23	04256			44 10033	-70 35341 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
59	Point	1058	WAGNER MOVING AND STORAGE INC.	RAIL	RAIL & TRUCK	PADUCAH	KY	21				37 26705	-88 82447 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
60	Point	1059	CRYSTAL TRANSPORTATION SERVICES, INC.	RAIL	RAIL & TRUCK	EDWARDSBURG	IA	19	50704			42 54165	-92 32262 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
61	Point	1060	CEAR RAPIDS WAREHOUSE AND TRANSFER	RAIL	RAIL & TRUCK	CEAR RAPIDS	IA	19	52404			41 80535	-91 69128 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
62	Point	1061	QUALITY CARRIERS	RAIL	RAIL & TRUCK	APPLETON	WI	55	54914	4613		44 25852	-88 43988 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
63	Point	1062	CHANNING DISTRIBUTION CENTER	RAIL	RAIL & TRUCK	MEMPHIS	TX	47	38109	2408		35 36594	-90 07698 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
64	Point	1063	ALCO LINE, INC.	RAIL	RAIL & TRUCK	VICKSBURG	MS	28	39180			32 39141	-90 88081 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN
65	Point	1064	SUPERIOR PRODUCT TRANSFER SOLUTIONS	RAIL	RAIL & TRUCK	WAVEN	MS	28	48009			42 45953	-83 00789 000	2000 STREETS	480003	INDUS	-#n/a-	01	CN

Figure 27. Facilities attributes table



Notes:

- The status of “Not on rail spoke” is a judgment call where the distance between two terminal facilities is less than 2 km
- The status of “Way off” is a judgment call where the distance between two terminal facilities is more than 2 km.
- The status of “Good” is a judgment call where the distance between two terminal facilities is within 50 m.

There are a total of approximately 410 major carriers listed from the US NTAD facilities. The status help give a descriptive analysis between two terminal facilities from two different sources. It is determined that there are thirty-four facilities that are listed as “Fair”, one-hundred fifteen facilities listed as “Good”, fifteen facilities listed as “Marginally Off”, two hundred twenty nine facilities listed as “Missing”, and sixteen facilities listed as “Wrong Carriers”. The status is assigned based on the distance between two terminal facilities.

APPENDIX E: Calculating Emissions from First Principles

The emissions obtained through the emissions calculator employed in the model are calculated using equations derived from the basic principles of physics. These principles involve the energy, materials content in fuels, engine efficiency etc. This section describes the equations and the associated theory.

The terms utilized in the equations are described below:

Load factor (ξ): This factor is a numerical measure which describes the effective utilization of the output power of the engine under consideration. It is expressed as a percentage of the full available capacity of the engine. So, a 0.5 value of the load factor for an engine implies that only 50% of the full available capacity of the engine is being utilized.

Horse power (hp): The power outputs of the engines are expressed in this standard unit of power.

Engine Efficiency (η): For combustion engines, it is the relationship between the total energy contained in the fuel, and the amount of energy used to perform useful work. It is expressed as a ratio of the energy output to the energy input. The value of 0.35 is commonly used for diesel engines.

Horse power hour (hp-hr)/ Kilowatt hour (KWh): These are derived units of energy. An hp-hr signifies the amount of the work done by an engine rated 1hp in 1 hr. Similarly, a KWh is the amount of work done by an engine rated 1 KW in 1 hr. Although hp-hr is not an SI unit, it is nevertheless utilized in various literatures to express the emission factors or emission intensities. Emission intensities are average emission rate of a given pollutant from a given source relative to the intensity of a specific activity; for example grams of carbon dioxide released per hp-hr energy produced.

The basic theory in calculating the emissions can be summed up by the following equation:

$$\text{Emission}_{\text{pollutant}} = \text{Activity} * \text{Emission Factor}_{\text{pollutant}}$$

Thus, the total emissions resulting from an activity can be described by a relation between the intensity of the activity and the polluting factor for the activity. The units for the emissions are expressed in either grams/mi or just grams. The units for the emission factors are mostly expressed in grams/hp-hr (and sometimes in grams/KWh).

Note: The total emissions in the model are also expressed in grams/ TEU-mile or grams/ ton-mile.

Calculation of emissions of CO₂ and SO₂

The emission calculations for carbon dioxide and sulfur utilize the concept of engine efficiency and materials content in fuels. The following paragraphs describe the procedure in a step-by-step fashion.

CO₂ emissions

In order to find the emissions, we first calculate the energy produced by the engine for doing a particular task e.g. moving goods from point A to point B. We then find out the energy required (input energy) in terms of gallons of fuel needed to produce the equivalent amount of work. Finally, the knowledge of the carbon content of the fuel used lets us compute the emissions produced by the burning of the requisite amount of fuel for the aforementioned task.

The following equation outputs the energy produced in terms of the amount of work done for a particular task:

$$\xi * \text{hpout} * (d/v)$$

where

ξ = load factor for the engine utilized

hpout= horsepower (output) rating of the engine utilized

d=distance traveled in doing the task (in miles)

v=velocity of the equipment used (truck, rail or ship) (in miles per hr)

The resultant unit for the above equation is hp-hr. (Note: 1 hp-hr = 0.746 KWh)

The above equation gives the work done in terms of the output horsepower. This is different from the input horsepower which is the output horsepower divided by the engine efficiency. Thus, we get the input horsepower or the input energy by utilizing the following equation:

$$\text{hpin} = \text{hpout} / \eta$$

where

η = engine efficiency

Once we have the input horsepower, we can convert it to equivalent units of BTUs (British Thermal Units → a unit of energy) through the following conversion:

$$1 \text{ hp-hr} = 2544 \text{ BTUs}$$

On obtaining the total amount of BTUs needed to perform the task, we then calculate the amount of fuel needed in gallons by using the following equation:

$$\text{Gallons of fuel} = \text{BTUin} / \text{energy density of fuel}$$

Note: The energy density of fuel is expressed in terms of BTUs/gallon.

The amount of carbon present in the fuel is given by the mass density (expressed in grams/gallon). Thus, we get the total amount of carbon burnt (when the fuel is burned) by using the following equation:

$$\text{Carbon burned (grams)} = \text{Amount of fuel used (gallons)} * \text{mass density (grams/gallon)}$$

The principles of chemistry state that the molecular weight of carbon is 44 grams/mol of which 27.29% (12 grams/mol) is composed of carbon and the rest oxygen. In other words, the burning of every 12 grams of carbon releases 44 grams of carbon dioxide. So, we utilize a conversion factor of 3.67 (=44/12) to convert the amount of carbon burned into equivalent amount of CO₂.

Thus we get the total amount of CO₂ generated (in grams) for a particular task, say transporting goods between two geographic locations.

In order to find the amount of CO₂ generated in terms of grams/TEU-mile, we divide the total amount of CO₂ by the product of the total amount of TEUs per load and the distance traveled. A TEU is a twenty-foot-equivalent standardized cargo container. If we know the net weight of the cargo in a single container in tons, we can calculate the emissions in terms of grams/ton-mile.

SO₂ emissions

The procedure for calculating the sulfur emissions are similar to that for CO₂ emission calculations except for a few minor differences.

The amount of sulfur present in the fuel is usually expressed in ppm(parts per million). In order to convert ppm to an equivalent percentage amount, the following conversion is used:

1000ppm= 0.1 % (by weight of fuel)

The molecular weight of SO₂ is 64 grams/mol of which 50% (32grams/mol) is sulfur. Thus, the burning of every 32 grams of sulfur produces 64 grams of SO₂. So, a conversion factor of 2 (=64/32) is utilized to convert the amount sulfur burnt into equivalent amounts of SO₂.

Calculation of emissions of PM₁₀ and NO_x

The resultant emissions for PM₁₀ and NO_x are estimated in a different manner. The following equation is utilized in calculating the total emissions for either PM₁₀ or NO_x:

$$\xi * \text{hpout} * (d/v) * \text{emission factor}$$

where

ξ = load factor for the engine utilized

hpout= horsepower (output) rating of the engine utilized

d=distance traveled in doing the task (in miles)

v=velocity of the equipment used (truck, rail or ship) (in miles per hr)

emission factor = average emission rate of a given pollutant from a given source (expressed in grams/hp-hr)

The resultant unit for the above equation is grams (of either PM₁₀ or NO_x).

Note: The emission factors for various modes of transportation (rail, truck, ship) and equipments (RTG cranes, yard holsters etc) are sourced from various literature.

For finding the emissions in terms of grams/TEU-mile or grams/ton-mile, we follow the same procedure as used for CO₂ and SO₂ emissions.

APPENDIX F: Creation of Origin-Destination Volume Flow Model

As GIFT requires location of the origin and destination pair (O/D pair) in order to generate optimized routes and the flows of freight in the region, one of the first important steps is to obtain O/D pairs which reflect the flow of freight for the ports of interest. The *Task 3: Model Selection and Modification* report identifies the origination and destination data sources used in the study, based on the *Task 2: Data Compilation*.

Origination and Destination Data Sources

The origins and destinations for the routes were sourced from the 2007 Commodity Flow Survey (CFS) data which is published on the U.S. Census Bureau website (<http://factfinder.census.gov>). CFS provides a comprehensive picture of national freight flows which includes estimated shipping volumes (value, tons, and ton-miles) by commodity and mode of transportation at varying levels of geographic detail (i.e., national, state, select MSAs/ CSAs). The CFS is a shipper-based survey, and captures data on shipments originating from select types of business establishments located in the 50 states and the District of Columbia. The survey is conducted as a partnership between the Bureau of Transportation Statistics and the U.S. Census Bureau, on a five-year cycle as a component of the economic census (Bureau of Transportation Statistics, 2007).

The following characteristics of the data make it an attractive source for freight modeling purposes in the model:

- Only available source of data that provides about 71% of the value and 69% of the tonnage of freight transported through the highways
- Provides estimated shipping volumes (value, tons and ton-miles) by commodity and mode of transportation at varying levels of geographic detail
- CFS data are used as the basis for the Federal Highway Administration's Freight Analysis Framework (FAF), a model that displays by mode the movement of goods over the national transportation network

Figure 29 gives an example of the listing of CFS data for the Los Angeles-Long Beach-Riverside Combined Statistical Area (CSA). The data lists the dollar value and the tonnage of the total freight flow from the origin area to the rest of the U.S., along with figures for individual origin and destination pairs, which include states (as a whole) and select MSAs/ CSAs within those states. There are also entries which represent areas of the state which are not part of the listed MSAs/ CSAs, and are labeled "Remainder of (State)" as such.

In some cases, data was suppressed (shown by S in Figure 29), either because of the requirement of avoiding disclosure of confidential data or because of reasons of poor data quality standards. While importing CFS data, these entries were assumed to be '0' for all purposes. The entries for the States (as a whole) were excluded from the final dataset as they represented the totals for the list of MSAs/CSAs regions and the "Remainder of" regions of the states.

Geographic Area Name	Meaning of Destination geography	Year	Value(\$mil)	Tons (thous)
Los Angeles-Long Beach-Riverside, CA CFS Area United States		2007	758,517	421,081
Los Angeles-Long Beach-Riverside, CA CFS Area Alabama		2007	2,817	355
Los Angeles-Long Beach-Riverside, CA CFS Area Birmingham-Hoover-Cullman, AL Combined Statistical Area		2007	1,010	140
Los Angeles-Long Beach-Riverside, CA CFS Area Mobile-Daphne-Fairhope, AL Combined Statistical Area		2007	754	S
Los Angeles-Long Beach-Riverside, CA CFS Area Remainder of Alabama		2007	1,053	88
Los Angeles-Long Beach-Riverside, CA CFS Area Alaska		2007	1,136	49
Los Angeles-Long Beach-Riverside, CA CFS Area Arizona		2007	24,825	8,504
Los Angeles-Long Beach-Riverside, CA CFS Area Phoenix-Mesa-Scottsdale, AZ Metropolitan Statistical Area		2007	17,929	5,787
Los Angeles-Long Beach-Riverside, CA CFS Area Tucson, AZ Metropolitan Statistical Area		2007	2,894	709
Los Angeles-Long Beach-Riverside, CA CFS Area Remainder of Arizona		2007	4,002	2,008
Los Angeles-Long Beach-Riverside, CA CFS Area Arkansas		2007	1,587	260
Los Angeles-Long Beach-Riverside, CA CFS Area California		2007	469,899	368,538
Los Angeles-Long Beach-Riverside, CA CFS Area Los Angeles-Long Beach-Riverside, CA Combined Statistical Area		2007	378,196	327,397
Los Angeles-Long Beach-Riverside, CA CFS Area Sacramento--Arden-Arcade--Truckee, CA-NV Combined Statistical Area (CA Part)		2007	7,012	2,739
Los Angeles-Long Beach-Riverside, CA CFS Area San Diego-Carlsbad-San Marcos, CA Metropolitan Statistical Area		2007	27,214	11,174
Los Angeles-Long Beach-Riverside, CA CFS Area San Jose-San Francisco-Oakland, CA Combined Statistical Area		2007	24,783	7,243
Los Angeles-Long Beach-Riverside, CA CFS Area Remainder of California		2007	32,695	19,985
Los Angeles-Long Beach-Riverside, CA CFS Area Colorado		2007	6,661	1,286
Los Angeles-Long Beach-Riverside, CA CFS Area Denver-Aurora-Boulder, CO Combined Statistical Area		2007	4,871	998

Figure 29. CFS data for Los Angeles - Long Beach Area (Source: Commodity Flow Survey 2007)

The following modes of transportation are covered in the survey: For-Hire Truck, Private truck, Rail, Air, Shallow draft vessel, Deep draft vessel, Pipeline, Parcel, U.S. Postal Service, or courier, and other and unknown modes. For this deliverable, we consider the total amount (tons) of goods moved across all modes as representative of the freight movement.

The most important feature of the CFS dataset is that the shipping volumes can be obtained at varying levels of geographic detail. This helps in creating the listing of O/D pairs that can be utilized in the mode to mode freight flow emissions. The levels of geographic detail in the CFS dataset can be broadly classified into 3 categories: State, Combined Statistical Area (CSA), Metropolitan Statistical Area (MSA), and Remainder of State (areas of state outside the CSA/MSA). A number of adjacent MSAs, in various combinations, can become part of a new complementary area, defined as a CSA (Office of Management and Budget, 2000; Univ of Iowa). Thus, a State is comprised of CSA(s) and/or MSA(s) and the Remainder of State region. Together, they make up the State as a whole. Figure 30 illustrates the concept of the CFS regions in the context of California. The CFS data defines a total of 73 select CSAs/MSAs in a total of 35 states. Each of these 35 states also has a "Remainder of State" region. The remaining states are not defined to have any CSAs/MSAs, as per CFS.

The CFS provides the freight volume between an origin region located in a CSA/MSA and a destination region located in a CSA/MSA. These data were used to build a listing of O/D pair regions which represented freight flows. In the model evaluation task, we concentrated on the three major ports on the west coast represented by the following CSAs:

- San Jose-San Francisco-Oakland, CA Combined Statistical Area
- Los Angeles-Long Beach-Riverside, CA Combined Statistical Area
- Seattle-Tacoma-Olympia, WA Combined Statistical Area

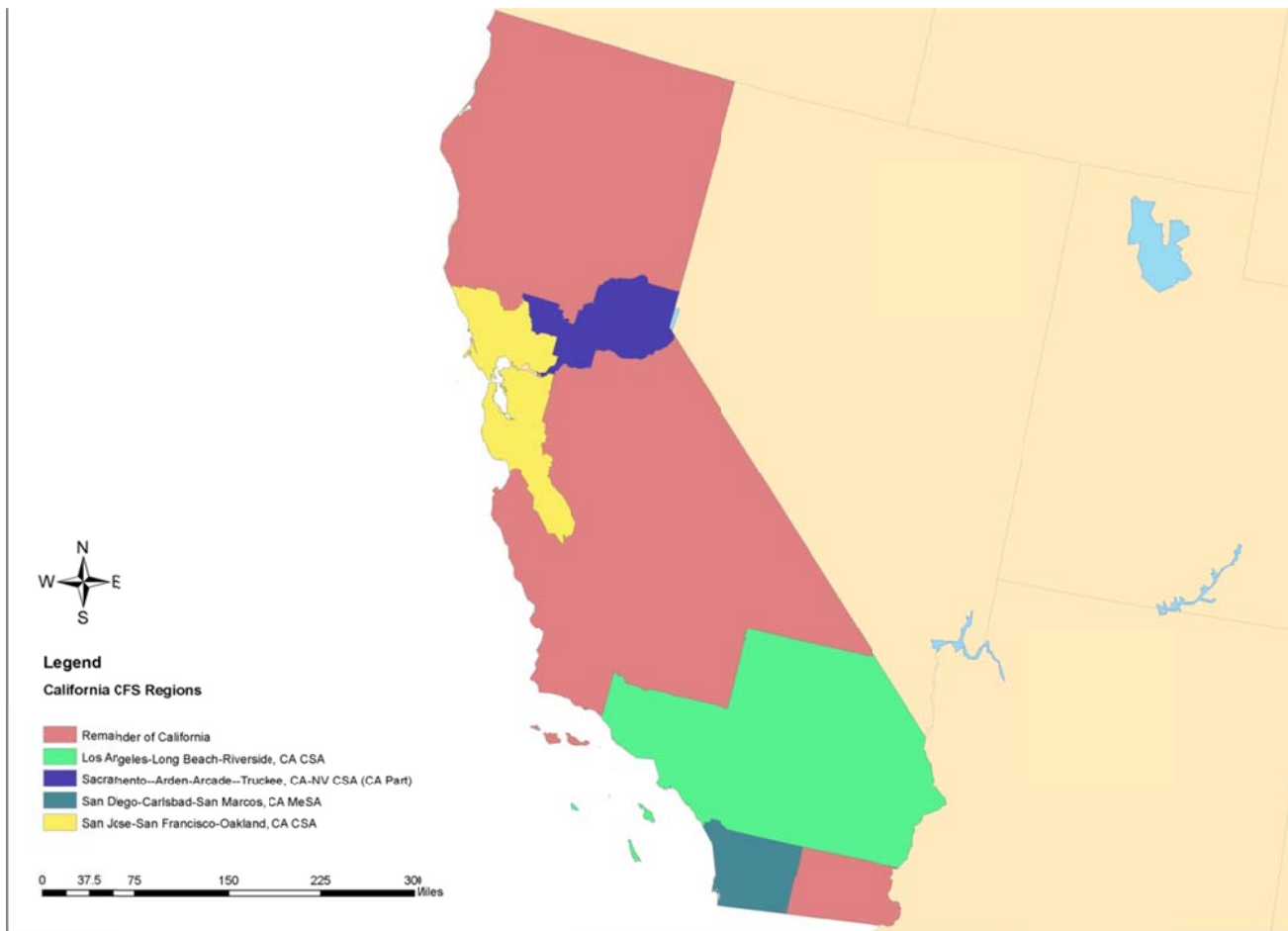


Figure 30. California CFS Regions

The focus in this project is on modeling the containerized freight traffic generating from the ports. The aforementioned ports were considered as they handle a major portion of the total container traffic in the U.S. Together, the three port regions of Los Angeles-Long Beach, Oakland, and Seattle-Tacoma accounted for 52 percent of the total container imports in the U.S. for 2008 (See Figure 31).

Port Container Statistics

The other important dataset was the container traffic for the three ports of interest. Since CFS does not provide freight figures specific to container traffic, a separate data source was needed to account for the container freight that originated at the ports. For this, we utilized the data available from the Waterborne Commerce Statistics Center (WCSC), maintained by the U.S. Army Corps of Engineers (USACE).



Figure 31. Top 25 Container Ports 2008 (Source: BTS, U.S. DoT)

Table 11 shows the format of the information that was obtained from the WCSC (U.S. Census Bureau, 2009; US Army Corps of Engineers). The data includes container traffic (in TEUs) handled at the ports and the volume of cargo (in tons) handled at the ports. Since the focus was on modeling the port generated traffic (outbound traffic from the ports to the U.S. mainland), we took into account the domestic outbound shipment and the foreign inbound receipts when calculating the total outbound container traffic from the ports to the U.S. mainland. To facilitate understanding the terminology used by the WCSC (US Army Corps of Engineers, 2008) are listed below:

- Domestic Outbound/ Domestic Shipment: Traffic moving from one location to another (within the contiguous and non-contiguous states and territories of the U.S.) where the origin is within the limits of the subject port.
- Foreign Inbound/ Foreign Receipt: Inbound merchandise originating in foreign countries and arriving by marine vessel for direct U.S. consumption and entries into custom bonded storage and manufacturing warehouses.

Table 11. West Coast Port Statistics (Source: USACE)

Table 1051. Selected U.S. Ports/Waterways by Container Traffic: 2007

Port/waterway name	Rank	Domestic Outbound loaded (^{'000} TEUs)	Foreign Inbound loaded (^{'000} TEUs)	(A) Total Outbound loaded (^{'000} TEUs)	Domestic shipment (tons)	Foreign Receipt (tons)	(B) Total Outbound Shipment (tons)	Tons per TEU (B/A)
Long Beach, CA	2	265.3	3,540.5	3,805.8	2,869,556	49,706,082	52,575,638	13.8144926
Los Angeles, CA	1	0	4,141.3	4,141.3	2,310,236	40,466,058	42,776,294	10.32924458
Oakland, CA	6	165.7	769.4	935.1	1,123,035	6,317,303	7,440,338	7.957095664
Seattle, WA	7	160.1	708.6	868.7	2,043,829	9,511,764	11,555,593	13.3017848
Tacoma, WA	8	238.7	713.4	952.1	2,750,117	6,845,029	9,595,146	10.077654

Source: U.S. Army Corps of Engineers, "U.S.

Waterborne Container Traffic for U.S. Port/Waterway in 2007".

[A TEU is a measure of containerized cargo capacity equal to 1

standard 20'0foot length by 8'0foot width by 8'0foot 6'0inch height container]

Avg tons/TEU 11.09505433

To get a measure of the total port-generated traffic, we summed up the total domestic outbound loaded containers and the total foreign inbound loaded containers.

Another input value that was derived from the USACE data was the average tons per TEU. This estimate was utilized in the emissions calculator. It was calculated by dividing the total outbound shipment in tons by the total outbound shipment in TEUs for each port of interest and then averaging across the ports. The mean tons per TEU was estimated to be ~ 11 tons. For simplicity we assumed the average weight of cargo in a TEU to be 10 tons. This can be adjusted for final case study definition.

Note: The CFS freight figures and the statistics from WCSC were the best available data that we could find for our purpose. It is to be emphasized that the model is data-neutral. The methodology that is described in the following section can be replicated for a comparable source of data.

Obtaining the Freight Distribution

In creating the database of the origin-destination pairs that represent container freight flow, the first step involved was to calculate the distribution of freight tonnage as per the CFS figures. The rationale was to estimate how freight gets distributed from the origins of interest – the three west coast port regions – to the rest of the U.S. The distribution of freight was obtained as a percent of the total tonnage moving out of the port region to the different regions of the U.S. as defined by CFS. The estimation of the freight distribution used of the following equation:

$$F_{ij} = \left(\frac{\text{tons}_{ij}}{\sum_j \text{tons}_{ij}} \right) \cdot 100$$

Equation 2

Where,

i = Origin (port region)

j = Destination (MSA/CSA, Remainder of State etc)

F_{ij} = Freight flow from ***i*** to ***j*** (as percent of total freight flow from ***i*** to all ***j***)

tons_{ij} = Tons of freight flow from ***i*** to ***j*** (as obtained from CFS)

and

i = 1, 2, 3 (for the three port regions)

j = 1, 2, 3, 4,...,123 for each ***i***

As illustrated by the parameters of Equation 2, there were a total of 123 destinations for each origin (port) region of interest. These 123 destinations included the MSA/CSA regions and the Remainder of State regions as defined in the CFS dataset, and the States for which there were no defined CSAs/MSAs. A total of 123 O/D pairs were identified from the CFS dataset. Note that this figure is less than the number of defined CFS regions. The reason for this difference can be attributed to the exclusion of the state level data for those states which were defined to have a CSA/MSA and a 'Remainder of' region. The rationale for this exclusion was to eliminate any extraneous data as the tonnage figures for the state level data were just the total of the tonnage figures for the MSAs/CSAs and Remainder regions of the state.

The freight distribution, as obtained through Equation 2 for each of the three port regions, was then tabulated in a Microsoft Excel file along with the list of the O/D pairs. The freight distribution was helpful in visualizing how freight moves in the geospatial context. For example, Figure 32 shows the freight distribution obtained for the origin region of Los Angeles-Long Beach-Riverside CSA. As can be seen from the map the majority (~87%) of the freight originating from the region moves within the region itself and to destinations located within the state of California. Less than 15 % of the total freight originating from the Los Angeles-Long Beach-Riverside CSA moves to locations outside of California. Such an observation is in accordance with the gravity model of freight transport i.e. freight volume between an O/D pair is inversely related to the distance between the O/D pair.

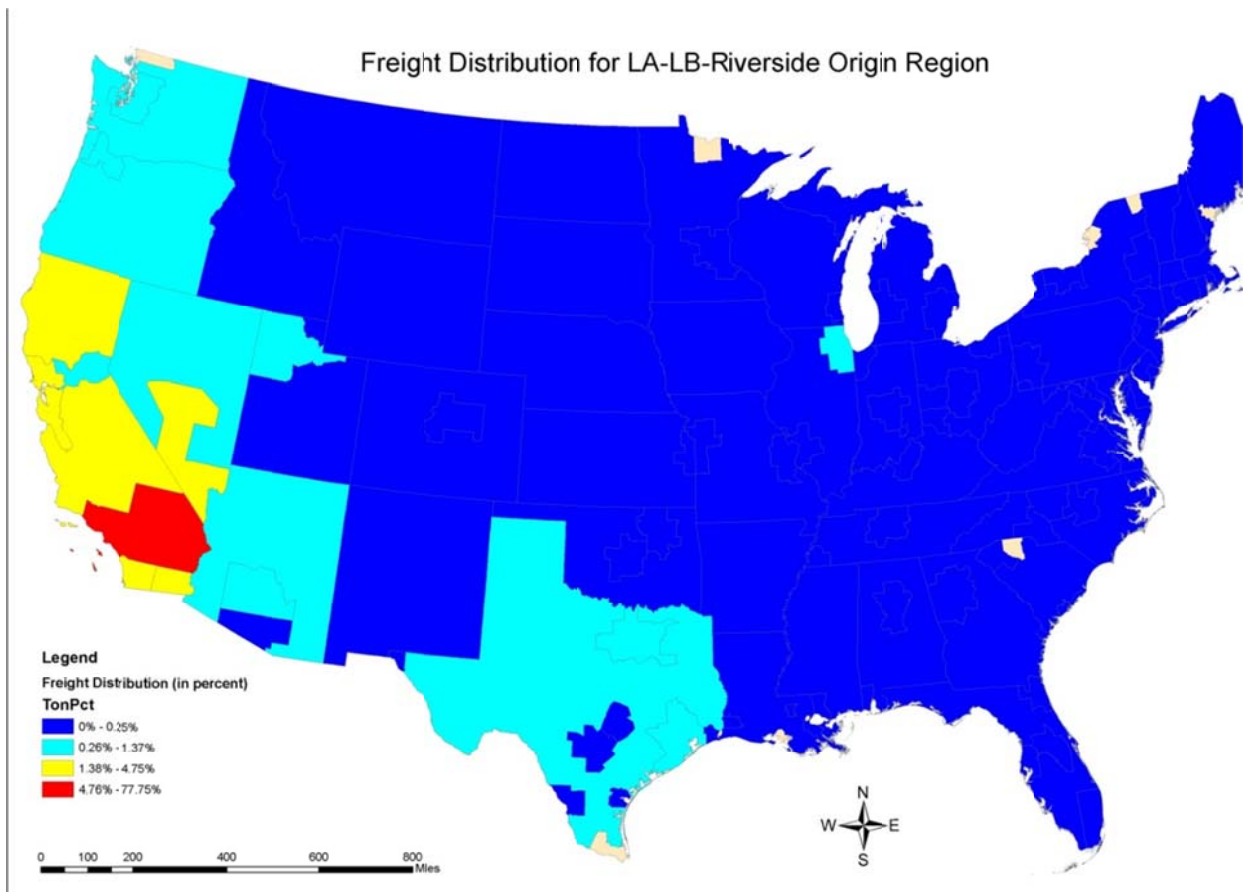


Figure 32. CFS Freight Distribution for LA/LB

Accounting for the “Remainder” regions of the States

In order to provide a better geographical resolution, multiple destinations were represented within the ‘Remainder of’ regions in the 35 states as listed in the CFS dataset. These additional destinations numbered either 2 or 3 for each of the states and represent other major metropolitan areas within the state not captured by the CSA regions. In splitting the remainder region of a state into multiple destinations, the tonnage figures for the region (as obtained from CFS) were distributed evenly among the derivative destinations. To illustrate the concept, consider the ‘Remainder of Arizona’ region. A total of two destinations were chosen within this region – ‘Remainder of Arizona 1’ and ‘Remainder of Arizona 2’. Thus, we have

- **Tonnage for Remainder of Arizona = 2,008 tons**
- **Tonnage for Remainder of Arizona 1 = $2,008 / 2 = 1,004$ tons**
- **Tonnage for Remainder of Arizona 2 = $2,008 / 2 = 1,004$ tons**

For a region with 3 destinations, the tonnage figures were split in 3 parts. This additional number of derivative destinations increased the O/D pair list by 27 to bring the total count of the O/D pairs to 150.

Processing the data for California

Since the objective of the project is to develop a California-specific intermodal freight transport analysis, the data obtained from CFS were tailored to enable a better resolution for the estimation of the energy and environmental impacts of freight movement through California. In this process, we considered three different approaches. They are discussed in the following paragraphs.

Approach 1 – Distributing Freight at the CSA/MSA Level

In this approach, the list of destinations was the same as specified in the CFS dataset. Thus, California had a total of 5 destination regions – 4 CSAs and the Remainder of the state. The list of the CSAs/MSAs is mentioned below:

- San Jose-San Francisco-Oakland, CA Combined Statistical Area
- Los Angeles-Long Beach-Riverside, CA Combined Statistical Area
- Sacramento--Arden-Arcade--Truckee, CA-NV Combined Statistical Area (CA Part)
- San Diego-Carlsbad-San Marcos, CA Metropolitan Statistical Area

The distribution of freight to these destination regions was obtained using Equation 2, as explained in previous sections. This was the default level of resolution of freight distribution for California. The list of the destinations outside the state of California was kept the same as was listed in the original CFS dataset. Thus, the number of total O/D pairs was 150.

Approach 2 – Distributing Freight at the County Level

In this case, the freight destined for the CFS regions within the state of California was disaggregated at the county level. The purpose was to achieve a higher resolution for analyzing freight movement in the state. As in the previous case, the list of the destinations outside the state of California was kept the same as was listed in the original CFS dataset. The process involved finding the list of all the counties (a total of 58) in California, along with their 2007 population estimates. These data were obtained from the California Department of Finance (State of California Department of Finance, 2009). Counties within each of the 5 regions specified in the CFS dataset were identified and categorized accordingly. The county distribution among the CFS regions is highlighted in Figure 33 and is summarized below:

- San Jose-San Francisco-Oakland, CA Combined Statistical Area → 9 counties
- Los Angeles-Long Beach-Riverside, CA Combined Statistical Area → 5 counties
- Sacramento--Arden-Arcade--Truckee, CA-NV Combined Statistical Area (CA Part) → 4 counties
- San Diego-Carlsbad-San Marcos, CA Metropolitan Statistical Area → 1 county
- Remainder of CA → 39 counties

Having found out the number of counties in a CFS region and their respective populations, the next step was to obtain a population distribution across the counties within each region. The rationale behind this step was the assumption that the population of a region would be a deciding factor in attracting freight to that region i.e. population drives consumption. Obtaining population distribution for the counties would then enable the estimation of the freight distribution at the county level for California. To calculate the population distribution across the counties, the following equation was utilized

$$P_{wkj} = \left(\frac{P_{kj}}{\sum_j \sum_k P_{kj}} \right) \cdot 100$$

Equation 3

Where,

P_{wkj} = Weighted population of county k in CFS region j (as percent of the total population of region j)

P_{kj} = Population of county k in CFS region j

and

k = variable, for each j (dependent upon number of counties in a particular region)

j = 1 to 5 (for the five CFS defined regions in CA)

The weighted population values for each of the counties indicated the distribution of population across the counties in a region. The values are tabulated in Figure 33. For example, it can be seen that Los Angeles County has 56.3% of the total population of all the counties in the Los Angeles-Long Beach-Riverside, CA Combined Statistical Area. This implies that Los Angeles County would have the highest attraction for freight amongst the counties which make up the CFS region.

The final step was to estimate the freight distribution based on the calculated population distribution across the counties in California. In effect, it meant the freight distribution for a region was weighed by the population distribution of the region. The following equation illustrates this concept:

$$F_{ik} = \left(\frac{P_{kj}}{\sum_j \sum_k P_{kj}} \right) \cdot \left(\frac{tons_{ij}}{\sum_j tons_{ij}} \right) \cdot 100$$

Equation 4

Where,

i = Origin (port region)

j = Destination region (MSA/CSA, Remainder of State)

k = County within region j

P_{kj} = Population of county k in CFS region j

$tons_{ij}$ = Tons of freight flow from i to j (as obtained from CFS)

F_{ik} = Freight flow from i to k (as percent of total freight flow from i to j in which k resides)

and

$i = 1, 2, 3$ (for the three port regions)

$j = 1$ to 5 (for the five CFS defined regions in CA)

k = variable, for each j (dependent upon number of counties in a particular region)

County	Pop_2007	Wgted_Pop	County	Pop_2007	Wgted_Pop
El Dorado	177,379	8.44%	Alpine	1,255	0.02%
Sacramento	1,402,728	66.76%	Amador	38,116	0.55%
Yolo	194,864	9.27%	Butte	218,023	3.16%
Placer	326,107	15.52%	Calaveras	45,737	0.66%
Los Angeles	10,243,764	56.29%	Colusa	21,616	0.31%
Orange	3,080,383	16.93%	Del Norte	29,142	0.42%
San Bernardino	2,022,710	11.12%	Fresno	912,725	13.25%
Riverside	2,030,315	11.16%	Glenn	28,784	0.42%
Ventura	820,550	4.51%	Humboldt	131,904	1.91%
Alameda	1,519,326	21.12%	Imperial	170,990	2.48%
Marin	254,527	3.54%	Inyo	18,220	0.26%
Napa	134,559	1.87%	Kern	798,621	11.59%
San Francisco	823,004	11.44%	Kings	151,249	2.20%
San Mateo	728,314	10.12%	Lake	63,682	0.92%
Santa Clara	1,798,242	24.99%	Lassen	35,871	0.52%
Solano	422,477	5.87%	Madera	147,346	2.14%
Sonoma	478,662	6.65%	Mariposa	18,241	0.26%
Contra Costa	1,035,322	14.39%	Mendocino	89,380	1.30%
San Diego	3,088,891	100.00%	Merced	250,022	3.63%
			Modoc	9,685	0.14%
			Mono	13,765	0.20%
			Monterey	422,586	6.13%
			Nevada	99,265	1.44%
			Plumas	20,972	0.30%
			San Benito	57,162	0.83%
			San Joaquin	674,331	9.79%
			San Luis Obispo	265,786	3.86%
			Santa Barbara	422,835	6.14%
			Santa Cruz	263,105	3.82%
			Shasta	180,446	2.62%
			Sierra	3,431	0.05%
			Siskiyou	45,607	0.66%
			Stanislaus	517,837	7.52%
			Sutter	93,687	1.36%
			Tehama	61,626	0.89%
			Trinity	13,935	0.20%
			Tulare	425,677	6.18%
			Tuolumne	56,733	0.82%
			Yuba	70,555	1.02%

Sacramento--Arden-Arcade--Truckee, CA-NV Combined Statistical Area (CA Part)

Los Angeles-Long Beach-Riverside, CA Combined Statistical Area

San Jose-San Francisco-Oakland, CA Combined Statistical Area

San Diego-Carlsbad-San Marcos, CA Metropolitan Statistical Area

Remainder of California

List of CFS Regions in California

Figure 33. CA Counties and associated CFS regions (Source: California Dept of Finance, State of California)

This level of resolution resulted in the inclusion of additional destinations for the three port origin regions. Disaggregating the 5 CFS regions within the state of California into their respective counties increased the total number of O/D pairs to 203. Comparing Equation 4 with Equation 2, it can be seen that the freight distribution at the county level is the freight distribution at the CSA/MSA level weighed by the population of the counties which make up the CSA/MSA region.

Approach 3 – Distributing Freight at the Sub- In this scenario (the next higher level of resolution)

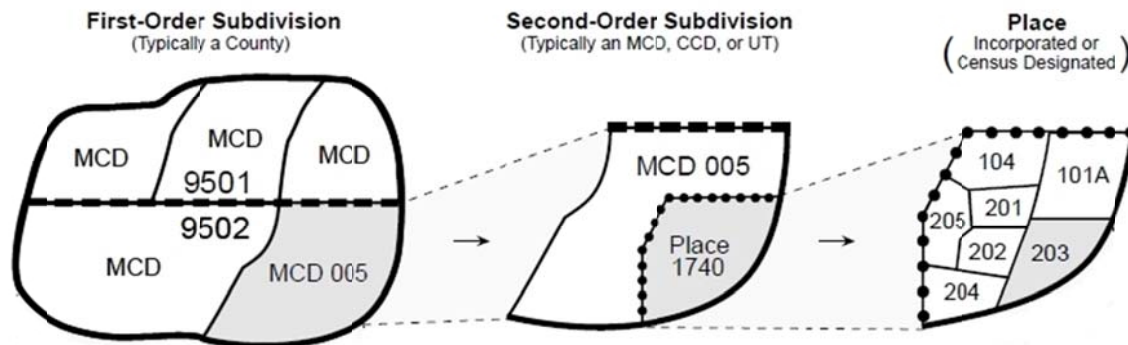


Figure 34. Census Geographic Areas (Source: US Census GARM Ch2)

Figure 34 illustrates the hierarchical relationship between a county and an incorporated place. A county is made up of subdivisions- typically called a Minor Civil Division (MCD) or Census County Division (CCD). An MCD is a legal entity with a governmental unit and legal boundaries. MCDs are thus primary subcounty administrative units. A CCD is a statistical equivalent of an MCD, which has been designated by the Census Bureau in cooperation with the State officials and census statistical areas committees. CCDs have no governmental or administrative functions. They are established in places where either MCDs do not exist or are insufficient for census statistics data purposes. So, a state has either MCDs or CCDs as the county subdivisions, not both. California has 386 CCDs (Bureau, 1994; US Census Bureau, 1994). A place can be considered as a subdivision of an MCD or CCD. A place can be either legally incorporated under the laws of the state or can be a statistical equivalent in which case it is referred to as a Census Designated Place (CDP). CDPs, as in the case of CCDs lack separate governments. There are rules for establishing an incorporated place. In the case of California, a minimum of 500 registered voters are required. Most of the incorporated places have strong local governments and are cities, towns, villages or boroughs. Incorporated places do not extend into more than one state and in California they do not cross county boundaries (US Census Bureau, 1994).

For this project, we considered only the incorporated

- Los Angeles County → 88 incorporated cities
- Orange County → 34 incorporated cities
- Riverside County → 24 incorporated cities
- San Bernardino County → 24 incorporated cities
- Ventura County → 10 incorporated cities

Figure 35 shows, for example, the layout of the incorporated areas in LA County. The total number of incorporated places within the county numbered 88 with the smallest being Vernon with a 2007 population estimate of 95 and the largest being Los Angeles with an estimated population of approximately 4 million (State of California Department of Finance, 2009). Most of the incorporated

areas are in the vicinity of the city of Los Angeles itself. Another point of note is the existence of unincorporated areas in the county. These areas, also referred to as balance of county, contain territories that are generally remote and sparsely populated with ill-defined boundaries (US Census Bureau).

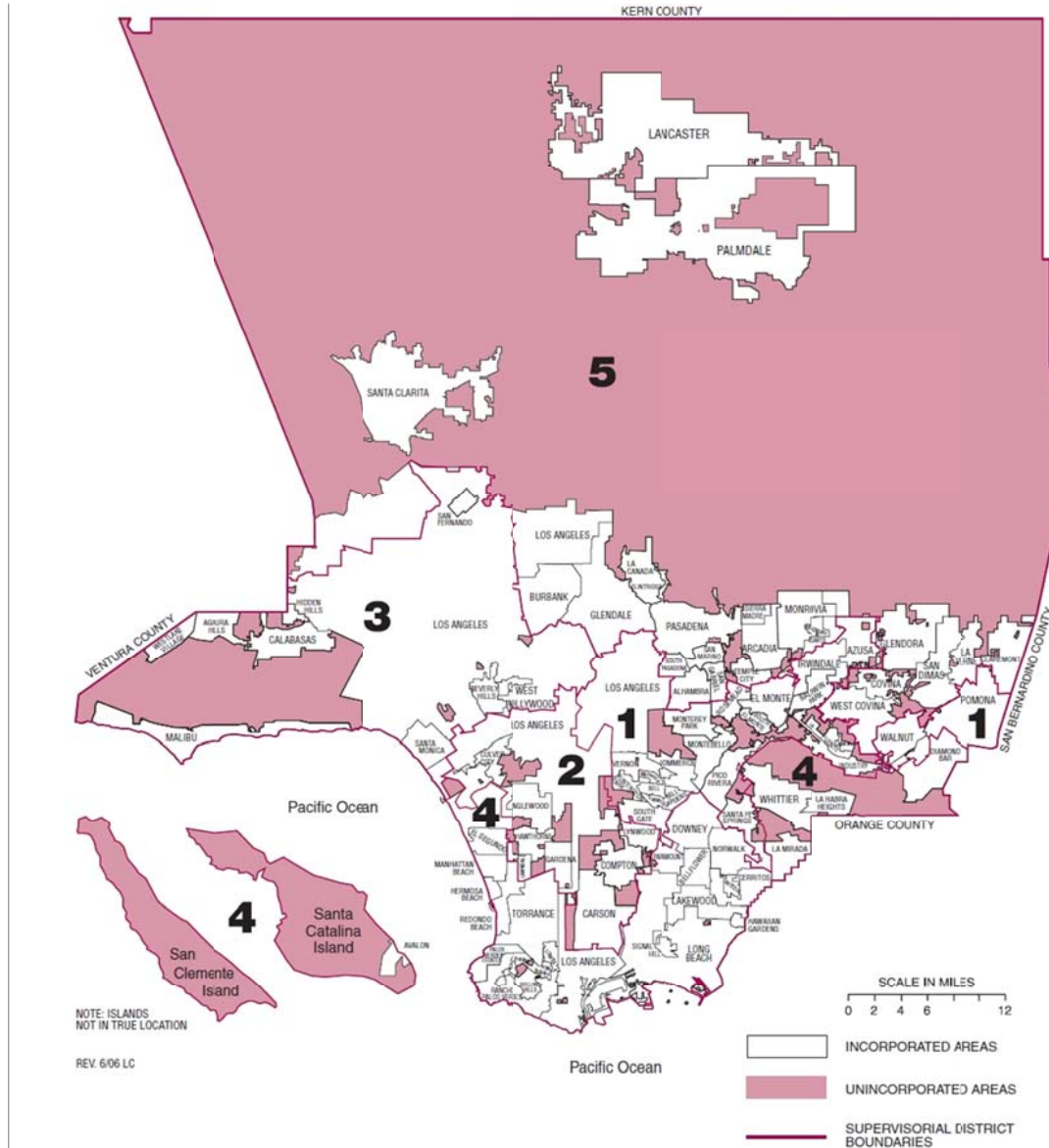


Figure 35. LA County Incorporated Places (Source: LA County Chamber of Commerce)

The process for obtaining the freight distribution at the city level was similar to that followed for obtaining the distribution at the county level. The first step was to obtain the population of the identified incorporated cities within the five counties. These data were obtained from the California Department of Finance website (State of California Department of Finance, 2009). Then, the population distribution across the incorporated cities was calculated, as percent of the population of the county. For example, the city of Los Angeles has about 56% of the total population in LA County. These city-level population distributions were then applied to the freight distribution obtained at the county level (which was obtained

using Equation 4), as illustrated by
$$f_{ik} = \left(\frac{P_{ik}}{P_{kj}} \right) \cdot \left(\frac{P_{kj}}{\sum_j \sum_k P_{kj}} \right) \cdot \left(\frac{tons_{ij}}{\sum_j tons_{ij}} \right) \cdot 100$$

Equation 5.

$$f_{il} = \left(\frac{P_{lk}}{P_{kj}} \right) \cdot \left(\frac{P_{kj}}{\sum_j \sum_k P_{kj}} \right) \cdot \left(\frac{tons_{ij}}{\sum_j tons_{ij}} \right) \cdot 100$$

Equation 5

Where,

i = Origin (port region)

j = Destination region (MSA/CSA, Remainder of State)

k = County within region ***j***

l = Incorporated city within County ***k*** within region ***j***

P_{lk} = Population of city ***l*** within County ***k***

P_{kj} = Population of county ***k*** in CFS region ***j***

tons_{ij} = Tons of freight flow from ***i*** to ***j*** (as obtained from CFS)

f_{il} = Freight flow from ***i*** to ***l*** (as percent of total freight flow from ***i*** to ***j*** in which ***k*** resides)

and

i = 1, 2, 3 (for the three port regions)

j = 1 to 5 (for the five CFS defined regions in CA)

k = variable, for each ***j*** (dependent upon number of counties in a particular region)

l = variable, for each ***k*** (dependent upon number of incorporated cities in a particular county)

Comparison of the three freight distribution approaches

The three approaches can be summarized by Figure 36. The three approaches to distributing freight in the state of California were discussed to demonstrate the flexibility of modeling freight distribution at varying levels of geographic detail. Any of these approaches can be utilized for the California-specific GIFT model, provided there is accurate data available on the movement of goods between the port regions and the aforementioned destinations i.e. CSA/MSA regions, counties and incorporated cities.

Approaches for distributing freight within California

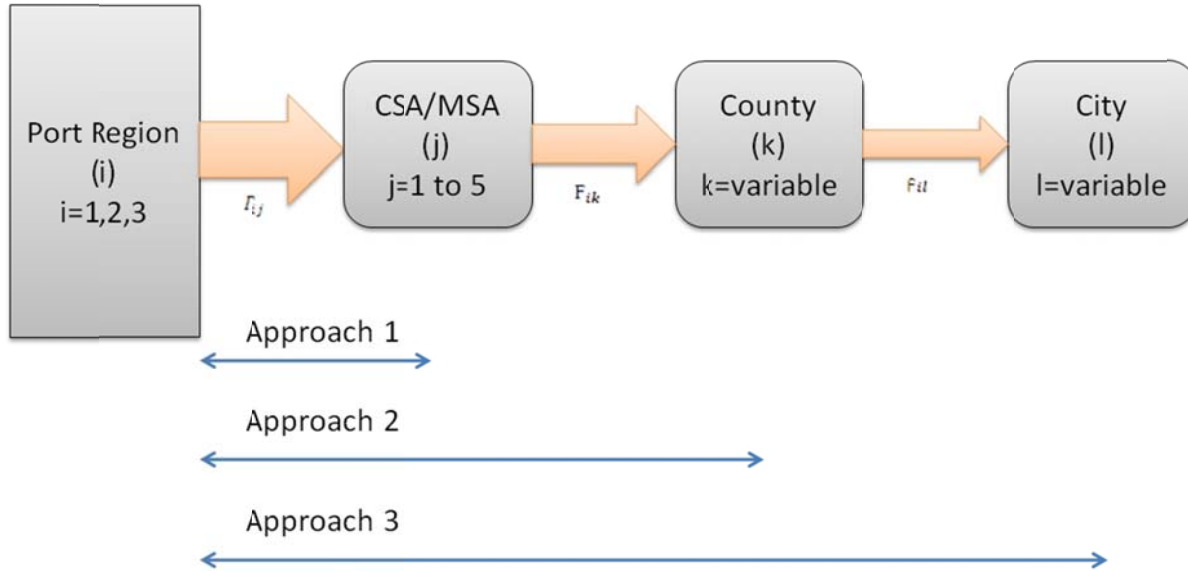


Figure 36. Distributing freight flow

The three approaches to distributing freight in the state of California were discussed to demonstrate the flexibility of modeling freight distribution at varying levels of geographic detail. Any of these approaches can be utilized for the California-specific GIFT model, provided there is accurate data available on the movement of goods between the port regions and the aforementioned destinations i.e. CSA/MSA regions, counties and incorporated cities.

Applying the freight distribution to the Port generated traffic

As mentioned before, the dataset available from CFS does not list the amount of containerized freight moving in between O/D pairs in terms of TEUs. It lists the total tonnage amount which includes all kinds of freight movement (containerized and bulk) between origins and destinations in the U.S. As the focus of the study was to model containerized freight flow, the freight distribution obtained from the CFS data (as explained in the previous sections) was applied to the port container traffic figures that were obtained from the Army Corps of Engineers WCSC. The premise behind doing so was the assumption that the port generated container traffic would follow the same distribution pattern as obtained for freight from the CFS dataset. Applying the CFS freight distribution to the port generated container gave an estimation of the container traffic (in TEUs) between O/D pairs (O/D TEUs). This estimation was derived using the following sets of equations:

$$T_{il} = f_{il} \cdot \tau_i$$

Equation 6

$$T_{ik} = F_{ik} \cdot \tau_i$$

Equation 7

$$T_{ij} = \Gamma_{ij} \cdot \tau_i$$

Equation 8

Where,

i = Origin (port region)

j = Destination region (MSA/CSA, Remainder of State)

k = County within region j

l = Incorporated city within County k within region j

f_{il} = Freight flow from i to l (as percent of total freight flow from i to j in which k resides) (from

$$Equation 5) \quad F_{il} = \left(\frac{P_{lk}}{P_{kj}} \right) \cdot \left(\frac{P_{kj}}{\sum_k P_{kj}} \right) \cdot \left(\frac{tons_{ij}}{\sum_j tons_{ij}} \right) \cdot 100$$

Equation 5)

F_{ik} = Freight flow from i to k (as percent of total freight flow from i to j in which k resides) (from Equation 4)

Γ_{ij} = Freight flow from i to j (as percent of total freight flow from i to all j) (from Equation 2)

τ_i = Port generated container traffic in TEUs for port region i

T_{il} = Container traffic in TEUs from origin port i to incorporated city l

T_{ik} = Container traffic in TEUs from origin port i to county k

T_{ij} = Container traffic in TEUs from origin port i to region j

The last three terms listed above represent the estimated O/D TEUs at varying levels of geographic details (as explored by our three different approaches to freight distribution). Figure 37 illustrates the complete process workflow for our three approaches to freight distribution.

Thus, our methodology of assigning freight to destinations at varying levels of geographic detail (county and incorporated city) is population-based. This methodology, as mentioned before, stems from the assumption that population drives consumption and hence, is a factor influencing freight attraction for a region.

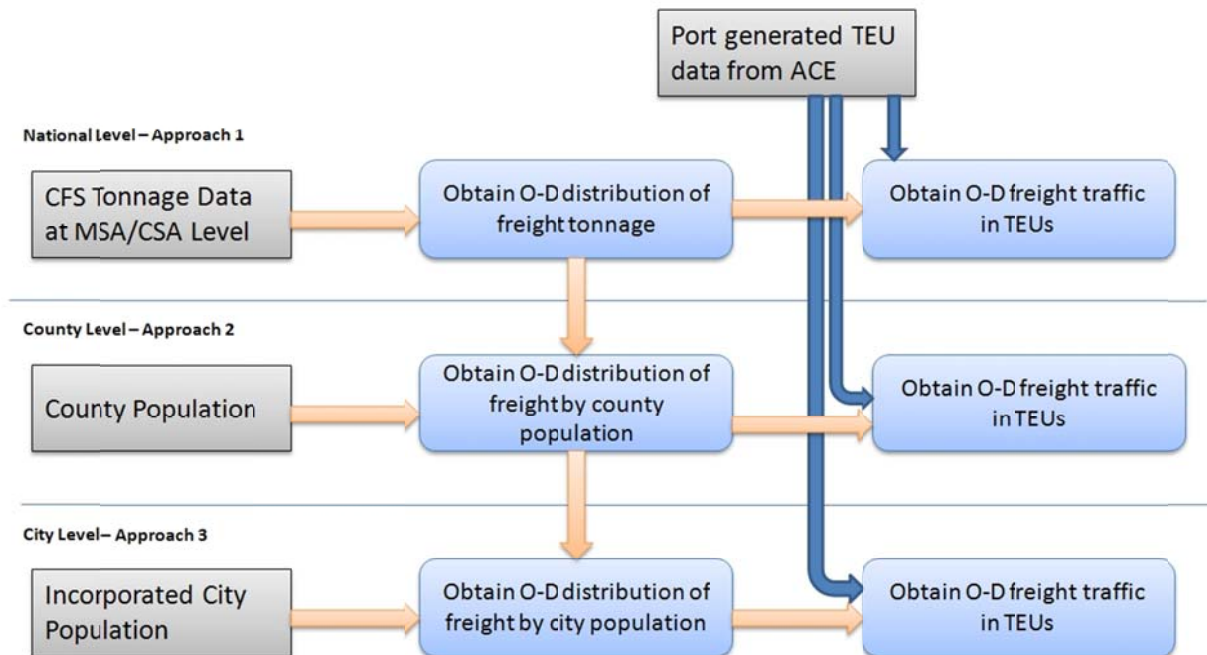


Figure 37. Process Workflow for freight distribution

The next step in building the freight flow model was to locate the intermodal facilities. Each of the origins ports was visually verified on Google Maps™ and its geospatial information was noted down. For the destinations, a similar process was followed. In case of the MSAs/CSAs, the destination location was chosen to be a centrally located point in the largest city of the region. This would usually be a NTAD intermodal facility – if it existed – or an industrial area, shopping mall or retail center – if there were no facilities in the region. Figure 40 shows the overall process of building the origin-destination framework for the west coast ports. Within the state of California, there was a single destination within each county. This destination was chosen to be the most populous incorporated city of the county. Outside the state of California, the locations for the “Remainder of” regions were chosen to be the next major urban areas apart from the listed MSA/CSA for a particular state. For example, Remainder of Arizona 1 was chosen to be Flagstaff and Remainder of Arizona 2 was chosen as Yuma, with Phoenix and Tucson as the listed MSA/CSAs for the state. Once again, Google Maps™ was helpful in locating the regions (See Figure 38).



Figure 38. CFS Destinations in Arizona (Source: Google Maps™)

The final output of the O/D pairs list contained the geospatial information for each destination along with freight and container traffic data. Figure 39 shows a partial view of the resultant data set for the Oakland port area. The inclusion of geospatial information in the O/D pair data set facilitates seamless transfer of the data to ArcMap™ and enables GIFT to analyze it with ease. Figure 41 shows, for example, the locations of the different destinations for the west coast ports, as obtained from the CFS data set.

Destination geography	Value(\$mil)	Tons (thous)	% of Total ton of freight	Outbound Traffic (TEUs)	O-D TEUs	Latitude-D	Longitude-D
San Jose-San Francisco-Oakland, CA CSA	131,274	163,783	79.99%	935,100	747,944	37.328124	-121.8902
Remainder of California (Fresno)	15,885	19,530	9.54%	935,100	69,187	36.771863	-119.844128
Sacramento-Arden-Arcade-Truckee, CA-NV CSA (CA Part)	6,508	7,170	3.50%	935,100	32,743	38.57354372	-121.4871472
Los Angeles-Long Beach-Riverside, CA CSA	27,024	6,552	3.20%	935,100	29,921	34.05215027	-118.243425
Seattle-Tacoma-Olympia, WA CSA	2,194	829	0.40%	935,100	3,786	47.62090164	-122.347275
Portland-Vancouver-Beaverton, OR-WA MeSA (OR Part)	1,735	708	0.35%	935,100	3,233	45.52375683	-122.6704
Phoenix-Mesa-Scottsdale, AZ MeSA	3,373	495	0.24%	935,100	2,261	33.44801913	-112.0738222
Dallas-Fort Worth, TX CSA	3,965	432	0.21%	935,100	1,973	32.78084153	-96.79711111
Salt Lake City-Ogden-Clearfield, UT CSA	1,075	423	0.21%	935,100	1,932	40.7715082	-111.8881694
Chicago-Naperville-Michigan City, IL-IN-WI CSA (IL Part)	3,192	331	0.16%	935,100	1,512	41.87932514	-87.62433333
Remainder of Nevada 1 (Mesquite)	2,565	318	0.16%	935,100	1,452	36.803912	-114.069632
Remainder of Nevada 2 (Reno)		318	0.16%	935,100	1,452	39.527668	-119.813572
Denver-Aurora-Boulder, CO CSA	1,485	281	0.14%	935,100	1,283	39.75500546	-104.9881056
Remainder of Oregon (Eugene)	868	232	0.11%	935,100	1,059	44.052053	-123.09033
Houston-Baytown-Huntsville, TX CSA	3,380	165	0.08%	935,100	754	29.75979235	-95.36253333
Boise, Idaho	1,072	157	0.08%	935,100	717	43.59702459	-116.2999361
Remainder of Washington 1 (Spokane)	1,178	156	0.08%	935,100	712	47.675279	-117.325323
Remainder of Washington 2 (Vancouver)		156	0.08%	935,100	712	45.640167	-122.67182
Remainder of Washington 3 (Kennewick)		156	0.08%	935,100	712	46.214446	-119.157078
Honolulu, HI MeSA	829	132	0.06%	935,100	603	21.306944	-157.858333
Detroit-Warren-Flint, MI CSA	993	128	0.06%	935,100	585	42.331427	-83.045754
Las Vegas-Paradise-Pahrump, NV CSA	801	127	0.06%	935,100	580	36.1144071	-115.1728167
San Diego-Carlsbad-San Marcos, CA MeSA	2,118	122	0.06%	935,100	557	32.705164	-117.151254
New York-Newark-Bridgeport, NY-NJ-CT-PA CSA (NJ Part)	1,953	107	0.05%	935,100	489	40.732074	-74.174142
New York-Newark-Bridgeport, NY-NJ-CT-PA CSA (NY Part)	2,418	94	0.05%	935,100	429	40.75595355	-73.986895
Miami-Fort Lauderdale-Pompano Beach, FL MeSA	3,004	85	0.04%	935,100	388	25.774266	-80.193669
Minneapolis-St. Paul-St. Cloud, MN-WI CSA (MN Part)	729	78	0.04%	935,100	356	44.979965	-93.263836
St. Louis-St. Charles-Farmington, MO-IL CSA (MO Part)	513	75	0.04%	935,100	343	38.62731421	-90.19841667
Austin-Round Rock, TX MeSA	1,091	68	0.03%	935,100	311	30.267161	-97.743046
Boston-Worcester-Manchester, MA-NH CSA (MA Part)	1,484	56	0.03%	935,100	256	42.358431	-71.059773
Columbus-Marion-Chillicothe, OH CSA	321	54	0.03%	935,100	247	39.9620082	-83.000675

Figure 39. O/D pair Data Set for Oakland port Area

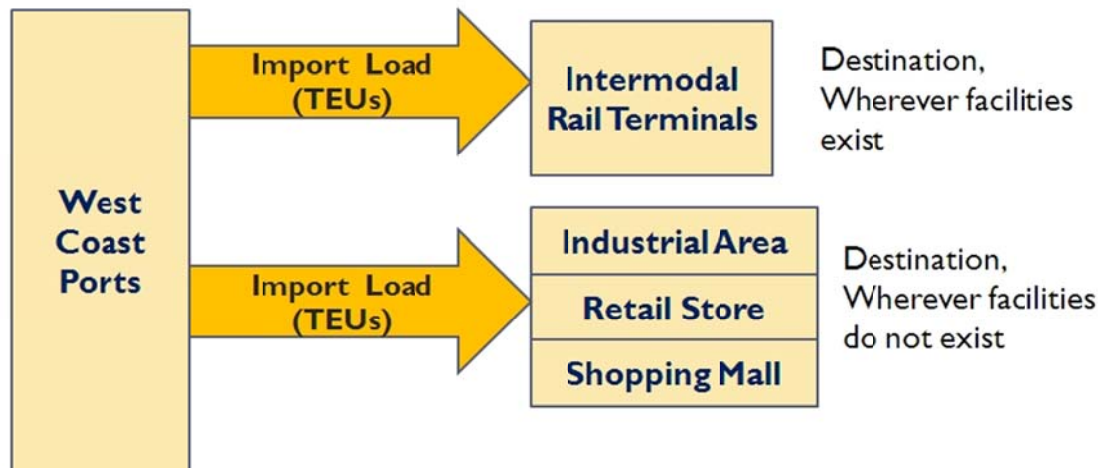


Figure 40. Building the O/D pair framework

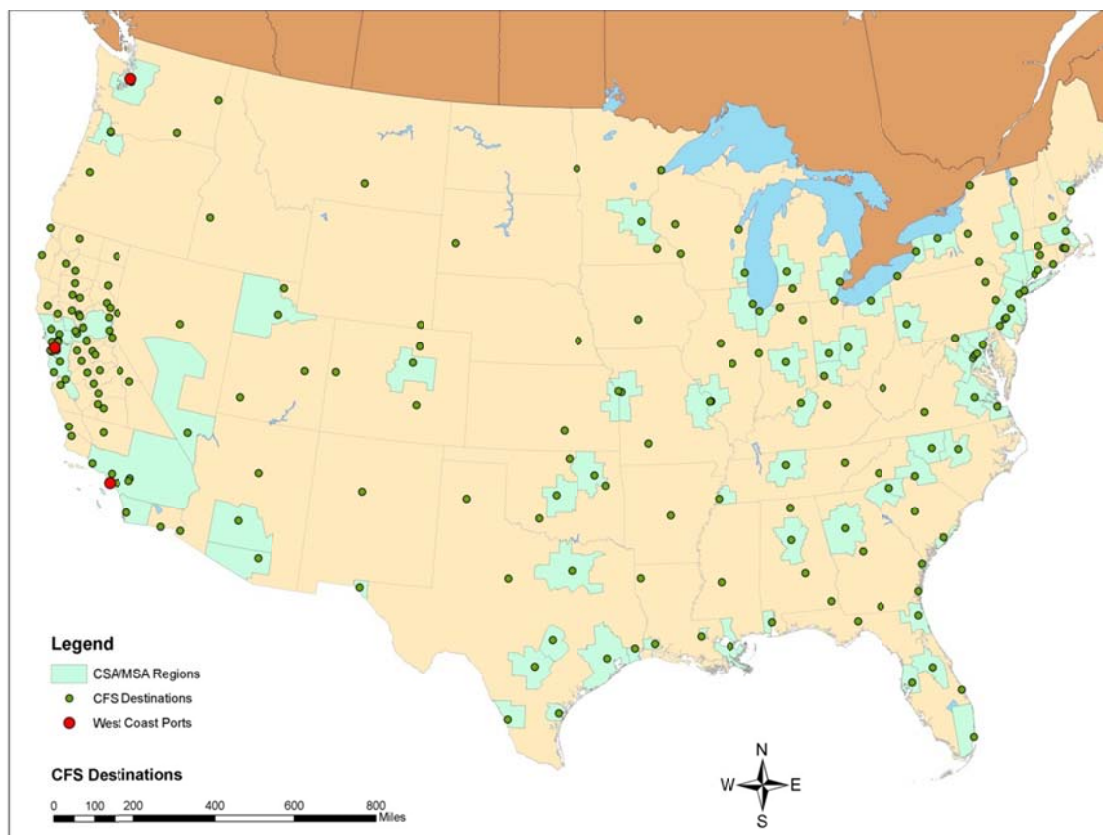


Figure 41. CFS destinations for the West Coast Ports

APPENDIX G: Cambridge Systematics Inc FAF2 Disaggregation Methodology

We studied another data set which was provided to us by CARB. This data set, developed by Cambridge Systematics Inc., used the Freight Analysis Framework 2.0 (FAF2) data, based on 2002 CFS data, to obtain O/D tonnage figures at the county level for California. The methodology adopted by Cambridge Systematics (CS) was different than the one adopted by the GIFT team for estimating the O/D tonnage figures at the county level for California. The following section briefly explains the CS methodology as a point of comparison.

Cambridge Systematics used regression analysis to generate equations for production and attraction for the counties in California and other FAF2 regions outside of California (Since the FAF2 data was generated from 2002 CFS, the FAF2 zones share their boundaries with the CFS defined CSAs/MSAs and “Remainder of” regions).

For the regression equations, the tonnage figures were the dependent variable. The explanatory variables were factors which thought to affect the amount of a commodity produced in a region or destined for a region, such as employment by industry (using the North American Industry Classification System), total employment, population etc. Thus, a region with zero employment in an industry would not produce/attract any freight in commodities associated with that industry.

The production and attraction equations were generated by commodity groups as shown on the following page.

$$Production (Commodity Group) = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

(Here the explanatory variables includes employment in industry that produce the specific commodity group along with other variables)

$$Attraction (Commodity Group) = \beta_1 X_1 + \beta_2 X_2$$

(Here the explanatory variables include employment in industry that consume the specific commodity group along with other variables)

Using the above two regression models, the production of a particular commodity in a county- $P_c(i)$; and the attraction of a particular commodity to a county- $A_c(i)$ were estimated. These figures were then aggregated to compute the production (or attraction) of a particular commodity in the FAF2 zone which the counties were associated with. The following equations illustrate the concept

$$P_{FAF}(i) = \sum_i P_c(i)$$

$$A_{FAF}(i) = \sum_i A_c(i)$$

Finally, the ratio of the county production (or attraction) to the FAF2 zone production (or attraction) was utilized to break down the original 114 by 114 FAF2 O/D pair database to the county level ,which resulted in a 3140 by 3140 O/D pair database, thereby including all the counties in the US. The following equation sums this process:

$$County(i,j) = FAF(k,l) \times \left(\frac{P_c(i)}{P_{FAF}(i)} \right) \times \left(\frac{A_c(i)}{A_{FAF}(i)} \right)$$

For California, the figures were adjusted for modal accessibility.

In this way, the Cambridge Systematics FAF2 disaggregated database provided direct figures for the percent of freight flowing from a CSA/MSA (or a port region) to a particular county.