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Application to Marine Highway Systems (MHS)

FINAL REPORT

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1. EXECUTIVE SUMMARY

This project report presents details of research carried out by the George Mason University Consortium under a research contract from the U.S. Department of Transportation's Research and Innovative Technology Administration (RITA), in support of the Commercial Remote Sensing and Spatial Information (CRS&SI) Technology program.

The Consortium research focused on developing first line decision making tools for state and local agencies for identifying alternate freight transportation options using available waterways. The marine highway freight system (MHFS) offers the opportunity for increasing freight capacity and relieving highway congestion with low infrastructure investments. The GMU Consortium study showed that planning of marine highways can be accomplished cost effectively using results of model analysis and by applying emerging CRS&SI tools.

The project developed methods to compare potential cost savings in marine highways by coupling the following three modeling and analysis processes: 1) A highway model for freight flow leading to the ports; 2) a waterway model for marine transportation and 3) a drayage freight flow analysis system. The results have generic application nationwide for marine highways. For proof of concept purposes, the study focused on the Eastern corridor region (I-95 Corridor).

The highway model applied the latest nationwide Freight Analysis Framework (FAF) data available, in conjunction with TransCAD software and integrated analysis results for estimating freight flow in regions close to ports. The impact of a hypothetical diversion of a portion of freight (30%) was then considered. The resulting data formed the input for evaluating freight diversion impact in a selected short-haul marine highway route (James River water way from the port of Richmond to the Port of Virginia), and a long–haul marine highway route linking three major ports in the Eastern corridor (Cape Canaveral, FL, Port of Virginia, and New Bedford, MA).

The waterway analysis model was developed using ExtendSim 8 Discrete Event Simulation (DES) software. The model provided a flexible and scalable system for estimating the logistics and economic costs of transporting diverted freight in marine highway routes. The system consists of scalable building blocks that model different components common to marine highways by incorporating freight traffic input from the highway diversion model. The modeling results presented in the report show effectiveness for application to estimate cost savings factors for marine highway.

The drayage freight flow analysis model was developed to provide a system analysis for estimating average drayage cost in a network that extends between port terminals and inland facilities. The analysis provided estimates of travel time and congestion delay costs for the drayage activity. A specific port site (Port of Newark/Elizabeth) was used for analysis verifications.

The results for the modeling process from various freight diversion scenarios were applied to planning marine highways, using advances in commercial remote sensing technologies and high resolution satellite imagery. The technology application enabled rapid collection of broad area geographic and physical data for spatial planning of marine highway infrastructure requirements in developed or undeveloped ports.

The report of the project study include guidelines for applying the modeling and remote sensing technology tools for assisting a first line decision process for potential marine highways. The application methodologies developed from the study are powerful tools for examining waterways nationwide and provide a potential for developing a national baseline document on infrastructure investments for future marine highway operations.

2. INTRODUCTION AND RESEARCH APPROACH

The marine highway consortium research was performed by George Mason University (GMU) in technical partnership with the CSC Advanced Marine Division assisting with waterway model development; GeoEye Incorporated assisting with satellite imagery analysis; Rutgers University's Center for Advanced Infrastructure and Transportation (CAIT) assisting with drayage modeling; and the German Aerospace and Transportation Studies Center (DLR) assisting with European technology transfer for U.S marine highways.

The Marine highway system is in the forefront of alternate transportation concepts considered for meeting future freight capacity requirements. Moving freight by waterways reduces the impact of highway freight on the environment, saves transportation related fuel consumption, and reduces infrastructure maintenance cost, specifically on pavements and bridges. The system has the potential for complementing and increasing the productivity and performance of other intermodal systems. Marine highway infrastructure can be implemented at significant cost savings, compared with highway infrastructure expansion. Navigable waterways, if present in pathways paralleling or connecting current freight corridors would have an immediate potential to relieve freight congestion on highways An example is the 64 Express barge line in the James River, paralleling I-64 between Richmond and the Port of Virginia

Existing marine highway services including short-distance ferries and medium-distance and interregional transport of freight have demonstrated the market viability of marine highways in a handful of waterways. However, current operations have not yet captured adequate non-bulk freight market share to make measureable and significant regional or national impact. A viable and scalable system analysis will guide the planning process by providing tools for cost effectively developing options for alternate transportation system to accommodate the 21st Century freight capacity demand.

The GMU Consortium research focused on a systematic approach for examining the viability of the marine highway freight system for alternate transportation. Significant development issues were incorporated in the project study as follows:

1. A flexible modeling process was developed for analyzing diversion of freight from highways to waterways, interlinking results from the highway diversion model with a scalable waterway (marine) model. The results enable estimation of the cost and other advantages of the marine highway system. The quantification of direct and indirect benefits will guide the initial decision making process for planning marine highway. The model is constructed to be flexible and scalable for application to any waterway and highway system for rapid comparisons of advantages to support first line decision making.
2. The advances in remote sensing imageries provide a new potential for national examination of waterways for marine highway service evaluation. Innovative and advanced tools from commercial remote sensing and satellite imagery systems were applied for rapid and cost effective analysis for marine highway routing and infrastructure assessment to support a first line decision process. The results will potentially be useful for making investment decisions for planning marine highway infrastructure.
3. The European Union is making concerted efforts to increase the volume of short sea shipping as well and to implement additional routes for transition from road freight to marine freight. Europe has been practicing short sea shipping for several decades and has a wealth of technical, operational and policy experience that is transferrable. In Europe, short sea shipping currently has a market share of 32% of freight transported and is increasing about 4% each year. The study examined the successful process and technologies used in deploying European Short Sea Shipping Systems and lessons that could be applied to U.S. marine highway systems.
4. Reaching out and training practitioners in regional, state and local agencies are important for successful results application. The Consortium focused on developing simple, usable guidelines and organized special meeting sessions with state agencies, operators and regional transportation policy makers. The outreach process focused on helping local and regional transportation decision makers in seeking investment partnerships for establishing or expanding waterways for linking with marine highway corridors.

3. HIGHWAY FREIGHT DIVERSION ANALYSIS

3.1 Introduction

The modeling process for marine highway is performed by coupling three analysis models:

1) Highway model on freight flow leading to ports;
2) Marine highway model;
3) Evaluations of freight flow and drayage at and around the port.

Figure 3-1 provides an overview of the modeling process. The data stream from the highway model serves as the driver for the marine highway and drayage analysis models. Integrated evaluations are made for comparing the direct and indirect cost between moving freight by highways and marine highways. Direct cost includes cost of fuel and operations. Indirect cost

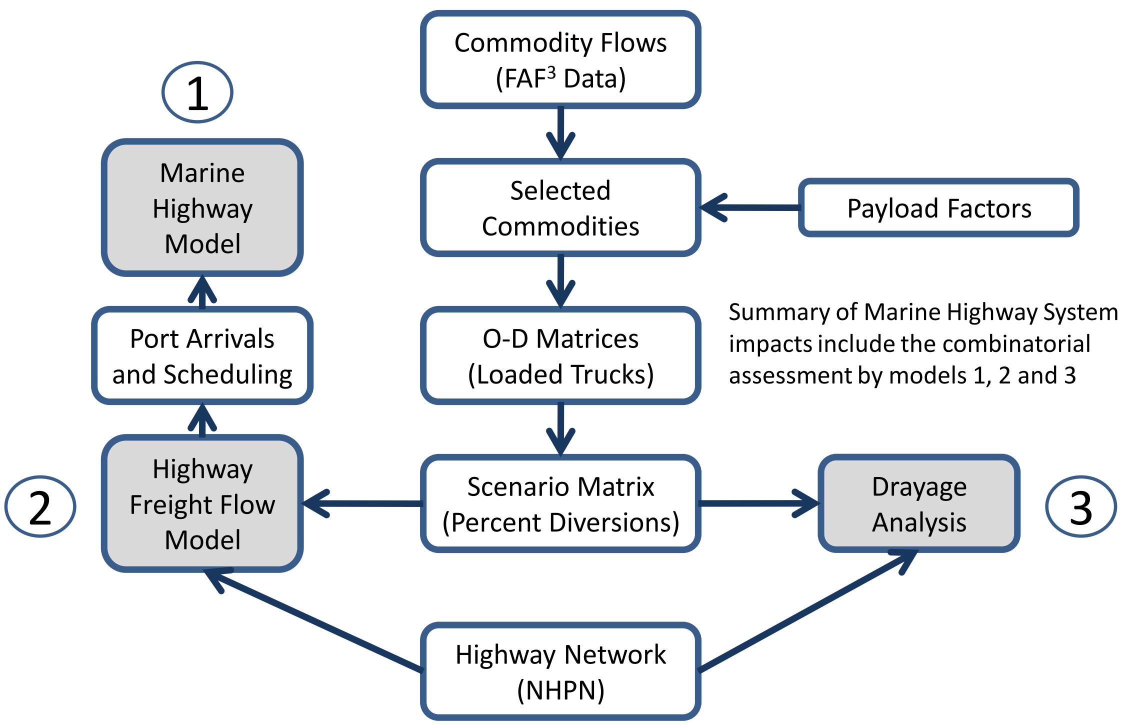


Figure 3-1 Schematic Representation of Modeling Methodology

includes relative cost savings from reducing highway congestion, safety incidents, and highway maintenance cost and emissions impact.

In the highway freight flow model commodity based computations are made for highway freight flow by synthesizing nationwide FAF-3 data, analyzing flow into port regions and integrating results using TransCAD.

3.2 The Freight Analysis Framework (FAF)

The Freight Analysis Framework (FAF) integrates data from a variety of sources to create a comprehensive picture of freight movement among states and major metropolitan areas by all modes of transportation. FAF is designed to enable the Federal Highway Administration (FHWA) to conduct investment and policy analysis and to support legislative activities. With data from the 2007 Commodity Flow Survey (CFS) and additional sources, FAF version 3 (FAF3) provides estimates for commodity tonnage and value, by commodity type, mode, origin, and destination for 2007, the most recent year, and forecasts through 2040. Also included are truck flows assigned to the highway network for 2007 and 2040. FAF3 is a continuation of the original framework developed by the U.S. Department of Transportation, Federal Highway Administration.

FAF3 is organized as two separate primary products. The first of FAF3 products is the commodity flow origin-destination (O-D) data, which covers both the base year (2007) and future years between 2010 and 2040 with a 5-year interval. The second product is the freight movement data on all highway links within the FAF3 highway network. Since its inception, the application of FAF has permeated to many divisions within the U.S. Department of Transportation. While FAF3 is currently undergoing further development, the FHWA has been collaborating with state Departments of Transportation, metropolitan planning organizations, universities, and other institutions to develop methods and procedures to enable state and local government agencies to incorporate FAF3 data into the analysis process.

FAF Geography

The 2007 CFS commodity flow tables are based on a revised geography that contains 11 additional traffic analysis regions, for a total of 123 domestic regions in all. FAF3 uses the same geography. Figure 3-2 shows the boundaries of the 123 domestic FAF3 flow analysis regions, also referred to as FAF3 analysis zones (Southworth, 2010).

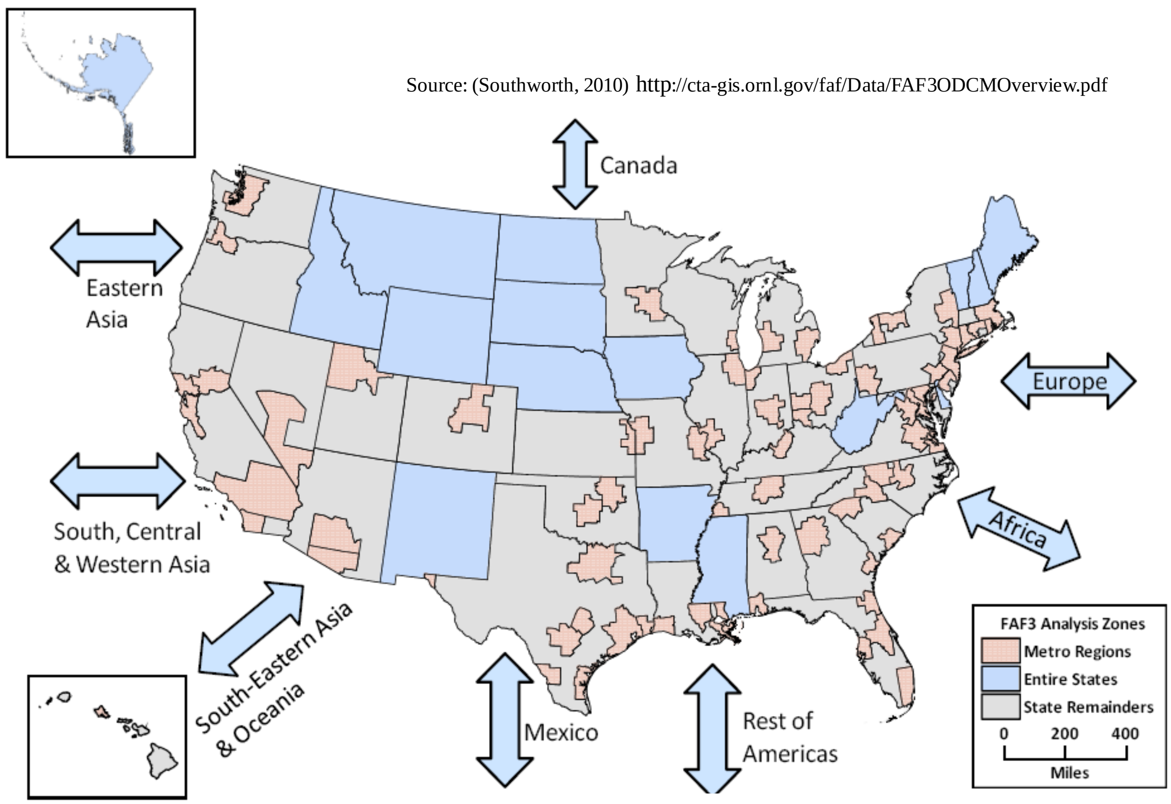


Figure 3-2 FAF3 Geography

Transportation Network

The geospatial coverage of the FAF3 network was developed using FHWA NHPN Version 2005.10. The NHPN was originally assimilated from the National Highway Planning Network (NHPN) and individual state interchange data, and contains a set of data attributes which are suited to analytical modeling of large-scale transportation activities. The accuracy of the version 4.0 database is at a scale of 1:100,000 (about 80-m accuracy).

Version 4.0 of the NHPN contains Route Attribute Tables that define Highway Inventory Route systems for each State and territory in the network database. These additions to the NHPN provide the data structures and keys necessary to overlay dynamically segmented State Inventory databases such as the Highway Performance Monitoring System (HPMS) post-1994 and the National Bridge Inventory database (NBI). Out of 454,662 miles of the NHPN network, 452,254 miles are included in the FAF3.

In recent years, the HPMS linear referencing geospatial schema was integrated as part of the NHPN network to allow capturing HPMS data elements. The HPMS is the nation's highway database maintained by the FHWA using data supplied by the states and updated on a regular basis. The database contains information reported by states such as mileage, average annual daily traffic (AADT), route number, jurisdiction, functional classification, number of lanes, service flow ratio (also a measure of capacity), and pavement condition. Other attributes of the network include:

- Designated sign routes of roads
- Functional classification of roads
- Length of road links

For 2005 base year and forecast year, the following traffic information is also available in the NHPN network:

- AADT: Annual average daily traffic
- AADTT: Truck volume based on HPMS average truck percentage
- FAF: Truck flow based on freight demand model and FAF 2.2 O-D database
- CAP: Estimated capacity using HCM 2000 methodology
- SF: Service flow volume/hour
- VCR: volume to capacity ratio
- SPEED: estimated peak period link speed, miles/hour
- DELAY: Link delays in hour

3.3 Data Preparation

The data in this analysis comes from the US DOT's Freight Analysis Framework (FAF). FAF data contains attributes for each highway segment which are used to estimate travel time for each highway segment. The highway data analysis thus can produce estimates of commodity flow on the highway segments, providing priorities for moving freight for specific highway segments from highways to nearby waterways.

FAF Commodity Classes

FAF3 reports annual tonnage and dollar valued freight flows using the same 43 two-digit Standard Classification of Transported Goods (SCTG) classes (Table 3-1) used by the 2007 U.S.

Table 3-1 FAF3 Commodity Classes

SCTG	Commodity	SCTG	Commodity	SCTG	Commodity
01	Live animals/fish	15	Coal	29	Printed products
02	Cereal grains	16	Crude petroleum	30	Textiles/leather
03	Other agricultural products.	17	Gasoline	31	Nonmetal mineral products
04	Animal feed	18	Fuel oils	32	Base metals
05	Meat/seafood	19	Coal-n.e.c.	33	Articles-base metal
06	Milled grain prods.	20	Basic chemicals	34	Machinery
07	Other foodstuffs	21	Pharmaceuticals	35	Electronics
08	Alcoholic beverages	22	Fertilizers	36	Motorized vehicles
09	Tobacco prods.	23	Chemical prods.	37	Transport equipment
10	Building stone	24	Plastics/rubber	38	Precision instruments
11	Natural sands	25	Logs	39	Furniture
12	Gravel	26	Wood products	40	Misc. mfg. products.
13	Nonmetallic minerals	27	Newsprint/paper	41	Waste/scrap
14	Metallic ores	28	Paper articles	43	Mixed freight
99	Commodity unknown				

Commodity Flow Survey (CFS). These flows are also broken down by seven modes of transportation: Truck, Rail, Water, Air (includes truck-air), Multiple Modes and Mail, Pipeline, and Other/Unknown. The "multiple modes and mail" category includes truck-rail, truck-water, and rail-water intermodal shipments involving one or more end-to-end transfers of cargo between two different modes.

O-D Flows and Commodity Category

The FAF Commodity flow database estimates tonnage and value of goods shipped by type of commodity and mode of transportation among and within 114 areas, as well as to and from 7 international trading regions though the 114 areas plus 17 additional international gateways. These regions and gateways can be displayed by geographic files. The 2007 estimate is based primarily on the Commodity Flow Survey (CFS) and other components of the Economic Census. Forecasts are included for 2010 to 2040 in 5 year increments. In this project, only 2007 data are analyzed.

The FAF3 modeling process draws from many data sources but the most important is the U.S. Commodity Flow Survey (CFS). Figure 3-3 shows the principal types of data used to construct the FAF3 freight flows matrix. This matrix construction process begins with the data reported by the 2007 CFS3, adopting both the CFS definitions for the 123 internal to the U.S. freight analysis zones and the same 43 SCTG 2-digit commodity classes, but using a modification of CFS modal definitions (Southworth, 2010).

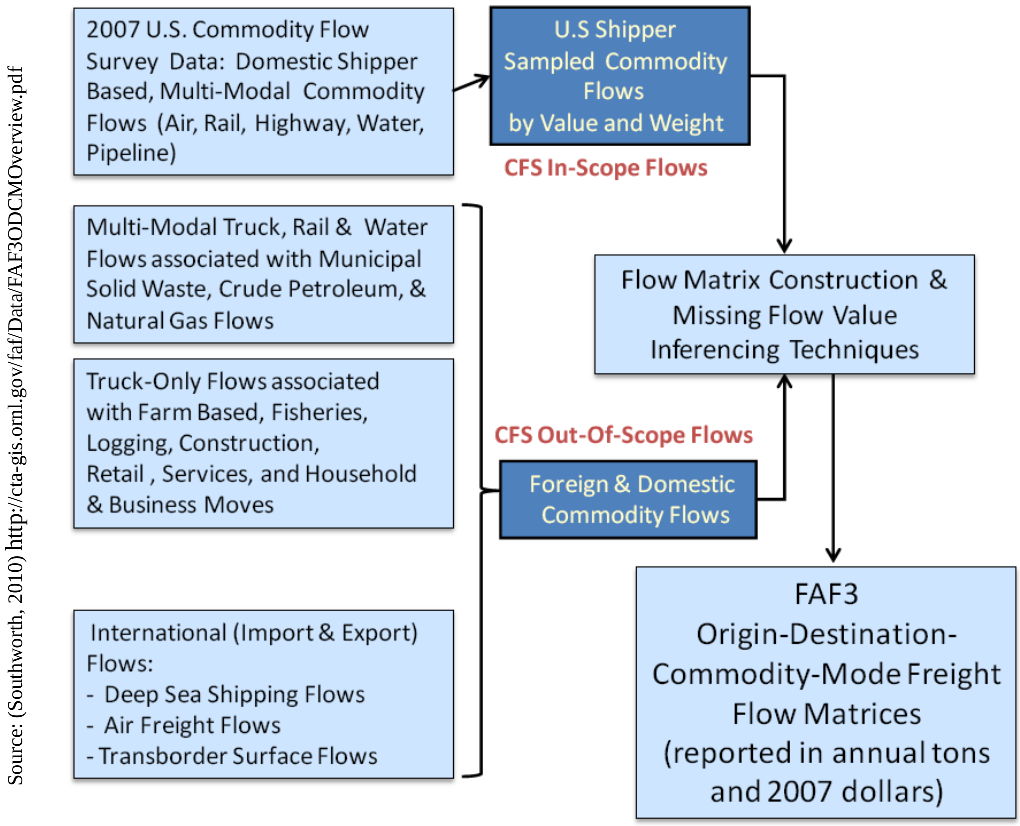


Figure 3-3 Overview of the FAF3 Freight Flow Matrix Construction Process

Candidate Routes

This project doesn't conduct the analyses at the nationwide level. The researchers are concerned with truck traffic along the east coast corridor, on both a long haul route and a short haul route.

The long haul route is from New Bedford, MA to Port Canaveral, FL with an intermediate stop at the Port of Virginia (Norfolk-Hampton Roads area). This route parallels the major length of I-95 in the Atlantic seaboard, and was selected as a good choice for carrying out comparative evaluations of marine highways.

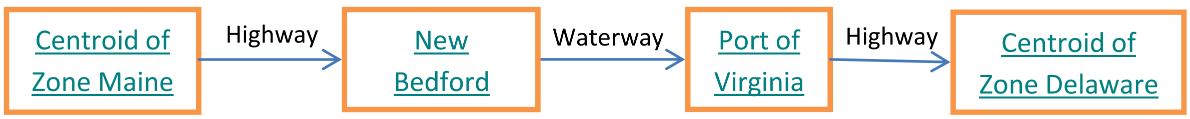
To evaluate the impacts of diversion on freight and road traffic conditions, a set of FAF zones along the eastern coast are selected based on the three port stops. All these zones are located within 120 miles from one of the three ports. Table 3-2 lists all these 22 zones and the three ports.

Table 3-2 FAF Zones Near Selected Ports

Port	Zone	Name
Port Canaveral	121	Jacksonville FL MSA (Metropolitan Statistical Area)
	122	Miami FL MSA
	123	Orlando FL CSA (Canaveral Statistical Area)
	124	Tampa FL MSA
	129	Remainder of Florida
Port of Virginia	100	Delaware
	111	Washington DC-VA-MD-WV MSA (DC Part)
	242	Washington DC-VA-MD-WV MSA (MD Part)
	249	Remainder of Maryland
	511	Richmond VA MSA
	512	Norfolk VA-NC MSA (VA Part)
	513	Washington DC-MD-VA-WV CSA (VA Part)
	519	Remainder of Virginia
New Bedford	91	Hartford CT CSA
	92	New York NY-NJ-CT-PA CSA (CT Part)
	99	Remainder of Connecticut
	230	Maine
	251	Boston MA-NH CSA (MA Part)
	259	Remainder of Massachusetts
	330	New Hampshire
	440	Rhode Island
	500	Vermont

These zones are divided into three groups based on the ports nearby. The proposed scenario selected by the GMU study team assumes that the diversion of 30% of truck freight volumes would happen between two zones which are not in the same group.

The diverted freight would be transported from the origin zone to one of the ports through highway system, then, after the waterway transporting, unloaded at another port, and moved to the destination zone by truck again. For instance, freight shipped from zone Maine to zone Delaware would follow the route below to utilize marine highway services:

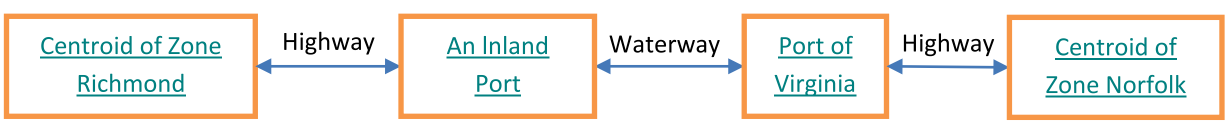


On the other hand, there is no diversion between those zones belonging to the same group.

The selected short haul route is an inland waterway route between Richmond and the Port of Virginia. The 64 Express barge service connecting these two ports was selected for analysis because it is an ongoing operation dedicated to relieving freight congestion on I-64 leading to the Port of Virginia. Also, there is a wealth of operating data and experience for this service, which proved valuable for model development and calibration.

In the long haul route analysis, there is no diversion between zones within the same group. However, for the short haul route the internal group freight flows have a great portion of the total flows, the change of which may have significant influence on regional traffic.

Since Norfolk is the only zone at the east end of I-64, most freight between Norfolk and those zones in the same group are transported through I-64. If a portion of that freight is diverted to waterway, the traffic on I-64 is expected to get relieved. A possible route could be:



3.4 Modeling Methodology

To do the scenario analysis, the preparation consists of two parts: building the network and developing trip matrix. The former part is completed with TransCAD, and the latter with MS Access. The analysis is conducted using TransCAD, which also produces the outputs.

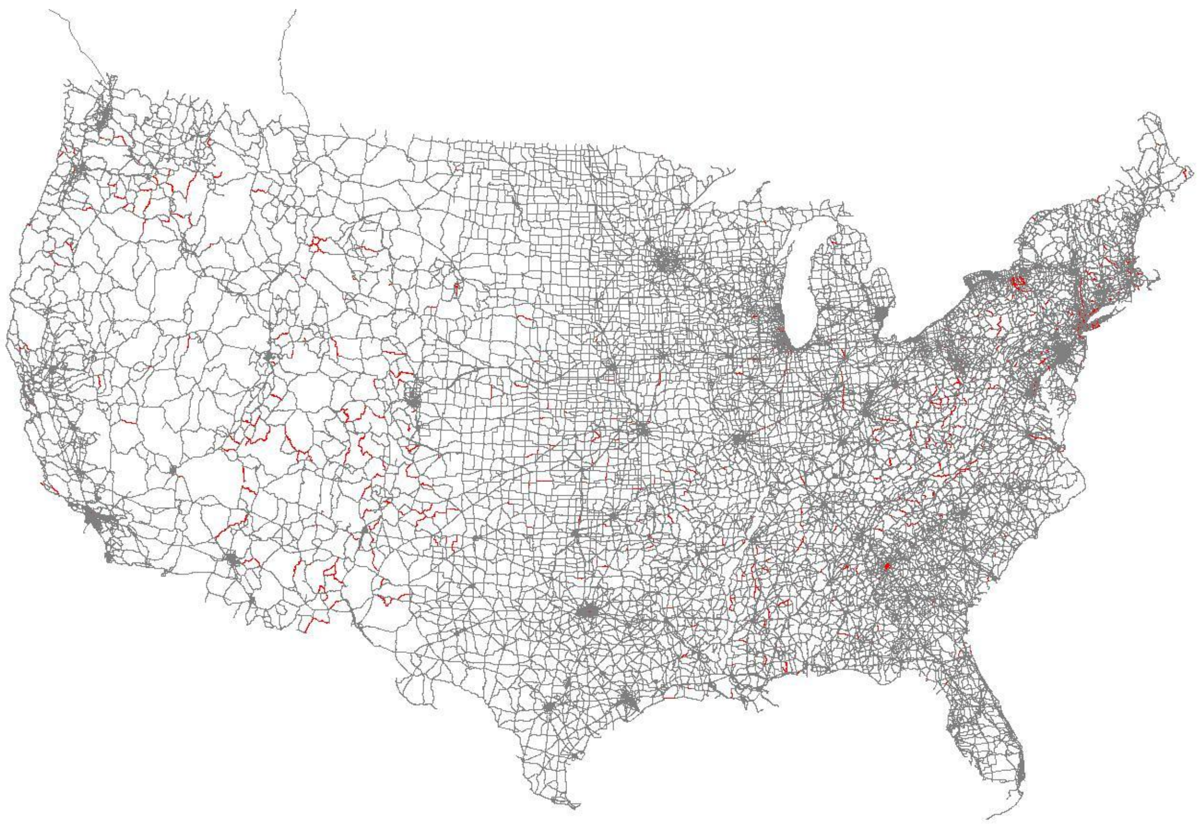
Build Truck Network

To build a network for traffic assignment in TransCAD, a link layer and a point layer including the selection set of origins and destinations are needed.

In the FAF highway network, some links are restricted for trucks. There is an attribute named [TRK_RTE] indicating whether a link allows truck traffic.

[TRK_RTE]: Truck route related restrictions
1 State designated truck route2 NN system
3 Long Combination Vehicle (LCV) route
5 Arc with state truck restriction
6 Low clearance8 NN with low clearance
9 NN with state truck restriction
11 Hazmat restriction09 Rural Local

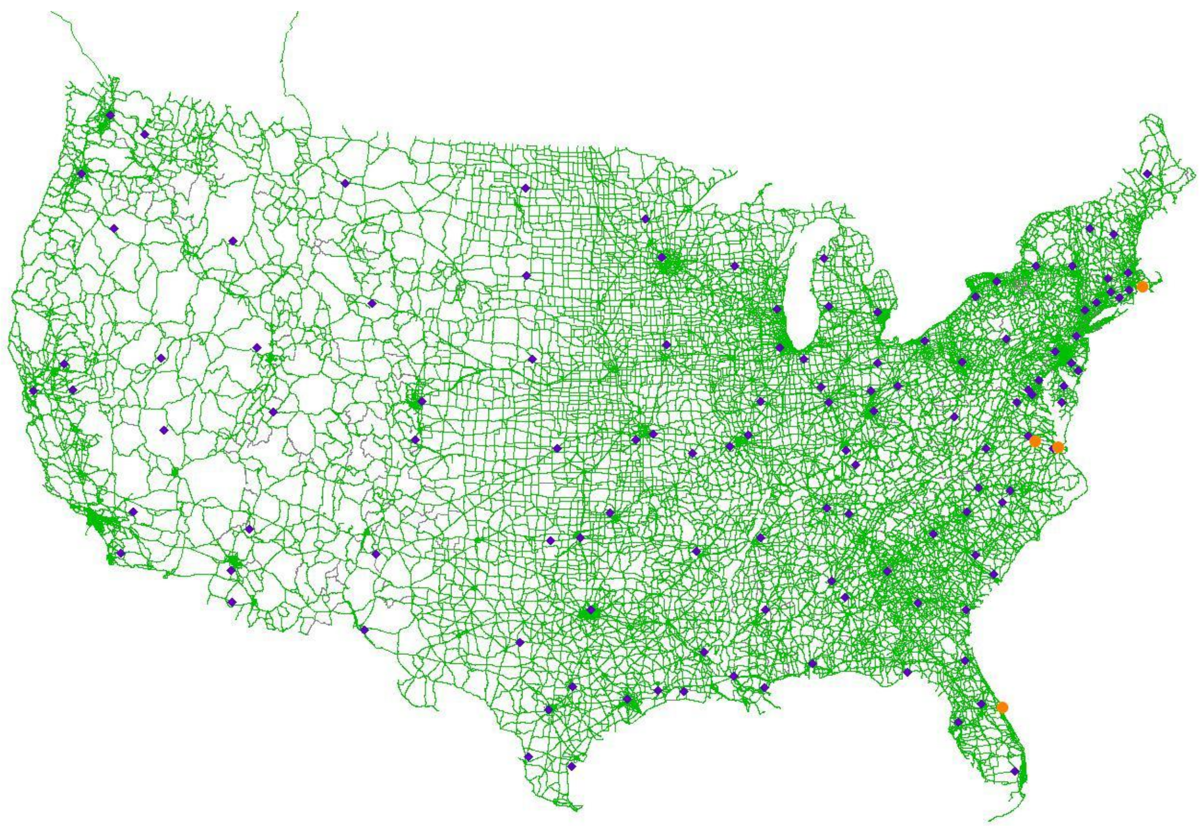
Based on this attribute, a selection set of truck routes is created.



In this figure, the red lines indicate the roads with truck restriction, which would be excluded when building the network.

Geographic centroids of 123 FAF3 domestic regions were first determined using TransCAD tools based on the FAF zone layer, although this project only involves the 22 selected zones listed in Table 3-2. However, in order to avoid any possible biases this process might inject into the analysis, the TransCAD model included all of the FAF3 zones. TransCAD is able to connect the centroids to the truck route layer through its "Centroid Connector" feature.

In the figure below the purple diamonds indicate centroids and the orange dots indicates the ports, which include the three ports for the long haul route and an alternative port Hopewell. Both selected centroids and ports would be the origins and destinations of commodity movements n the traffic assignment.



To create the network, the Time Field needs to be filled with estimated link travel times. Therefore, a new field named "MINUTE" is added to the truck route layer as the link impedance parameter in the assignment. The value of this new field is calculated based on the two other attributes: MILES and SPEED07:

$$MINUTE = \frac{60 \times MILES}{SPEED07}$$

When creating the network, the attribute MINUTE is identified as a time field. Its default value is set as 0, which applies to centroid connectors.

Development of Trip Matrices

The development of trip matrices consists of three steps:

Step 1. Filter out the commodity flows which have both origins and destinations within the list of selected zones, and calculate the diversions.

Since the analysis concentrates on the selected zones, the other zones should be eliminated. Also, the freight flows between same group zones won't be diverted. The following figure gives some examples. For OD pairs with origin and destination located in different groups, the last column shows the truck number with diversion, while for the internal flows, the last two columns have the same value.

Zone_O	ZoneName_O	Zone_D	ZoneName_D	Existing	30% Diversion
91	Hartford CT CSA	91	Hartford CT CSA	1528385	1528385
91	Hartford CT CSA	92	New York NY-NJ-CT-PA CSA	238971	238971
91	Hartford CT CSA	99	Remainder of Connecticut	39524	39524
91	Hartford CT CSA	100	Delaware	668	468
91	Hartford CT CSA	111	Washington DC-VA-MD-WV	176	123
91	Hartford CT CSA	121	Jacksonville FL MSA	536	375
91	Hartford CT CSA	122	Miami FL MSA	1446	1012
91	Hartford CT CSA	123	Orlando FL CSA	1283	898
91	Hartford CT CSA	124	Tampa FL MSA	2788	1952
91	Hartford CT CSA	129	Remainder of Florida	1538	1077
91	Hartford CT CSA	230	Maine	11571	11571
91	Hartford CT CSA	242	Washington DC-VA-MD-WV	2493	1745
91	Hartford CT CSA	249	Remainder of Maryland	363	254
91	Hartford CT CSA	251	Boston MA-NH CSA (MA Par	106060	106060
91	Hartford CT CSA	259	Remainder of Massachusett	63550	63550
91	Hartford CT CSA	330	New Hampshire	16399	16399
91	Hartford CT CSA	440	Rhode Island	38914	38914
91	Hartford CT CSA	500	Vermont	10534	10534
91	Hartford CT CSA	511	Richmond VA MSA	1238	867
91	Hartford CT CSA	512	Norfolk VA-NC MSA (VA Par	848	594
91	Hartford CT CSA	513	Washington DC-MD-VA-WV	2160	1512
91	Hartford CT CSA	519	Remainder of Virginia	1397	978
92	New York NY-NJ-(	91	Hartford CT CSA	319812	319812
92	New York NY-NJ-(	92	New York NY-NJ-CT-PA CSA	2270522	2270522
92	New York NY-NJ-(	99	Remainder of Connecticut	40390	40390
92	New York NY-NJ-(	100	Delaware	4560	3192
92	New York NY-NJ-(	111	Washington DC-VA-MD-WV	29	20
92	New York NY-NJ-(	121	Jacksonville FL MSA	372	260
92	New York NY-NJ-(	122	Miami FL MSA	9531	6672
92	New York NY-NJ-(	123	Orlando FL CSA	333	233
92	New York NY-NJ-(	124	Tampa FL MSA	1505	1054

Step 2. Generate drayage table.

Drayage refers to the flows between zones and ports, which doesn't exist before the diversion. The freight would be transported to the nearest port, so the drayage always occurs between the zone centroid and its corresponding port. The following figure is a snapshot of a drayage table. The "Existing" column is empty for all O-D pairs, and the last column shows how many trucks would travel between the zone-port pair with the diversion.

Zone_O	Zone_D	Existing	30% Drayage
2001	511		278
3000	259		1076
3000	440		321
3000	330		251
3000	259		631
3000	251		2005
2001	249		269
2001	242		158
3000	230		293
2001	111		67
2001	512		8321
3000	259		3
3000	440		21
3000	91		33
3000	92		87
3000	99		15
2001	100		106
2001	111		13
3000	230		44
2001	242		138
2001	249		384
3000	251		1104
3000	92		2639
3000	330		49
2001	519		836
2001	513		214
2001	512		1363

Combining the drayage table with the previous one, we can obtain a full table of current and proposed truck flows.

Step 3. Correspond the zone ID to the node ID of the truck network created in TransCAD.

TransCAD can't recognize the zone ID which is defined in the FAF data, so the node ID in the network must be applied to corresponding centroid before doing assignment. The figure below shows the table after adding node information for the zones.

Zone_O	ZoneName_O	Node_O	Zone_D	ZoneName_D	Node_D	Existing	30% Diversion
91	Hartford CT CSA	139736	91	Hartford CT CSA	139736	1528385	1528385
91	Hartford CT CSA	139736	92	New York NY-NJ-CT-PA CS	139737	238971	238971
91	Hartford CT CSA	139736	99	Remainder of Connecticut	139761	39524	39524
91	Hartford CT CSA	139736	100	Delaware	139740	668	468
91	Hartford CT CSA	139736	111	Washington DC-VA-MD-W	139756	176	123
91	Hartford CT CSA	139736	121	Jacksonville FL MSA	139700	536	375
91	Hartford CT CSA	139736	122	Miami FL MSA	139695	1446	1012
91	Hartford CT CSA	139736	123	Orlando FL CSA	139697	1283	898
91	Hartford CT CSA	139736	124	Tampa FL MSA	139698	2788	1952
91	Hartford CT CSA	139736	129	Remainder of Florida	139683	1538	1077
91	Hartford CT CSA	139736	230	Maine	139645	11571	11571
91	Hartford CT CSA	139736	242	Washington DC-VA-MD-W	139753	2493	1745
91	Hartford CT CSA	139736	249	Remainder of Maryland	139742	363	254
91	Hartford CT CSA	139736	251	Boston MA-NH CSA (MA P	139733	106060	106060
91	Hartford CT CSA	139736	259	Remainder of Massachuse	139734	63550	63550
91	Hartford CT CSA	139736	330	New Hampshire	139762	16399	16399
91	Hartford CT CSA	139736	440	Rhode Island	139735	38914	38914
91	Hartford CT CSA	139736	500	Vermont	139763	10534	10534
91	Hartford CT CSA	139736	511	Richmond VA MSA	139744	1238	867
91	Hartford CT CSA	139736	512	Norfolk VA-NC MSA (VA P	139752	848	594
91	Hartford CT CSA	139736	513	Washington DC-MD-VA-W	139754	2160	1512
91	Hartford CT CSA	139736	519	Remainder of Virginia	139743	1397	978
91	Hartford CT CSA	139736	3000	New Bedford	82761		5079
92	New York NY-NJ-CT-PA	139737	91	Hartford CT CSA	139736	319812	319812
92	New York NY-NJ-CT-PA	139737	92	New York NY-NJ-CT-PA CS	139737	2270522	2270522
92	New York NY-NJ-CT-PA	139737	99	Remainder of Connecticut	139761	40390	40390
92	New York NY-NJ-CT-PA	139737	100	Delaware	139740	4560	3192
92	New York NY-NJ-CT-PA	139737	111	Washington DC-VA-MD-W	139756	29	20
92	New York NY-NJ-CT-PA	139737	121	Jacksonville FL MSA	139700	372	260
92	New York NY-NJ-CT-PA	139737	122	Miami FL MSA	139695	9531	6672
92	New York NY-NJ-CT-PA	139737	123	Orlando FL CSA	139697	333	233
92	New York NY-NJ-CT-PA	139737	124	Tampa FL MSA	139698	1505	1054
92	New York NY-NJ-CT-PA	139737	129	Remainder of Florida	139683	1330	931
92	New York NY-NJ-CT-PA	139737	230	Maine	139645	13206	13206

After linking the zone centroids to the network nodes, the table can be imported to TransCAD to generate the matrices.

Matrix1 - sltAll_PortZones_S2 Matrix File (SumOfExisting)

	12265	13038	82761	114480	139645	139683	139695	139697	139698	139700	139733	139734	139735
12265	--	--	--	--	--	--	--	--	--	--	--	--	--
13038	--	--	--	--	--	--	--	--	--	--	--	--	--
82761	--	--	--	--	--	--	--	--	--	--	--	--	--
114480	--	--	--	--	--	--	--	--	--	--	--	--	--
139645	--	--	--	--	2436537.00	1828.00	1910.00	753.00	3247.00	1593.00	251725.00	18445.00	29301.00
139683	--	--	--	--	1996.00	9610097.00	463547.00	1195467.00	1019208.00	220005.00	9672.00	3587.00	685.00
139695	--	--	--	--	935.00	1261869.00	1426760.00	200774.00	165312.00	86698.00	6070.00	1566.00	406.00
139697	--	--	--	--	615.00	633942.00	225077.00	4053397.00	912598.00	82393.00	1517.00	808.00	58.00
139698	--	--	--	--	976.00	983090.00	258021.00	653589.00	3887720.00	106713.00	6683.00	2104.00	1070.00
139700	--	--	--	--	148.00	329779.00	212646.00	337136.00	92679.00	2259723.00	3679.00	9.00	71.00
139733	--	--	--	--	126175.00	3157.00	6295.00	1743.00	2288.00	5451.00	7056513.00	530799.00	247056.00
139734	--	--	--	--	8364.00	374.00	1099.00	547.00	255.00	202.00	276702.00	1256109.00	23759.00
139735	--	--	--	--	6861.00	729.00	856.00	519.00	226.00	107.00	181934.00	25535.00	944933.00
139736	--	--	--	--	11571.00	1538.00	1446.00	1283.00	2788.00	536.00	106060.00	63550.00	38914.00
139737	--	--	--	--	13206.00	1330.00	9531.00	333.00	1505.00	372.00	104268.00	23154.00	29448.00
139740	--	--	--	--	5747.00	3005.00	1441.00	1564.00	925.00	512.00	7917.00	744.00	1059.00
139742	--	--	--	--	1366.00	1145.00	1297.00	635.00	904.00	176.00	6277.00	4549.00	1001.00
139743	--	--	--	--	2587.00	40655.00	7551.00	4705.00	8642.00	9974.00	20482.00	9555.00	3448.00
139744	--	--	--	--	1100.00	8175.00	3363.00	1532.00	1734.00	3503.00	9689.00	536.00	1129.00
139752	--	--	--	--	784.00	18832.00	12718.00	6864.00	23590.00	7254.00	5221.00	1218.00	1369.00
139753	--	--	--	--	401.00	632.00	441.00	455.00	669.00	310.00	1801.00	565.00	428.00
139754	--	--	--	--	563.00	3496.00	5776.00	769.00	1323.00	3057.00	1454.00	183.00	702.00
139756	--	--	--	--	8.00	37.00	31.00	18.00	16.00	13.00	52.00	7.00	7.00
139761	--	--	--	--	2389.00	75.00	129.00	16.00	18.00	14.00	25605.00	3536.00	13631.00
139762	--	--	--	--	102519.00	1734.00	1611.00	493.00	1202.00	556.00	216172.00	24586.00	9802.00
139763	--	--	--	--	20431.00	922.00	745.00	387.00	317.00	224.00	47475.00	18382.00	8328.00

The empty cells indicate two types of OD pairs: port-to-port and port-to-zone in another group, so there is no flow either currently or with diversion.

With the network and matrix ready, the traffic assignment can be conducted in TransCAD. Because FAF only provides annual data, the All-or-Nothing assignment is chosen. The required parameters Time and Capacity are identified with fields MINUTE and CAPACITY, respectively.

Characteristics of the TransCAD Model

Geographic centroids of 123 FAF3 domestic regions were first determined. The resulting point layer is then added to the NHPN network as a set of O-D zones. The combined layer is then prepared as the network for traffic assignment using TransCAD. The analysis is mainly focused within the states spanned by the I-95 corridor. For this reason, a case can be made to derive a subset of the NHPN network and FAF data only for the areas served by the I-95 corridor. However, in order to avoid any possible biases this process might inject into the analysis, the TransCAD model included all of FAF3 zones and NHPN network for the 48 contiguous states.

3.5 Results

Figure3-4 shows the current truck traffic assignment without any diversion. I-95 has medium level of truck volumes, as well as I-64. On some segments within Virginia and the northeast area, there are over 500,000 trucks annually. Meanwhile it can be seen that the truck traffic is extremely high in the northwest part of Florida.

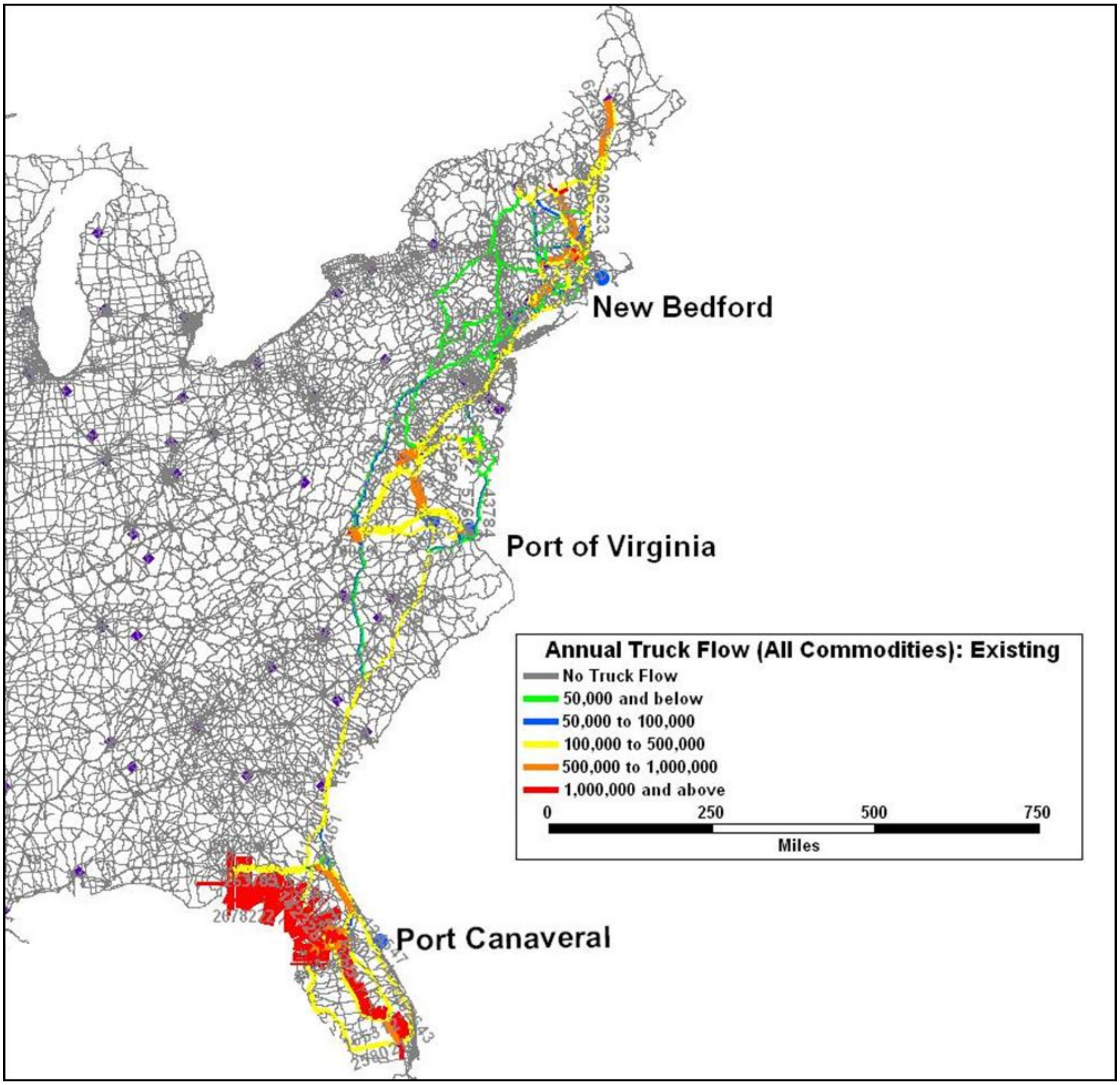


Figure 3-4 Base Truck Flow Volumes

Long Haul Sea Route

Figure 3-5 depicts the changes of truck flows after 30% of truck flows are diverted to the selected ports in the long haul route analysis. The Richmond-Norfolk area freight flow pattern is zoomed in the figure. The results show that the truck flow on I-95 is significantly reduced, represented by the green color in the figure, but the I-64 truck flow to ports undergoes a significant increase because additional freight would be transported to the port through I-64 with diversions.

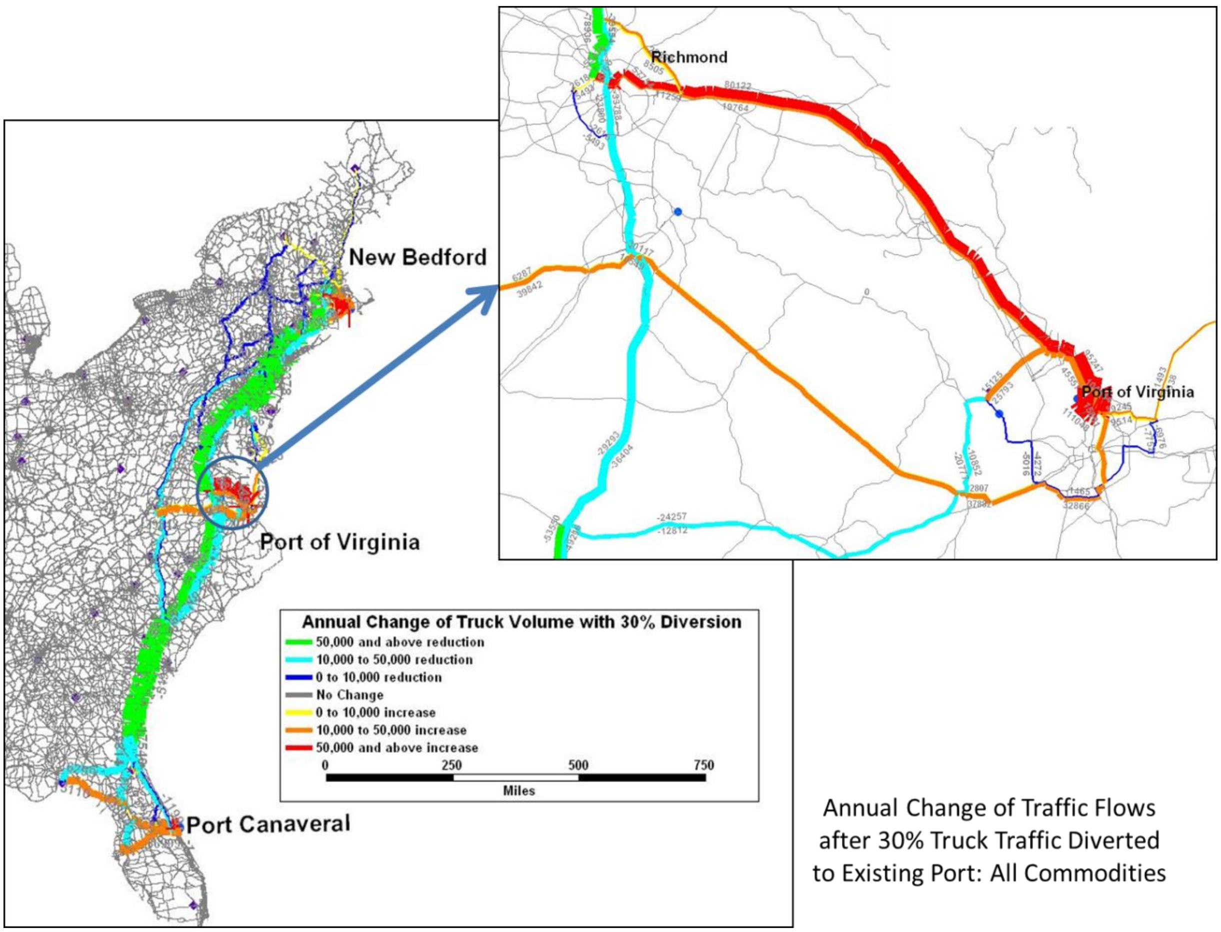


Figure 3-5 Truck Flow Changes with 30% Diversion to the Current Ports

To avoid increasing the traffic on I-64, another option is considered: instead of the current Port of Virginia, the port at Hopewell is used as the alternative. The diverted freight is loaded at Hopewell and transported through Hampton Roads to the Atlantic (Figure 3-6).

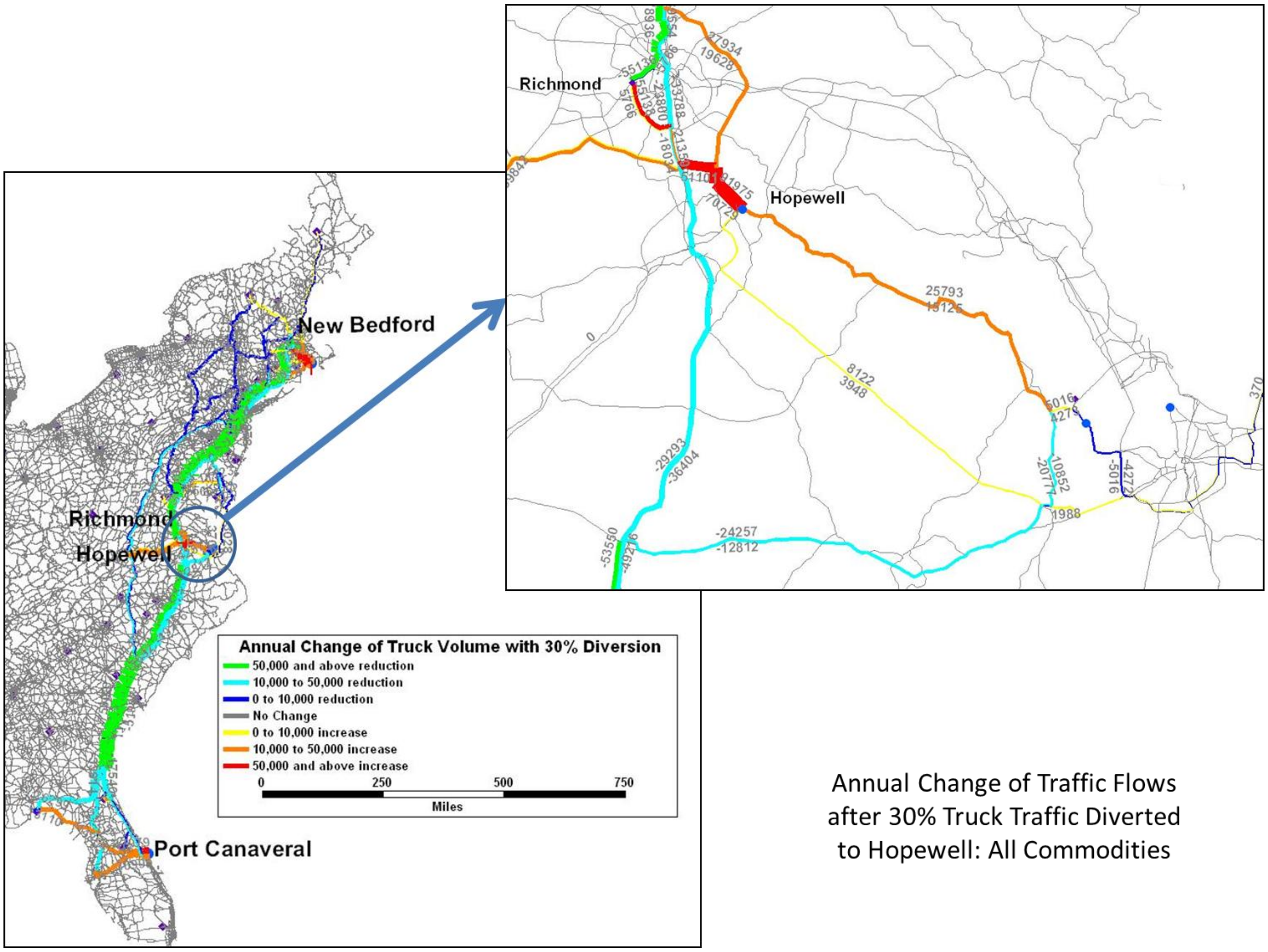


Figure 3-6 Truck Flow Changes with 30% Diversion to the Port at Hopewell

Comparing the option of Hopewell to the existing non-diversion scenario, since the diverted truck traffic is directed to Hopewell, a lot of extra truck traffic is going to Hopewell. The multiple access roads to Hopewell have increased truck volumes, as shown in Figure 3-7. This defines the need for infrastructure planning at the hypothetical Hopewell port to handle the increase in marine highway freight flow. The analysis results therefore serve as an illustration of planning infrastructure expansion at the Port of Hopewell to handle marine highway operations.

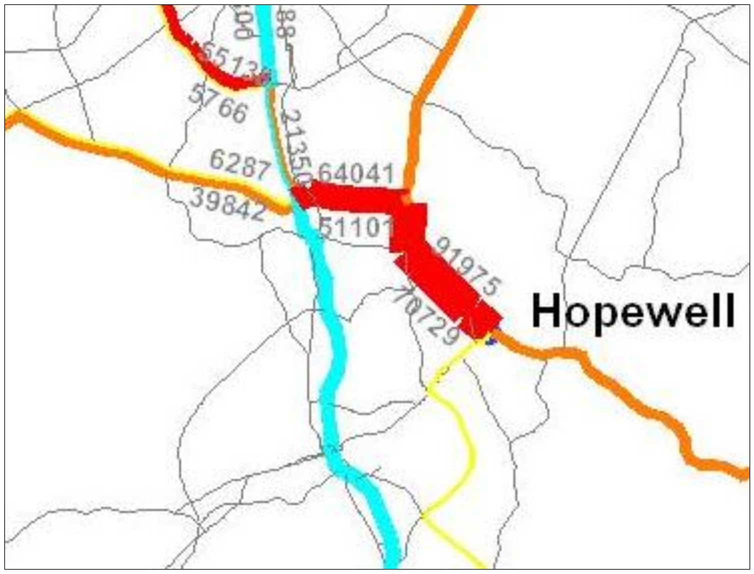


Figure 3-7 Local Truck Flows for Hopewell Example

Table 3-3 lists the specific number of vehicle miles traveled (VMT), and the percentage changes compared to existing conditions with the two options. The tables, as well as the figures, show these two options of diversion have similar influence on I-95. Significant reductions in truck traffic are found: around 15% for VMT. Figure 3-8 compares both options to the existing condition regarding the impacts on I-95.

Meanwhile, the option of Port of Virginia increases traffic on I-64 about 20%, while the option of Hopewell has almost no impact on I-64, only 0.57% reduction for VMT, which happens at the parts of I-64 which are close to the centroid of the Norfolk zone. The reason is that almost all current truck traffic on I-64 has either origin or destination of FAF zone Norfolk, which has the centroid close to Port of Virginia. In other words, there is no “through” traffic on I-64. Therefore, it would actually increase I-64 traffic if the diversion is to the current port, like Table 3-3 shows. Instead, if the freight is diverted to Hopewell, the additional “through” traffic wouldn’t go on I-64, which wouldn’t increase traffic, but the freight between Zone Norfolk and other zones in the same group would still go on it because it’s the best route. Some freight between Norfolk and zones in the other two groups might be diverted to Hopewell.

Table 3-3a Annual Changes of VMT (Diversion to Current Ports)

Corridor	Existing Condition	30% Diversion	
	VMT (Miles)	VMT (Miles)	Percentage Change
I-95	590,011,030	502,020,167	-14.91%
I-64 (Partial)	39,561,648	47,571,287	20.25%

*For I-64, only the segment between Richmond and Port of Virginia is computed

Table 3-3b Changes of VMT (Diversion to Hopewell)

Corridor	Existing Condition	30% Diversion	
	VMT (Miles)	VMT (Miles)	Percentage Change
I-95	590,011,030	503,286,250	-14.70%
I-64 (Partial)	39,561,648	39,336,392	-0.57%

*For I-64, only the segment between Richmond and Port of Virginia is computed

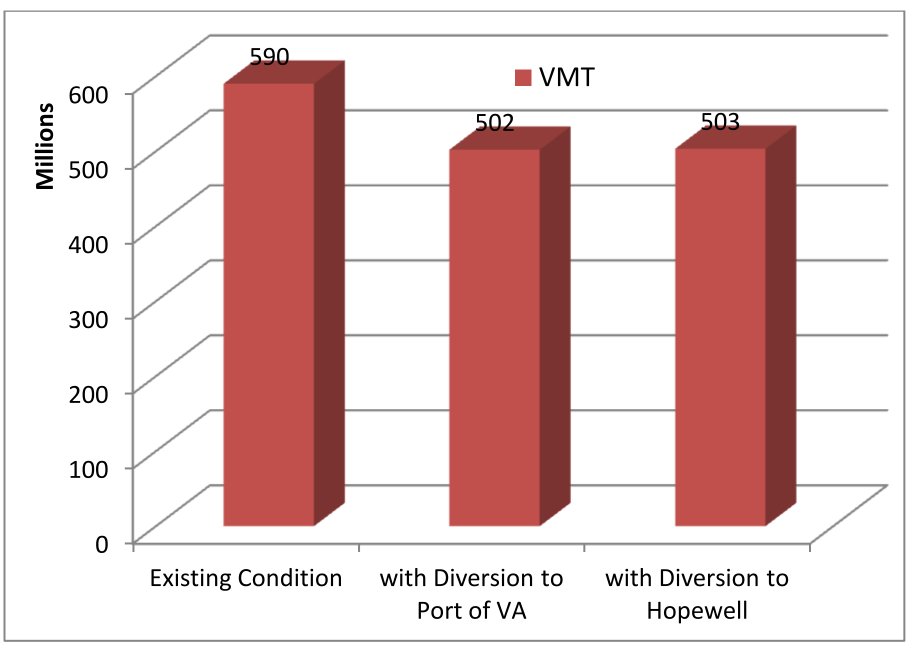


Figure 3-8 Truck VMT for Long Haul Case

Short Haul Inland Route

It can be seen from the analyses in the previous section that the I-64 traffic can't be improved with diverting freight to either Port of Virginia or Hopewell in the long haul transportation case. As shown in Figure 3-9, the diversion to Port of Virginia even worsens the traffic conditions on I-64.

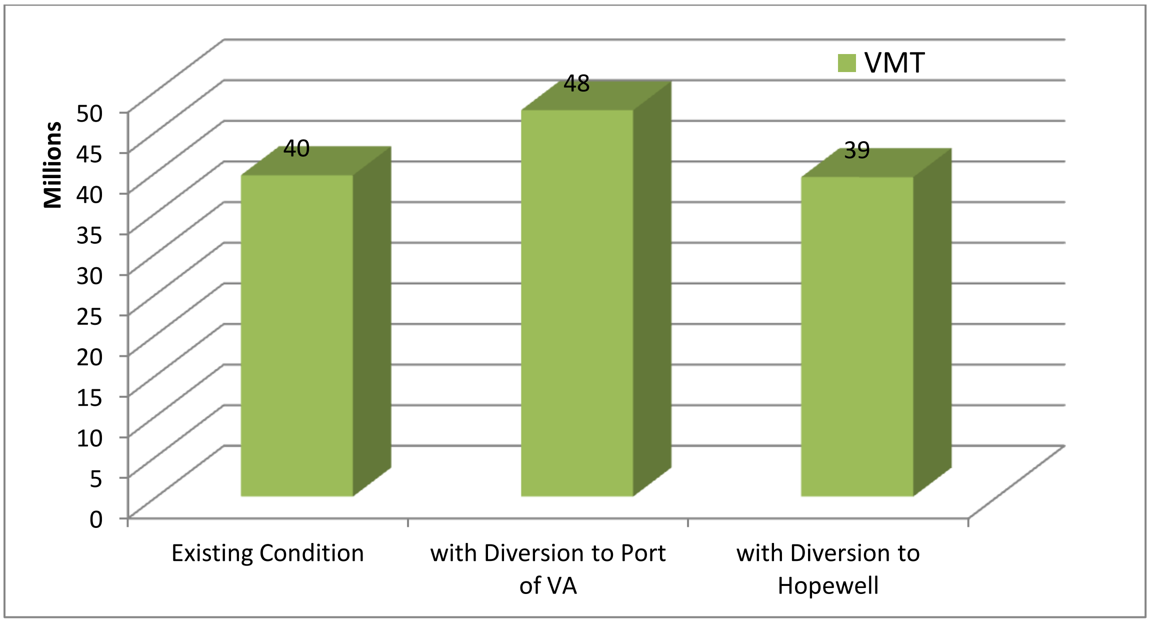


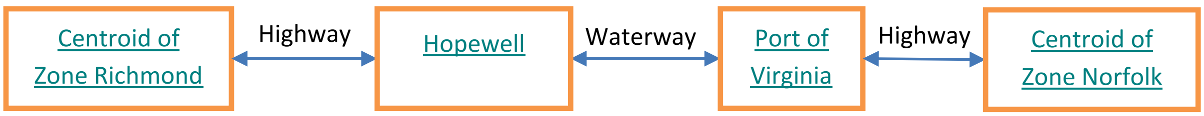
Figure 3-9 Truck VMT for Short Haul Case

As a result, a short haul inland route analysis is conducted, trying to find a way to relieve the congestion on I-64. Examining the freight between Norfolk and other zones in same Mid-Atlantic group, it can be found that the highest portion happens between Richmond and Norfolk, almost half of the total (Table 3-4).

Table 3-4 Truck Flows for Short Haul Case

Origin Zone	Destination Zone	Annual Truck Volume	Percentage	Richmond – Norfolk Total
Richmond VA MSA	**Norfolk**	**249,459**	**24.76%**	**42.62%**
Norfolk	**Richmond VA MSA**	**179,814**	**17.85%**	
Other zones in same group	Norfolk	282,192	28.01	57.38%
Norfolk	Other zones in same group	295,847	29.37	

With the condition that Richmond – Norfolk freight would have great influence on I-64 traffic, it's assumed that 30% truck volumes would be diverted to waterway through the following route:



With this diversion, the traffic on I-64 is reduced significantly (Figure 3-10). For all commodities, there are 53,944 and 74,838 truck reductions annually for two directions, which are 30% of the total truck flow between these two zones. The diversion results about 15% reduction on total I-64 truck traffic, as shown in Table 3-5.

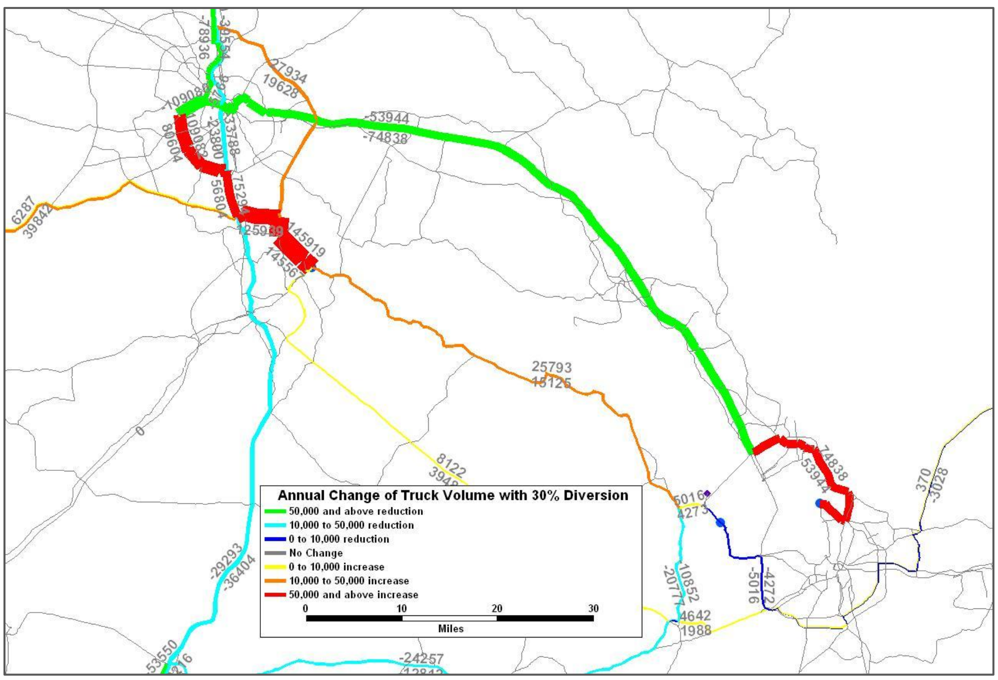


Figure 3-10 Traffic Reduction from Short Haul Analysis

Table 3-5 Traffic Reduction on I-64 for All Commodities

Annual Change of VMT	
Absolute Change (Truck Miles)	-6,283,345
Percentage	-15.88%

HAZMAT Freight Diversion

As a further example an individual analysis for hazardous materials was conducted. This analysis estimates the impacts of diverting hazardous materials only. According to FAF3 database, the following commodities are classified as hazardous materials (HAZMAT):

- Alcoholic beverages
- Crude petroleum
- Gasoline
- Fuel oils
- Basic chemicals
- Fertilizers
- Chemical products

These hazardous materials have various proportions in different areas. For instance, on a road segment shown in Figure3-11, which is on I-95 close to Richmond, VA, there is about 15% HAZMAT within all commodities, based on truck number. (Figure 3-12)

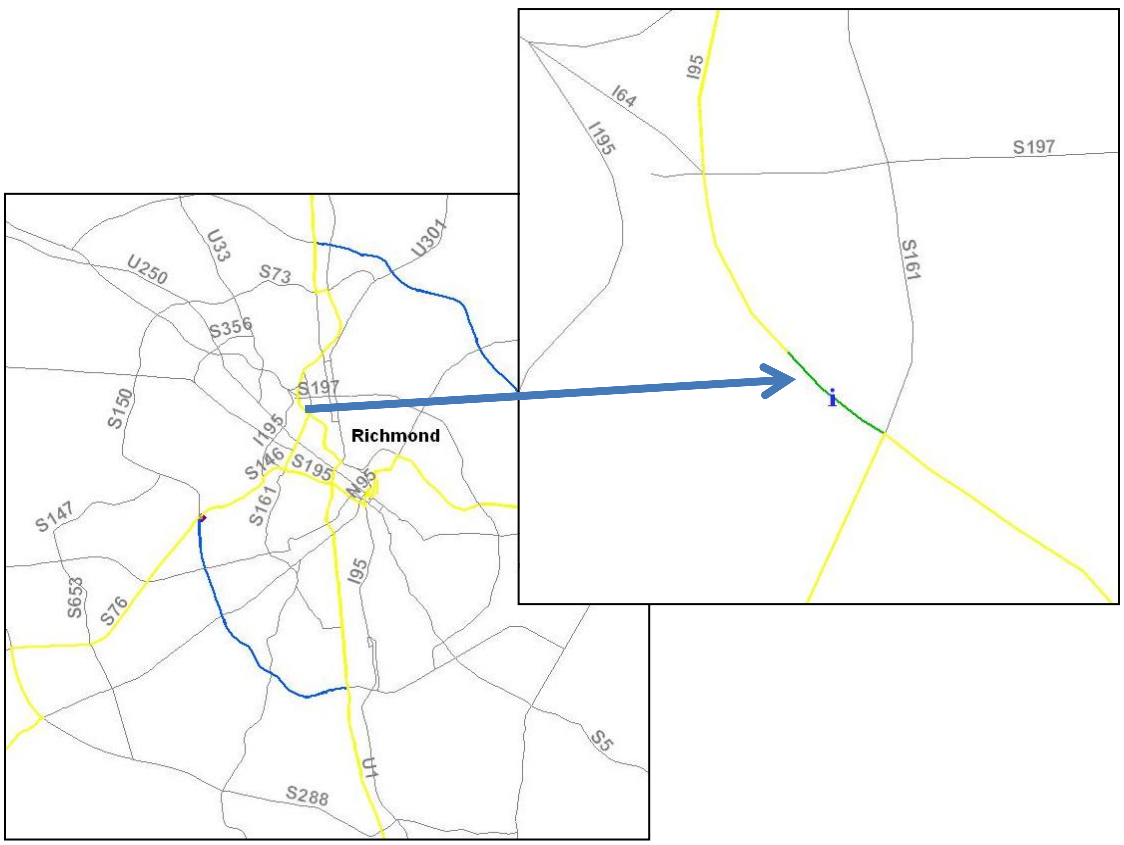


Figure 3-11 Hazardous Material Distribution

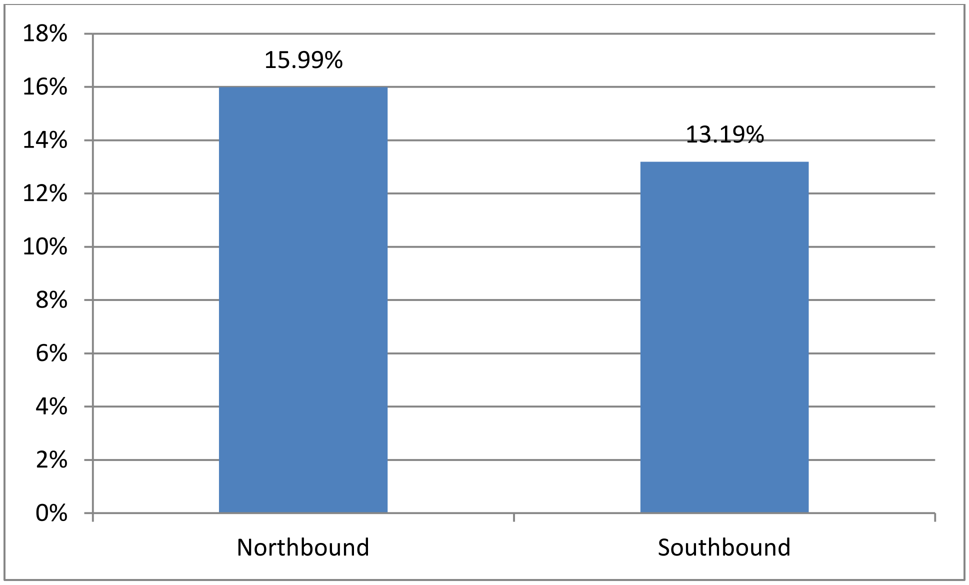


Figure 3-12 Total Flow of Hazardous Materials

It can be further broken down to each HAZMAT commodity. Figure 3-13 shows, for both directions, Alcoholic Beverages have the highest percentages, especially for northbound truck traffic. The next category is Fertilizers. Crude Petroleum and Fuel Oils only have small portions on this part of the highway system.

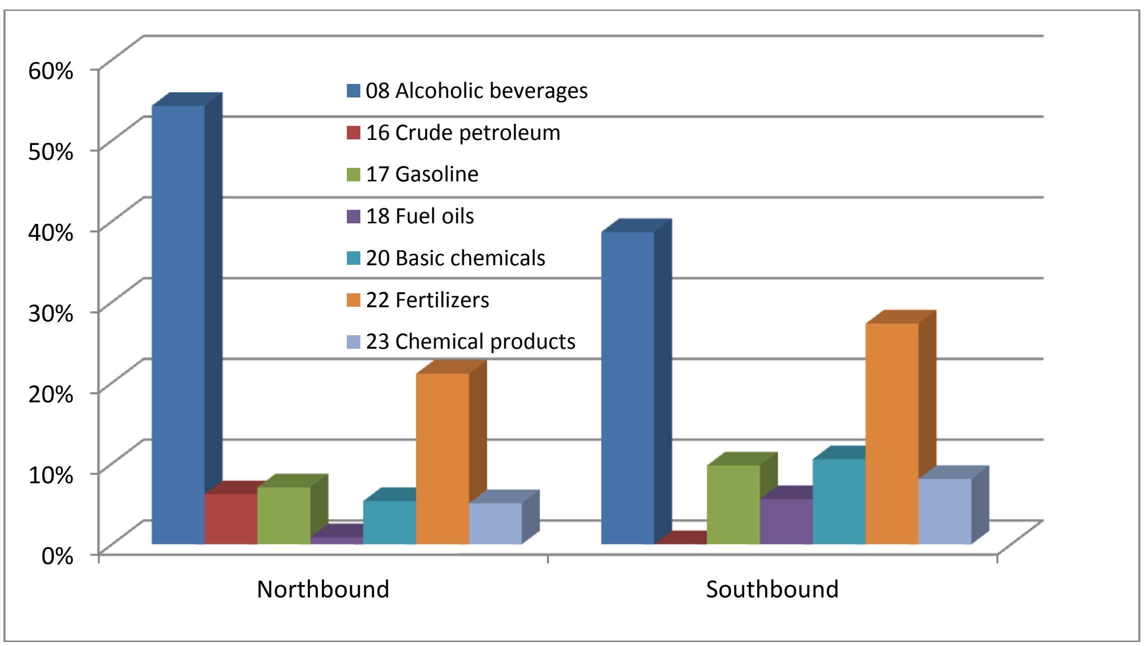


Figure 3-13 Flow of Hazardous Materials

Figure 3-14 shows different proportions of each commodity on some road segments in Massachusetts and Florida.

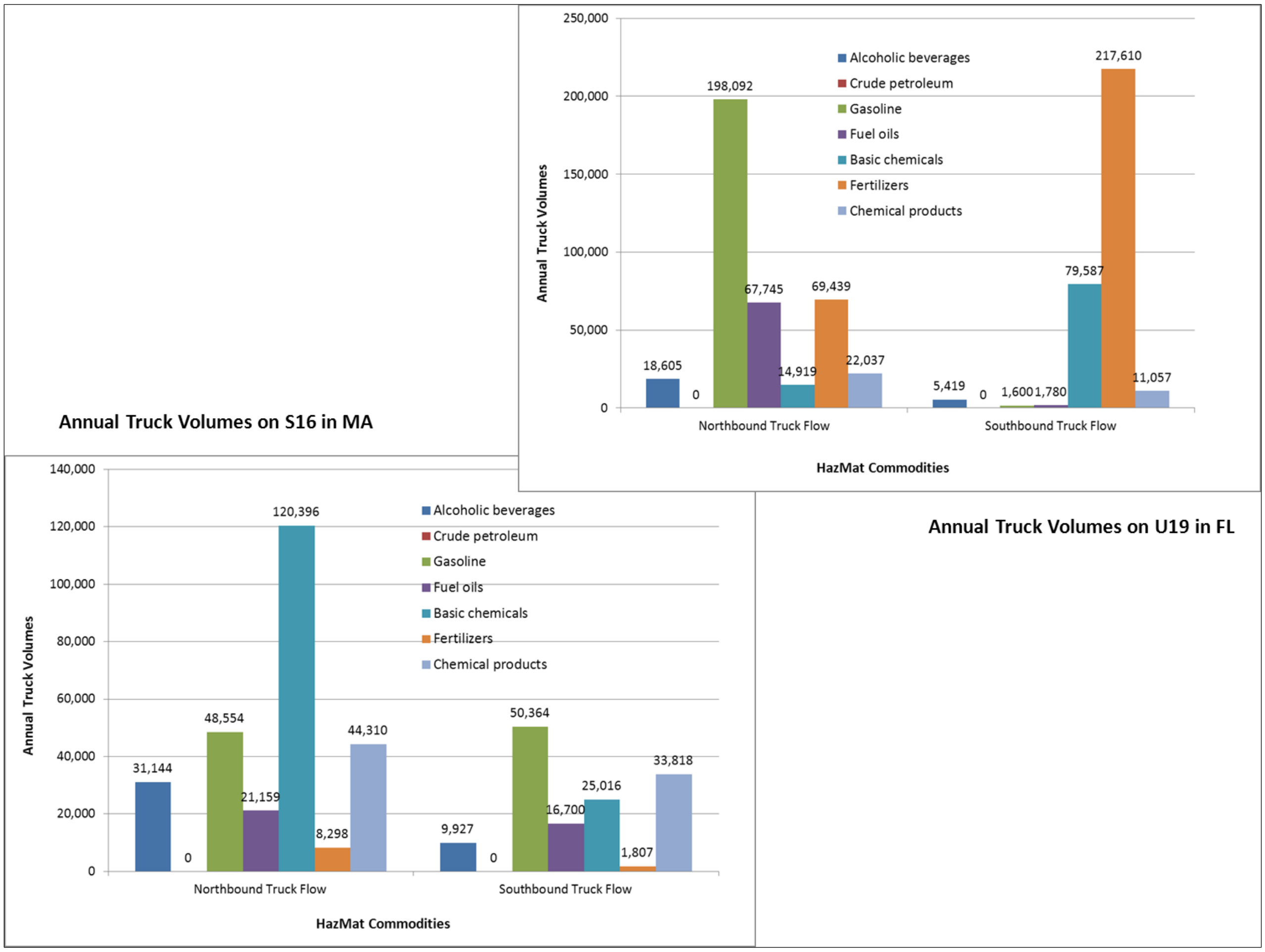


Figure 3-14 Distribution of Hazardous Materials

The methods used for the HAZMAT are similar to that used in previous analyses. It follows the same procedures to develop the matrices, which include only freight of HAZMAT, and uses the same truck network to assign the truck traffic.

The findings in the HAZMAT analysis are very close to those in the previous section. The diversion to the Port of Virginia would cause the traffic increase on I-64, although it's not as much as for all commodities. Great reduction happens on I-95. However, compared to the all-commodities scenario, the degree of reduction is less in the states north of Virginia. Figure 3-15 and Table 3-6 illustrate the results.

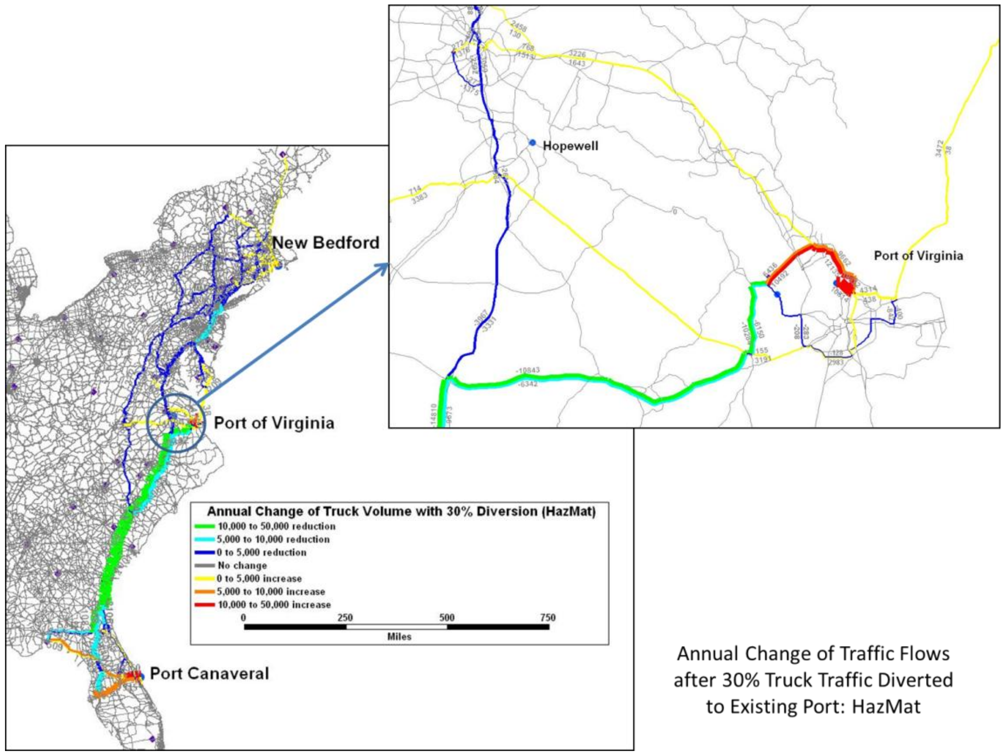


Figure 3-15 Truck Flow Changes with 30% Diversion (HazMat) to the Existing Port

Table 3-6 Annual Changes of VMT (Diversion to Current Ports)

Corridor	Existing Condition	With 30% Diversion	
	VMT (miles)	VMT (miles)	Percentage Change
I-95	100,514,359	86,440,620	-14.00%
I-64 (Partial)	2,025,949	2,578,796	27.29%

*For I-64, only the segment between Richmond and Port of Virginia is computed

Figure 3-16 shows the changes of truck flows after 30% truck flows are diverted to the Port of Hopewell instead of directly passing to the Port of Virginia. The results show again that the diversion reduces the truck traffic on I-95 significantly, since there are no additional truck volumes flowing through I-64. Table 3-7 lists the specific number of truck flows and vehicle miles traveled (VMT), and the percentage changes caused by the diversion compared with existing conditions.

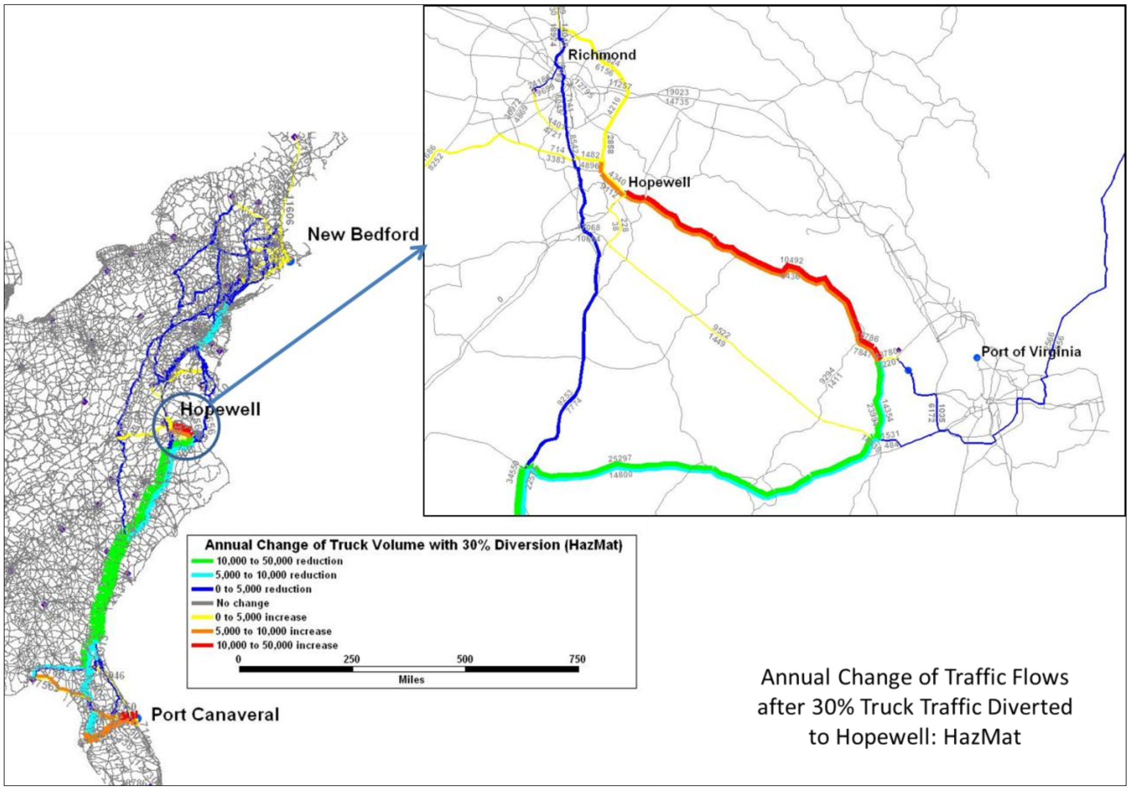


Figure 3-16 Annual Change in Hazmat Traffic Flows

Table 3-7 Changes of HAZMAT VMT (Diversion to Hopewell)

Corridor	Existing Condition	With 30% Diversion	
	VMT (Miles)	VMT (Miles)	Percentage Change
I-95	100,514,359	86,798,598	-13.65%
I-64 (Partial)	2,025,949	2,001,698	-1.20%

*For I-64, only the segment between Richmond and Port of Virginia is computed

The short haul route analysis is also conducted for hazardous materials, which obtains similar and slightly better results (Figure 3-17, Table 3-9). The reduction in truck VMT is about 17%, which may be because for HAZMAT, Richmond – Norfolk freight has a slightly bigger portion of the total, as shown in Table 3-8.

Table 3-8 Diversion of Hazmat Freight for Short Haul Case

Origin Zone	Destination Zone	Annual Truck Volume	Percentage	Richmond - Norfolk Total
Richmond VA MSA	**Norfolk**	**12,795**	**25.32%**	**47.60%**
Norfolk	**Richmond VA MSA**	**11,257**	**22.28%**	
Other zones in same group	Norfolk	3,723	7.37%	52.4%
Norfolk	Other zones in same group	22,750	45.03%	

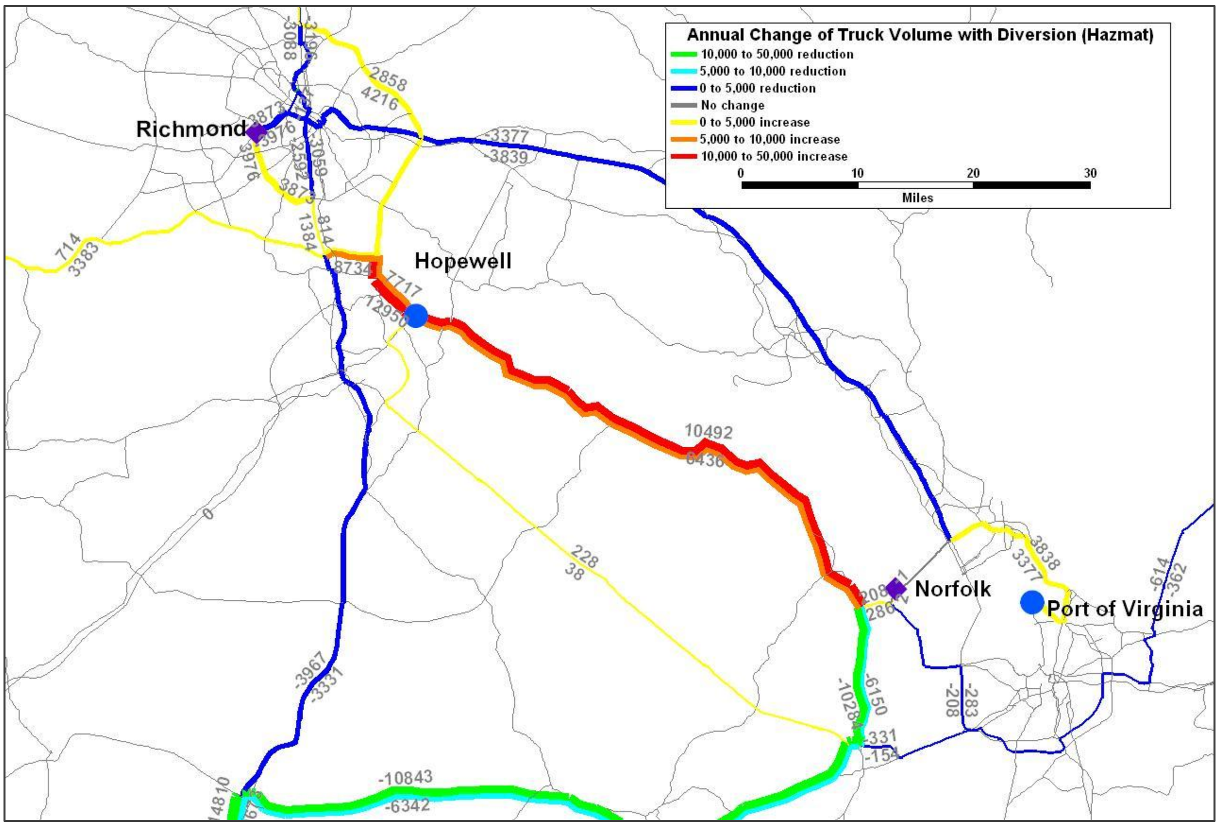


Figure 3-17 Annual Change of Truck Volume with Diversion (HAZMAT)

Table 3-9 Traffic Reduction for HAZMAT

Corridor	Existing Condition	With 30% Diversion	
	VMT (miles)	VMT (miles)	Percentage Change
I-64 (Partial)	2,025,949	1,662,236	-17.95%

*For I-64, only the segment between Richmond and Port of Virginia is computed

4. WATERWAY MODELING

4.1 Introduction to Model

A modeling method for this analysis was developed using ExtendSim 8 Discrete Event Simulation (DES) software. The resultant modeling toolkit is a flexible and scalable system for estimating the logistics, costs, environmental effects, and economics of routes involving marine highways. The toolkit consists of scalable building blocks that model different processes common to Marine Highways (MH). Because Marine Highway operations vary, the toolset allows the user to model the Marine Highway process by varying the selection and sequence of the individual building blocks depending on the level of information available. The operational attributes assigned for each building block are easily changed without the need to understand a building block's internal logic.

This type of modeling can show the impact of random events that may affect a shipping operation. DES modeling permits highly accurate analysis of specific alternatives and use of optimization routines that identify a system's bottlenecks. The model will include blocks of various complexities to model both a first round approach to test the feasibility of a Marine Highway business or to model a shipping route's timing, costs and bottlenecks with detailed data. This DES modeling toolkit can also help the user improve an operation's performance using optimization functionality.

A "marine highway" consists of both marine and highway components in its approach to moving cargo from an origin to a final destination. Figure 4-1 depicts the general elements needed to address the comparison of a traditional highway approach with that of a marine highway approach. Modeling the highway-only system involves analysis of the cargo movement from its origin to its destination using data or estimates of various characteristics of the transportation technology and infrastructure. Various measures such as cost, time to deliver, environmental impacts, and others of interest are then evaluated with the model by varying the various parameters present to account for expectations of delay from weather, congestion, and other factors. For the marine highway approach there are the highway modeling aspects with the addition of the logistics of transferring the cargo to and from marine vehicles for the marine

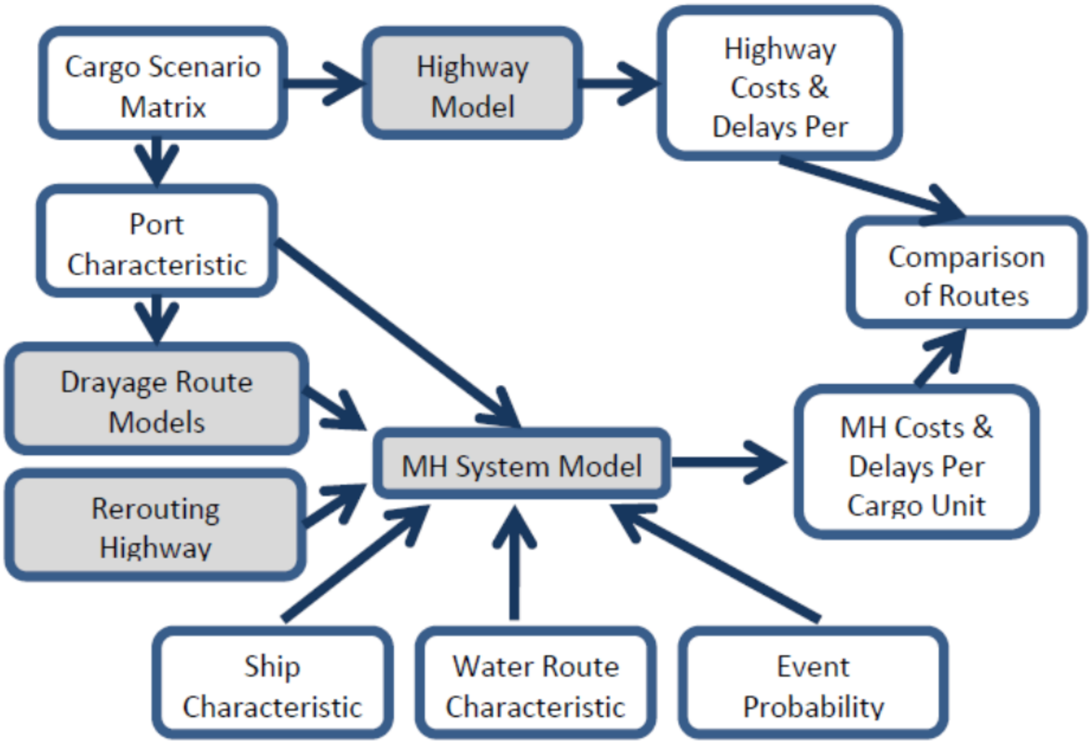


Figure 4-1 Comparison of Modeling of Highway Only vs. a Marine Highway Approach

transit portions involved. In both systems the expectations for the cargo flows in both directions is critical to the economics. Highly-reliable, on time deliveries are also critical in today's just-in-time freight movements which involve minimal warehouse resources. Modeling of all of these elements needs to be addressed to properly compare the marine highway with the highway-only approach.

The results of the Marine Highway system can then be compared to the trucking alternative. The model will output the following variables for each piece of cargo which can be directly compared to a trucking route:

- Time to transport cargo
  - This is the total movement time associated with a piece of cargo using a Marine Highway. This includes drayage times, time spent at a port and time spent at sea.

- Operating cost

  - This is the cost associated with using the trucking, port and ship/barge services. These costs can be applied as a fixed amount per each process or as a time dependent amount per each process. Fuel cost is tracked separately.
- Fuel Cost
  - This is the cost associated with fuel for both the ship and trucking operations. Fuel price is a global variable that may vary during the operation.
- Air emissions
  - This is a standardized dollar amount for carbon, sulfur and particulate emissions for both the trucking and ship operations.
- Roadway congestion reduction
  - For each stage of the journey that cargo uses a ship operation, it reduces roadway congestion. The congestion is monetized per cargo unit.
- Road maintenance cost reduction
  - Heavy cargo significantly increases road-wear. Each part of the journey that is taken by marine highway road will reduce the cost of road maintenance.
- Noise pollution reduction
  - Noise reduction cost from trucks is tracked per cargo unit.
- Accident rate reduction
  - A reduction in traffic corresponds to a reduction in accidents. The accident reduction rate is tracked per container.

4.2 Deliverable Goals

This project's goal was to deliver three models: a Short Route validation model, a Long Route validation model, and a two port MS Excel driven model.

The Short Route model simulates the I-64 Express barge operation that transports cargo between the Port of Richmond and the Port of Virginia. The delivered model is an MS Excel driven model that simulates this route specifically. This model uses three ports and does not use drayage at the Norfolk area ports. In addition, this model contains extra logic to model the James River current that has a large economic impact on this MH system.

The Long Route model models the route between Port Canaveral in Florida, Norfolk and New Bedford, MA. This route assumes that drayage occurs at each port. This model is throughput driven (not schedule driven). The model uses the same logic as the three-port generic model.

Additionally, a two-port model that can be used to test potential routes was developed. This model includes schedule driven ship logic and assumes that drayage occurs at both ports. The purpose of this model is to validate a simple two port route and explore if a more detailed analysis is necessary.

4.3 Model Functionality

The model is designed to be scalable for any MH system. This means that blocks can model different physical routes as well as modeling different sequences of ports and travel blocks. For instance the Waterway Travel block can handle a 5 NM route as well as a 200 NM route. In addition, if different conditions apply to segments of a longer waterway route, multiple waterway routes may be connected in series to simulate that route.

Many of the inputs allow for stochastic inputs. This model uses a triangular distribution input of minimums, maximums and most likely values. The performance of this distribution is similar to a normal distribution but allows for results to be “skewed” around the most likely value. Unlike a normal distribution, there is no possibility of outlying values. Note that the most likely value is the mode; the mean can be determined by summing the minimum, maximum, most likely value and dividing by three (3).

The system is created in a way to facilitate scheduled departures from a port or “Not In Use” block. The “Not In Use” block is a object where a ship can rest and not accumulate costs. This is useful in operations where a barge is used for a MH system but is only used for the operation for a few days each week. The schedule function controls when the barge will be released.

Failures and unexpected costs may have a large negative impact on a MH system. The model addresses this with a “Probability of Events” functionality. At every block, there is a loop that may have a specified amount of chance happenings. Each of these events may only happen within a certain amount of time and this period may be repeated. For instance, this functionality can model a water route’s cancellation due to weather that may happen 10% of the time but only in the spring months.

In addition, the model permits the option of cargo rerouting. This functionality is necessary for the cargo to arrive on time if a ship is cancelled or full. This is done by assigning a deadline for the cargo to arrive at a destination. If the model believes that it cannot use a waterway route for the cargo, it will send the cargo to its destination by truck.

4.4 Block Descriptions

Cargo Manager

The Cargo Manager block is the object that creates and destroys cargo unit items. The block assigns attributes and initialized dynamic variables to each cargo unit. In addition, it specifies the rate and distribution at which the cargo is introduced into the system.

User Input Cargo Unit Attributes:

- Destination
  - Each port has a designated identification number with a corresponding drayage path. The destination attribute specifies which area is the final destination of the cargo. This is necessary for a MH system with more than two ports.
- Container Full Check
  - In some cases it is necessary to track empty containers. The Container Full Check attribute allows the user to see how empty containers affect the economics of a Marine Highway.
- Delivery Deadline
  - Each cargo unit is assigned a deadline by which it needs to arrive at its destination. The Delivery Deadline attribute is specified in days.

Ship Manager

Ship attributes and dynamic variables are initiated in the Ship Manager block. This block specifies the number of ships and the time when they are introduced to the Marine Highway. This block is designed to facilitate LO-LO and RO-RO ships, and tug/barges.

User Input Ship Attributes

- Cruising Speed

- The speed in knots of the ship. This is designated by a triangular distribution specifying the minimum, mode, and maximum.

- Cruising Speed Fuel Burn Rate
    - The rate of fuel burned when at cruising speed in gallons per hour. This is designated by a triangular distribution (minimum, mode, and maximum).
- Idle Fuel Burn Rate
    - The rate of fuel burned when ship is idling in gallons per hour. This occurs when the ship is being loaded and unloaded. This attribute is designated by a triangular distribution (minimum, mode, and maximum).
- Maximum Cargo Capacity
    - Maximum amount of cargo units that can be loaded on the ship/barge.
- Secure to Pier Time
    - The time needed to secure the ship to a pier in hours.
- Cast Off Time
    - Time necessary for ship to cast off from pier in hours.

Roadway Travel

The Roadway Travel block allows the user to specify all of the attributes necessary for a road distance, including the fixed and time dependant costs associated with roadway travel.

Basic Roadway Travel User Inputs:

- Distance
    - Roadway distance in miles.
- Travel Speed
    - Speed in miles per hour. This attribute is designated by a triangular distribution (minimum, mode, and maximum).
- Fuel Burned Calculation Method
    - The fuel burned can be input as either a miles per gallon calculation or as a fixed amount.
    - The miles per gallon input is designated by a triangular distribution (minimum, mode, and maximum).

- The following attributes are specified with a fixed and time dependant cost:
  - Operation Cost
  - Air emissions
  - Roadway Congestion
  - Road maintenance
  - Noise pollution
  - Accident rate

Waterway Travel

The ship journey is modeled with a Waterway Travel block. The block tracks the transit time associated with the marine journey. The block is able to model current that the ship may encounter that may affect the travel time and costs. The current is input into a table with the assumed current at the beginning of the simulation. The current is interpolated based on the time the ship travels the leg of the journey and the 28 day phasing of current.

Waterway Travel User Inputs:

- Distance
  - The distance over water measured in nautical miles.
- Current Influence
  - The speed of the current in knots at the beginning of the simulation. This current has to be oriented in the appropriate direction.

Port Block

The Port block's main function is to simulate the marrying of cargo with ships. This block's architecture accommodates a varying amounts of area used for pier loading and cargo staging. This block also dictates the schedule at which the ships will leave port. The Port block contains logic to simulate intermediate ports or transfer points and the return of trucks. In addition, the block contains logic for when the ship sailing is cancelled and cargo needs to be rerouted by truck.

Port User Inputs:

- Port ID
    - Identification number for each port. This ID is used to make sure that cargo goes to its specified port.
- Arriving Cargo Cost
    - This is a fixed and time dependent cost associated with the transfer of cargo from a ship.
- Departing Cargo Cost
    - This is a fixed and time dependent cost associated with the transfer of cargo onto a ship.
- Ship Cost
- Rerouted Cargo Cost
- Release Schedule

Not In Use Block

This block is a storage area for a ship when it is not in a Marine Highway route. This block is controlled by schedule architecture. The typical areas to include this block are at the ends of a trip. This is where the ship can lay up or be prepared for the next sailing.

Other Events

Additionally, the block contains a Probability of Events calculator. This functionality checks the probability of certain events occurring before a ship sailing. It can add costs or cancel the trip for up to ten (10) different probabilities. Additionally, it has a parameter that checks which days of the year the event may happen. For example, this functionality is used to track sailing cancellations due to fog in Spring and Fall.

Model Validation

The model was validated with two methods. The first method was that each functionality and block was tested in an isolated environment to ensure that it generated expected results. Blocks were individually tested by using scalar value inputs and checking them against expected results. In addition, there were two ExtendSim developers checking block functionality to make sure the logic flow was appropriate.

In addition, the Short Route is used as a validation of the model as a whole. According to the I-64 Express operator, the operating and fuel cost per container using a tug/barge is under $300 while the barge is operating around 64% full (This cost excludes drayage around the Richmond area). This compares to a model derived barge cost of $255.59 when the barge is 59% full.

4.5 Guideline for Using Tool

The models provided all use the same basic architecture. Each model is composed of ExtendSim 8 and Excel components. The ExtendSim model is locked and controls the execution of the model while the Excel workbook can be edited by the user and contains the model inputs. The free runtime software for ExtendSim can be downloaded from the following link:

http://www.extendsim.com/prods_demo.html.

It is necessary to install this software before a simulation can be run.

Each model contains two parts: the ExtendSim *.mox run file and the Excel *.xls input file. All of the inputs are controlled from the Excel file except the duration of the simulation and number of runs. These inputs are controlled from Run > Simulation Setup. The default time unit of all models is in days; this means that day 1.25 indicates a time of 1 day 6 hours after the start of the simulation. In order to run the simulation, the user should select Run > Run Simulation from ExtendSim. (Note: the Excel and ExtendSim files *must* be in the same folder).

With the exception of the "64 Express" model, the provided models architecturally only vary the number of ports present. The 64 Express model has additional functionality corresponding to optimizing ship release and modeling river current.

The models contain horizontal item flow which corresponds to ship travel and vertical item flow that corresponds to drayage travel (Figure 4-2). Waterway Travel blocks control the horizontal movement while Roadway Travel blocks control vertical movement. Port blocks are the intersection of water and road travel and therefore control both directions of movement.

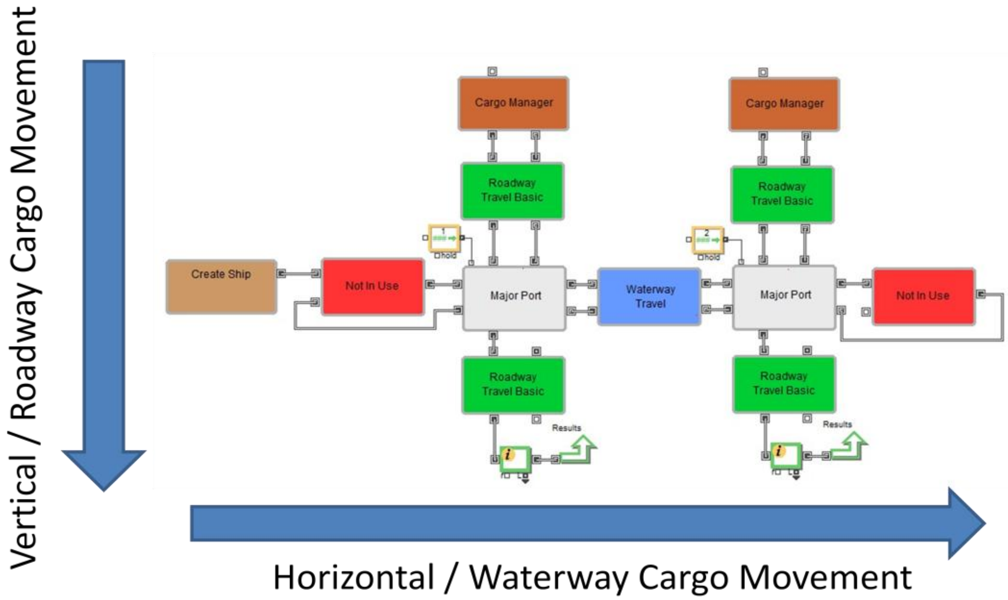


Figure 4-2 Illustration of Horizontal (Ship Flow) and Vertical (Drayage) Movement Organization of the Model

Horizontal item flow starts with a Ship Creation block. This block defines ships' characteristics and is always connected to a Not In Use block. Not In Use blocks frame the port travel by rerouting the ship in the other direction, and setting periods of time when the ship is used for purposes other than Marine Highway shipping or is idle. This is particularly useful for Marine Highway operations that use tug barges that run infrequently.

The model contains fuel prices in the "General" tab for the spreadsheet. It is important to note that the price of ship and truck fuel may vary.

When starting a model, the first inputs should be defining the number of ships (5 maximum) and ship capabilities in the "Ship Manager" sheet. This sheet allows the user to define the ships' speed, fuel, loading, and unloading characteristics. It also defines the maximum number of cargo units that can fit on the ship. The model is restricted on only one type of cargo "unit" which must remain constant throughout the model. For example, the ship input cannot have a cargo capacity based on TEUs while the truck inputs are based on 53-foot containers.

The second step is to input the appropriate data in the NotInUse tabs. NotInUse1 and NotInUse2 control the weekly release of each ship. The Open time is the specified earliest time when a ship can leave the Not In Use waiting area and the Close time is the last possible time. The time slot when a ship can leave is repeated on a weekly cycle (opening and closing times must be less than 7). Each ship has separately specified opening and closing times.

The NotInUse1 tab contains a Probability of Events section. The model is capable of modeling up to ten events that have a random occurrence chance. The user must indicate how many events may occur (max 10). Then the user must specify the interval time minimum and maximum of when the event occurs and the repeat cycle (maximum interval time must be less than repeat time). For that event, the user must specify the likelihood of the event happening as an event of 0 to 1 probability. If the event happens, the associated cost is added to the ship; or if the "Cancel Route" binary is set to 1, the trip is cancelled. For example, if the user wants to model a 20% probability of cancellation of a trip due to fog between the months February and April with an added cost of $3000, the inputs should be as shown in Table 4-1:

Table 4-1 Example Cancellation Model Inputs

Input Name	Value
Interval Min	31
Interval Max	120
Repeat Time	365
Probability	0.2
Operating Cost Base	3000

This assumes that the model begins on midnight of January 1st of a 365 day year. All other probability inputs are set to 0. The time domain based inputs will multiply the cost of the ship waiting by a factor of units per day.

The next step is to specify the inputs associated with each port. The costs in this spreadsheet specify the costs for the ship and cargo that are in the port. Arriving and departing cargo costs.

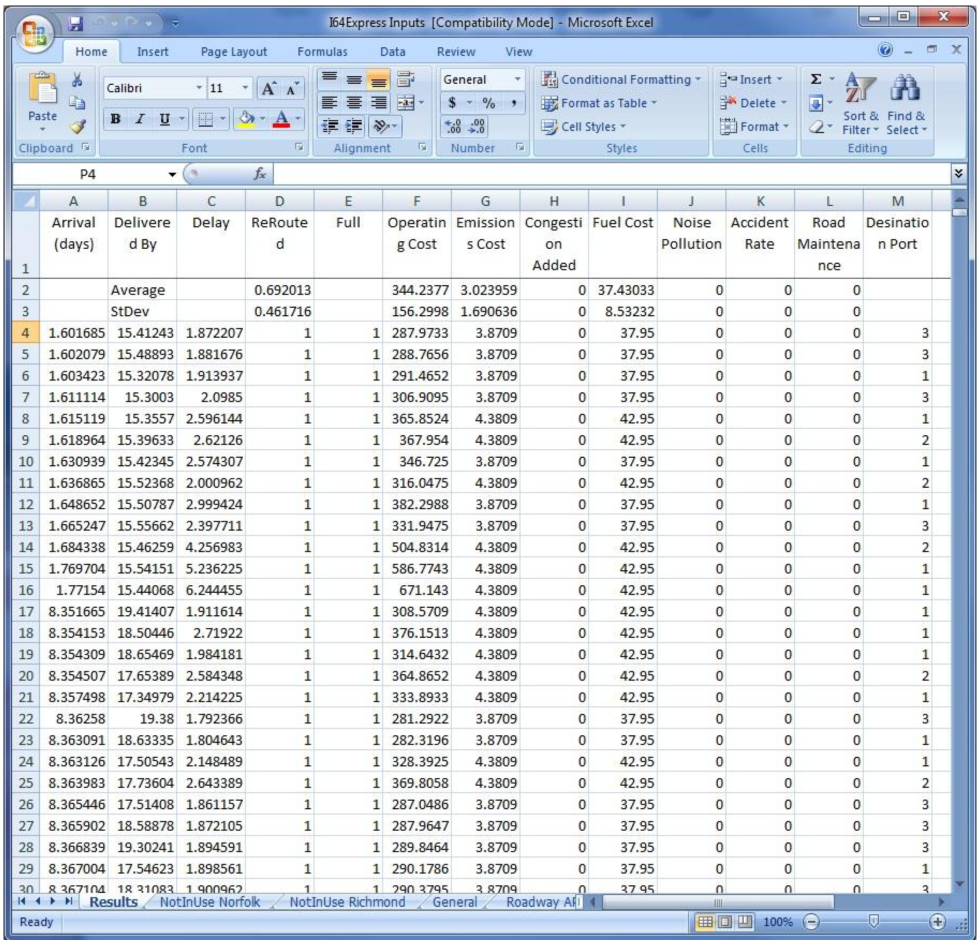
are dependent on the fees necessary to move the cargo on/off the ship and the time the cargo spends waiting at port. The arriving and departing ship costs add an operating cost to the ship which is distributed among the ship's cargo. The departing ship cost is only added to the cargo that is loaded at the port or stays on the vessel. The rerouted costs and delays are only applied to the cargo if cargo is rerouted.

The final step in the horizontal movement is to identify the marine route characteristics in the Waterway Route blocks. This block allows the user to specify the water distance and whether the ship travels at a fixed speed or its organic cruising speed. Additionally, the block allows the user to input various cargo or ship based variables. These variables can track things such as reduced congestion or road maintenance for each piece of cargo not present on the roadway system.

The vertical flow of cargo is initiated by the Cargo Manager (CM) block. Each CM block specifies the stochastic distribution of cargo creation. This distribution is controlled by a triangular distribution of the expected time interval at which cargo appears. The CM block additionally controls the daily and weekly time of operations; this allows the user to specify the working hours of when cargo might become available. Additionally, the CM block specifies the destination port number and the maximum time allowed before cargo needs to be at its destination.

Lastly, the user must specify the roadway characteristics. These roadway characteristics specify the road attributes themselves (i.e., distance, maximum speed) and the truck characteristics (i.e., operating cost, emissions cost). All of the roadway inputs are based on linear functions dependant on time or miles. It is important to note that these blocks assume that the characteristics are identical in both directions. Additionally, the roadway blocks above the port blocks model drayage characteristics, while the roadway blocks below the ports designate truck rerouting.

Once all of the appropriate inputs are saved in the MS Excel workbook, the model is executed in ExtendSim by clicking Run>Run Simulation. The simulation will then execute one iteration and the output will appear in the Results sheet of the workbook (see Figure 4-3). All of the inputs must have an input or ‘0’ entered; if any inputs are left blank, the model will not execute. Figure should be viewed as an example of a results output. The inputs for this example were not created to track noise pollution, accident rate, congestion added and road maintenance. A detailed description of the result attributes possible can be found in the introduction to the Marine Highway DES model.



	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Arrival (days)	Delivered By	Delay	ReRouted	Full	Operating Cost	Emissions Cost	Congestion Added	Fuel Cost	Noise Pollution	Accident Rate	Road Maintenance	Desination Port
2		Average		0.692013		344.2377	3.023959	0	37.43033	0	0	0	
3		StDev		0.461716		156.2998	1.690636	0	8.53232	0	0	0	
4	1.601685	15.41243	1.872207	1	1	287.9733	3.8709	0	37.95	0	0	0	3
5	1.602079	15.48893	1.881676	1	1	288.7656	3.8709	0	37.95	0	0	0	3
6	1.603423	15.32078	1.913937	1	1	291.4652	3.8709	0	37.95	0	0	0	1
7	1.611114	15.3003	2.0985	1	1	306.9095	3.8709	0	37.95	0	0	0	3
8	1.615119	15.3557	2.596144	1	1	365.8524	4.3809	0	42.95	0	0	0	1
9	1.618964	15.39633	2.62126	1	1	367.954	4.3809	0	42.95	0	0	0	2
10	1.630939	15.42345	2.574307	1	1	346.725	3.8709	0	37.95	0	0	0	1
11	1.636865	15.52368	2.000962	1	1	316.0475	4.3809	0	42.95	0	0	0	2
12	1.648652	15.50787	2.999424	1	1	382.2988	3.8709	0	37.95	0	0	0	1
13	1.665247	15.55662	2.397711	1	1	331.9475	3.8709	0	37.95	0	0	0	3
14	1.684338	15.46259	4.256983	1	1	504.8314	4.3809	0	42.95	0	0	0	2
15	1.769704	15.54151	5.236225	1	1	586.7743	4.3809	0	42.95	0	0	0	1
16	1.77154	15.44068	6.244455	1	1	671.143	4.3809	0	42.95	0	0	0	1
17	8.351665	19.41407	1.911614	1	1	308.5709	4.3809	0	42.95	0	0	0	1
18	8.354153	18.50446	2.71922	1	1	376.1513	4.3809	0	42.95	0	0	0	1
19	8.354309	18.65469	1.984181	1	1	314.6432	4.3809	0	42.95	0	0	0	1
20	8.354507	17.65389	2.584348	1	1	364.8652	4.3809	0	42.95	0	0	0	2
21	8.357498	17.34979	2.214225	1	1	333.8933	4.3809	0	42.95	0	0	0	1
22	8.36258	19.38	1.792366	1	1	281.2922	3.8709	0	37.95	0	0	0	3
23	8.363091	18.63335	1.804643	1	1	282.3196	3.8709	0	37.95	0	0	0	1
24	8.363126	17.50543	2.148489	1	1	328.3925	4.3809	0	42.95	0	0	0	1
25	8.363983	17.73604	2.643389	1	1	369.8058	4.3809	0	42.95	0	0	0	2
26	8.365446	17.51408	1.861157	1	1	287.0486	3.8709	0	37.95	0	0	0	3
27	8.365902	18.58878	1.872105	1	1	287.9647	3.8709	0	37.95	0	0	0	3
28	8.366839	19.30241	1.894591	1	1	289.8464	3.8709	0	37.95	0	0	0	3
29	8.367004	17.54623	1.898561	1	1	290.1786	3.8709	0	37.95	0	0	0	1
30	8.367104	18.31083	1.900962	1	1	290.3795	3.8709	0	37.95	0	0	0	3

Figure 4-3 Spreadsheet Providing Output from Iteration

When the simulation is finished, it will output a line item for each cargo unit delivered to its destination. Each attribute tracked by the model is summarized with a mean and standard deviation.

4.6 Short Route Analysis

Short Route Model and Inputs

The Short Route model simulates the I-64 Express barge operation that transports cargo between the Port of Richmond and the Port of Virginia (Figure 4-4). This model has some unique features that are not incorporated in the generic model. The most significant revision is that the ship release is not entirely controlled by schedule. The ship sailing time is optimized to be released when the current on the James River is optimal for sailing. In addition, the ship sailing may be cancelled if there are not enough cargo units available. If sailing is cancelled, the cargo is transported by truck.

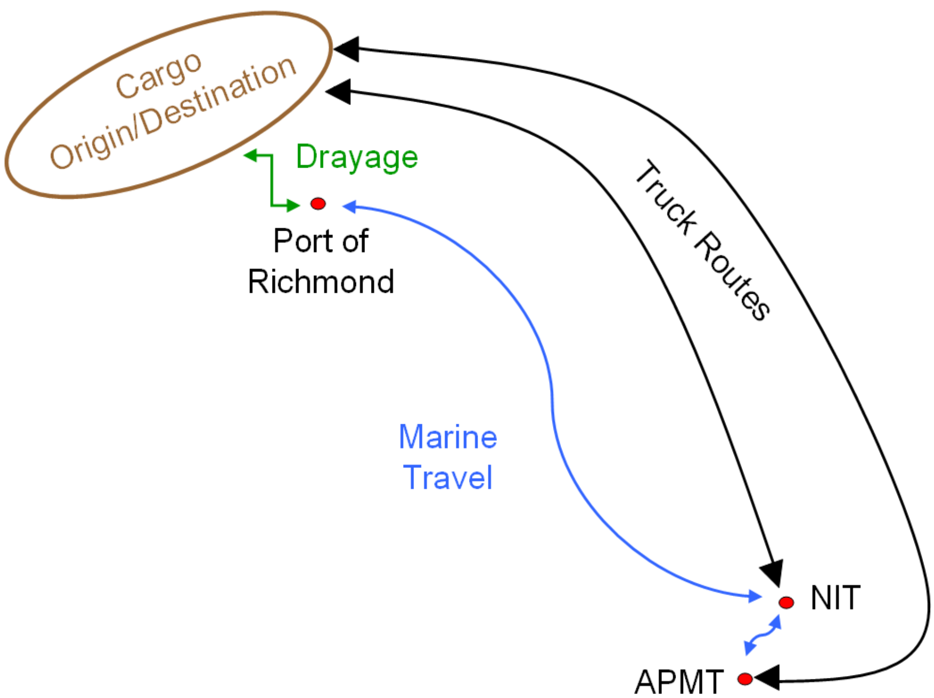


Figure 4-4 Short Route Comparative Modeling Approach

Figure 4-5 shows the ExtendSim model used to represents the I-64 Express. This image shows the interaction of the blocks as they relate to this scenario and approach based on a macro analysis of historic freight flows.

The fuel cost for this model was set at $3.00/gal for marine fuel and $4.00/gal for truck fuel.

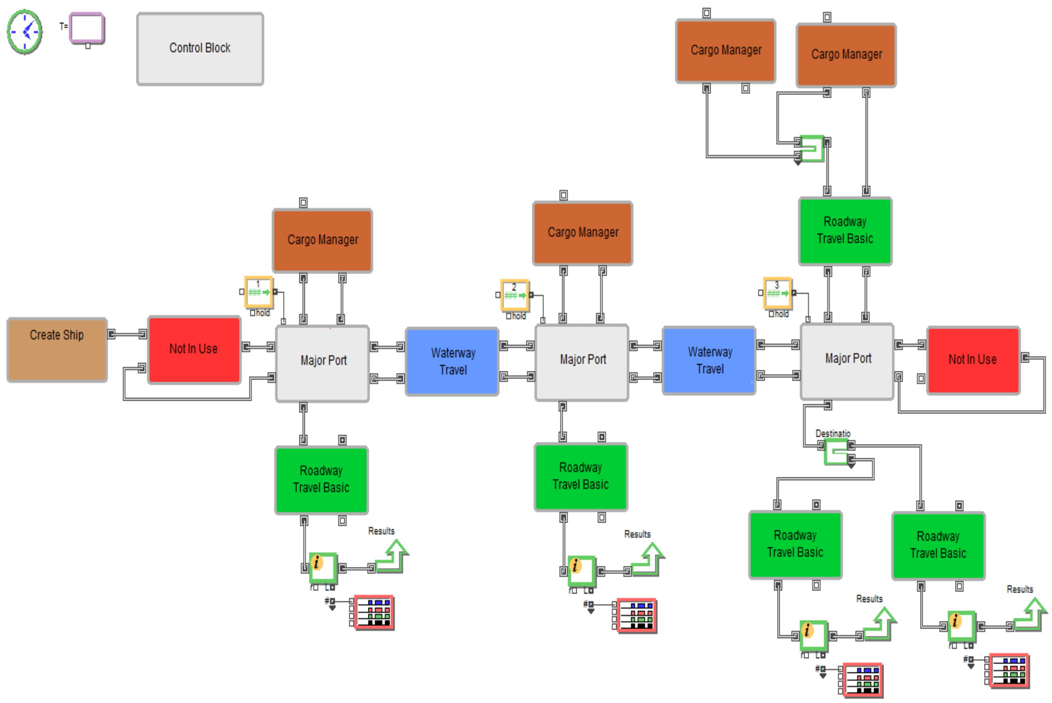


Figure 4-5 Short Route Model in ExtendSim

The model is tuned to provide enough cargo at each location to permit three (3) round trip sailings per week. The tuning resulted in a daily creation distribution of approximately 16 - 20 short ton 53-foot containers in both the AMPT and NIT and approximately 32 - 20 short ton 53-foot containers per day created in the Richmond cargo area. Cargo is created seven (7) days per week between the hours of 7:00AM and 6:00PM. This distribution is a close match to the 30% diversion rate that is modeled in the highway model (see Chapter 3 above).

The ship in this scenario is a tug pulling a barge with a capacity of 85 53-foot containers. The tug boat cruises at 6 knots while burning 65 gal/hour of fuel. Additionally, it has a 10 gal/hour burn rate when idling. The operating cost of each trip is $7,000 per trip ($14,000 per round trip). As stated in the introduction, the operating and fuel costs are distributed to each cargo unit.

All three ports are assumed to have the same move cost of $40 per container. The port blocks contain the logic that prevent a tug leaving if there is less than 50 containers within the system.

The port reroutes cargo if it is not expected to reach its destination within seven (7) days of creation.

This model includes two water segments: a short 1NM segment between APMT and NIT and an 85NM segment between NIT and Port of Richmond. The short segment uses a fixed speed of 5 knots while the long segment uses the ship's 6 knot cruising speed. In addition, the long route has a diurnal current cycle that is 3 knots at maximum and 0.5 knots at minimum.
The tug's departure is scheduled in such a way that the vessel will leave at the optimal time with regard to the current. As a result, the vessel has a minimal head current when sailing up river. In addition, the simulation models a 20% cancellation rate in Spring and Autumn (80-156th, 220-311th days of the year).

This scenario only contains one drayage operation which occurs in the Richmond area. It is modeled as being a traveling distance of 10 statute miles. The drayage truck speeds are modeled with a triangular distribution of 5 MPH minimum, 30 MPH most likely and 50 MPH maximum. In addition, the truck has a 5 MPG fuel efficiency and an operating cost of $83.68/hour plus $1.73/mile traveled.

The trucking distance between the ports is 75.9 statute miles. Trucking is only used if a cargo unit cannot be delivered on time by tug/barge. These truck speeds are modeled with a triangular distribution of 30 MPH minimum, 40 MPH most likely and 50 MPH maximum. The long distance trucks are modeled with identical fuel efficiency and operating costs as the drayage trucks.

Short Route Results

The results of this simulation are stochastic. When run with ten (10) iterations, the system responds with 19% of containers being rerouted by truck. The trucks are rerouted due to two reasons--either there is too much cargo for the system to handle or a seasonal cancellation has forced cargo to be rerouted in order to reach its destination in time. The average time necessary for a piece of cargo to be shipped is 1.69 days by ship. As a result, the barge is running at 94.8% full when sailing.

Table 4-2 shows the total cost per container in the "Average" column for the entire system. (This includes both marine and containers rerouted by truck.) The Tug/barge and Rerouted Truck columns show the difference in costs between the two modes of transportation. The simulation shows that using Tug/Barge can save $119 per container. In reality, this cost difference may be larger because the model assumes that a truck never travels empty. However, in many cases a rerouted truck will return to its origin empty thus adding operating cost, fuel cost and emissions.

Table 4-2 Fuel and Operating Cost per Container

	Average	Tug/Barge	Rerouted by Truck
Operating Cost	$237.06	$218.36	$317.30
Fuel Cost	$48.59	$44.84	$64.67
Total Cost	$285.65	$263.20	$381.97
CO_2 Emissions [g]	55,726	49,731	90,029

Emissions were tracked in this model assuming that a barge emitted 17.5 g CO_2 / ton-mile and a truck emits 72 g CO_2 / ton-mile. The result is that a barge route save approximately 50kg of CO_2 per container on this route.

Figure 4-6 shows the breakdown of the Marine relevant costs. It should be noted that these costs assume that a drayage truck will return with another full container. In reality, many of the trucks return empty meaning their cost will be added to the total marine operation cost.

4.7 Long Route Analysis

Long Route Model and Inputs

The long route model is similar to the short route model in that it has three ports. However, this model does not need to account for river current or seasonal cancellations. Figure 4-7 shows the arrangement of the three ports and the traffic between them. Figure 4-8 illustrates the ExtendSim logic that represents this process.

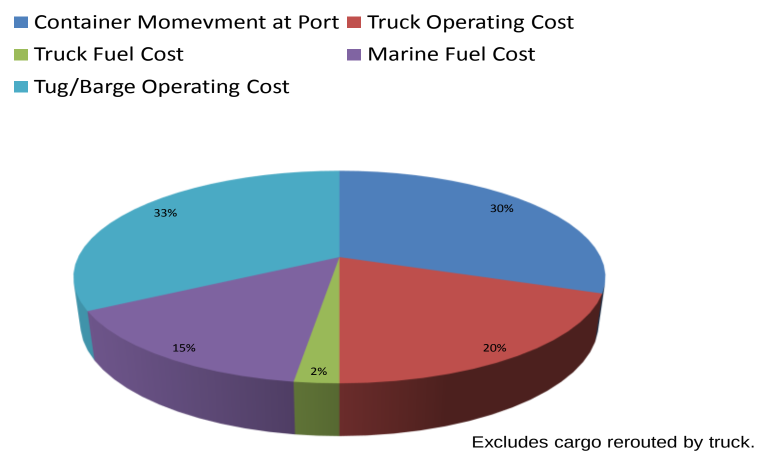


Figure 4-6 Cost Breakdown of Tug/Barge Operation

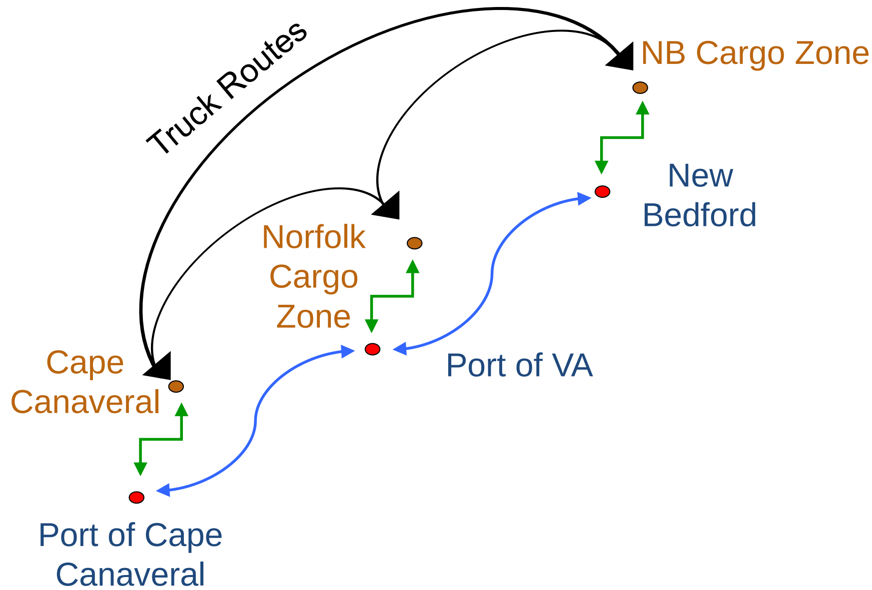


Figure 4-7 Diagram of Long Route Cargo Flow

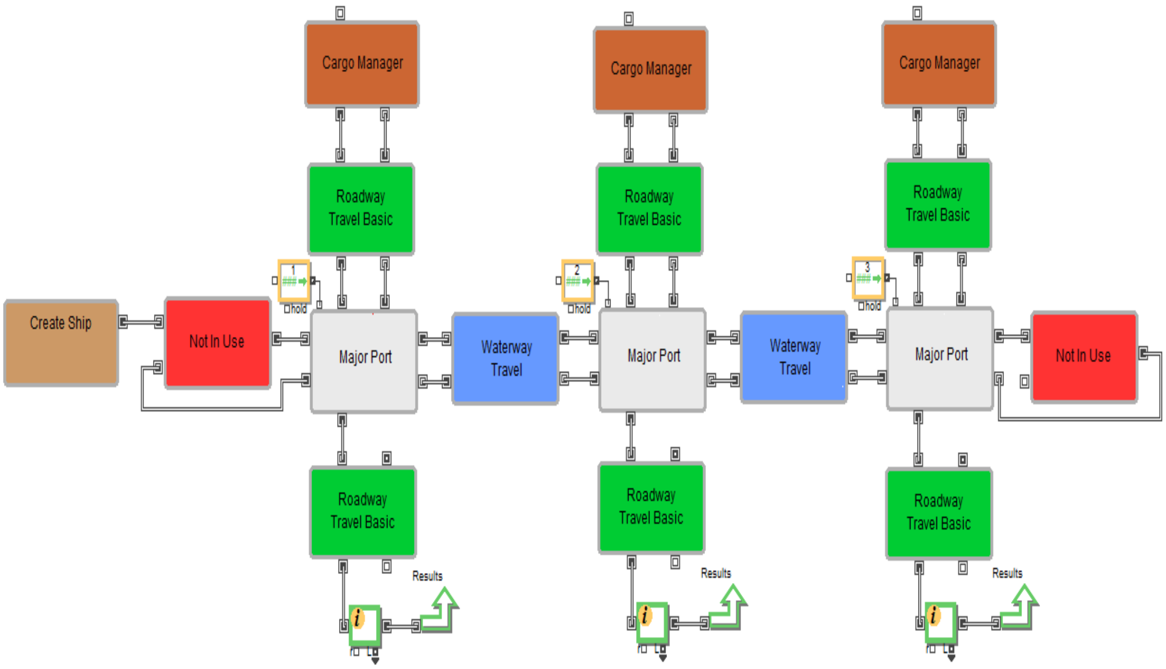


Figure 4-8 ExtendSim Long Route Model

The basic parameters are that marine fuel costs $3.00/gal and truck fuel costs $4.00/gal. The ship has a design speed of 23.7 knots and has the ability to carry a maximum of 255 53-foot containers. Additionally, the ship consumes 106 tons of fuel per day with an operating cost of $70,000. The operating cost includes finance costs, ownership costs, owner's return on equity, insurance and crew wages.

This scenario only contains one drayage operation which occurs in all port areas. It is modeled as being a traveling distance of 10 statute miles. The drayage truck speeds are modeled with a triangular distribution of 5 MPH minimum, 30 MPH most likely and 50 MPH maximum. In addition, the truck has a 5 MPG fuel efficiency and an operating cost of $83.68/hour plus $1.73/mile traveled.

All three ports are assumed to have the same move cost of $40 per container. Each container takes three (3) minutes to move with two (2) loading paths in parallel. The port blocks contain the logic that prevent a tug leaving if there is less than 100 containers within the system. Each system has a distribution that creates approximately 30 containers at each port. The marine routes are Canaveral/Norfolk 620 nautical miles and Norfolk/New Bedford 380 nautical miles.

Long Route Results

The door-to-door delivery times for this scenario with one round trip are shown in Table 4-3. The loading time accumulates with the travel time to result in a 6- to 8-day trip time.

Table 4-3 Delivery Time for Long Route Simulation

Port Pair	1 Ship Time [days]
Canaveral - Norfolk	6.84
Norfolk - New Bedford	6.47
Canaveral - New Bedford	8.19

The simulated costs of this operation can be seen in Table 4-4. As expected, ship efficiency increases when the ship approaches full load. The operator can save approximately $200 per container if capacity utilization is increased from 70% to 90%.

Table 4-4 Operating and Fuel Costs per Container for Long Route

	70% Full	80% Full	90% Full
Operating Cost	$1067.69	$1027.16	$982.93
Fuel Cost	$680.75	$611.58	$557.34
Total Cost	$1748.44	$1638.74	$1540.27

The long route operation is not efficient when rerouting by truck. In comparison, a truck's operating cost for this operation is $3,005 and its fuel cost is $705. Additionally, the emissions for the Ship/Drayage operation are 940,510g CO_2 compared to 1,296,900g CO_2 when using exclusively trucks.

It was common for the ship to lose efficiency if cargo distributions were not balanced. As a result, it will be important for the operator to plan his business in order to distribute cargo evenly on each leg of the journey.

5. DRAYAGE MODEL

5.1 Model Overview

The Cost Estimate Model for the drayage operations develops estimates of the societal costs of port related traffic, including vehicle operating, congestion, and air pollution costs. Several approaches are found in the literature for estimating the societal costs of traffic. A limited number of the studies focus on the impact of truck traffic. The excel-based application presented in this paper is developed based on the work by Berechman (2009) which, to the best of our knowledge, is the only one with a specific focus on port drayage operations. A description of the formulas used for the cost analysis of drayage operations is presented in the next section. The following section presents the excel-based application of the model.

5.2 Formulas

The *vehicle operating cost* (total, marginal, average) is estimated using the following formulas:

$$C_{opr} = 7208.73+0.12(m/a)+2783.3a+0.143m$$

$$MC_{opr}=0.12/a+0.143$$

$$AC_{opr}=7208.73/m+0.12/a+2783.3(a/m)+0.143$$

where: m = vehicle mileage (miles)

a = vehicle age (years)

The *congestion cost* is estimated using the following formulas:

For Q<=C

$$C_{cong}=Q*(d/V0)*(1+0.15(Q/C)^4)*VOT$$

$$MC_{cong}=(d/V0)*(1+0.15(Q/C)^4)*VOT+0.6*(d/V0)*(Q/C)^4*VOT$$

$$AC_{cong}=(d/V0)*(1+0.15(Q/C)^4)*VOT$$

For Q>C

$$C_{cong}=Q*(d/V0)*(1+0.15(Q/C)^4)*VOT+Q*(Q/C-1)*(VOT/2)$$

$$MC_{cong}=(d/V0)*(1+0.15(Q/C)^4)*VOT+0.6*(d/V0)*(Q/C)^4*VOT+VOT*(Q/C-0.5)$$

$$AC_{cong}=(d/V0)*(1+0.15(Q/C)^4)*VOT+(Q/C-1)*(VOT/2)$$

where: Q = traffic volume (veh/h)

C = capacity (veh/h)

D = distance (miles)

$V0$ = free flow speed (m/h)

VOT = value of time of truck ($/h)

The *air pollution cost* is estimated based on the formula:

$$C_{air} = Q(0.01094+0.2155F)$$

$$MC_{air} = 0.01094+0.2155*(F+\sigma F/\sigma Q)$$

$$AC_{air} = 0.01094 + 0.2155F$$

where: Q = traffic volume

F = fuel consumption at cruising speed (gallons/mile)

Fuel consumption is estimated based on the following formula:

$$F=0.0723-0.00312V+5.403*10^{-5}V^2$$

where: V = average speed (miles/hour)

5.3 Excel-Based Application

A generic model has been developed as an excel-based application. The user may copy the application folder and run the executable file. The application opens the main form of the model, which allows the selection among three choices, as shown in Figure 5-1. By selecting the “Original Version” the user may provide input for the variables and the parameters of the models for estimating total, marginal and average costs. The “Variable inputs” and “Parameter inputs” sheets focus on the marginal costs. “Variable inputs” allows for only the values of the variables to be changed, while the parameters have fixed values. “Parameter inputs” allows for both variable and parameter values to be changed.

Selecting the “Original Version” opens up a screen, with several tabs, each opening a separate sheet. The first sheet is the vehicle operating cost model, as shown in Figure 5-2.

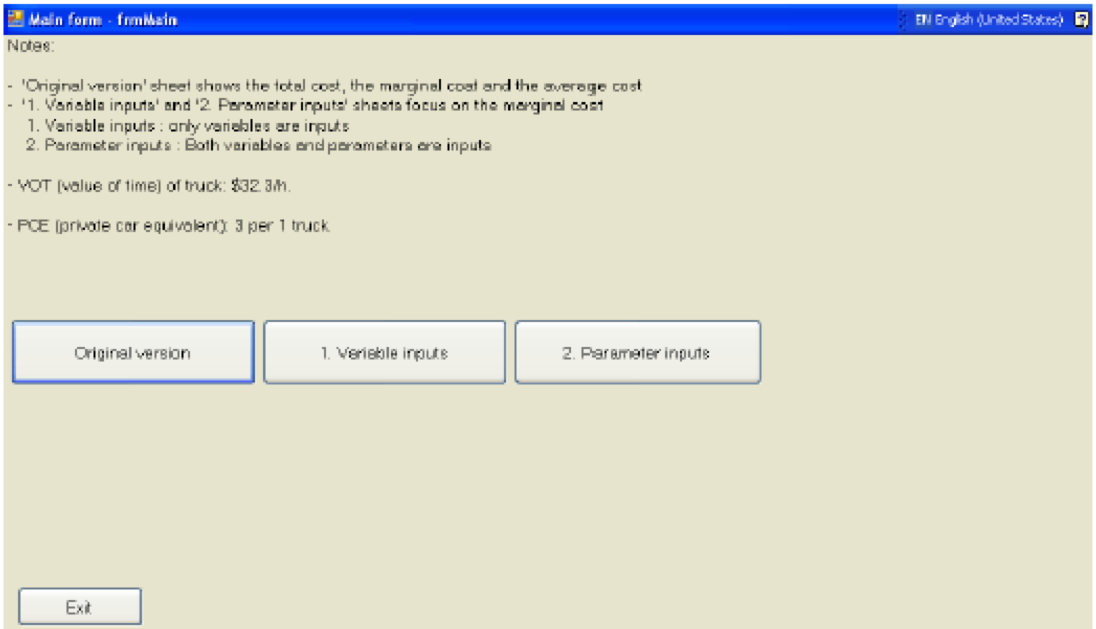


Figure 5-1 Main Sheet

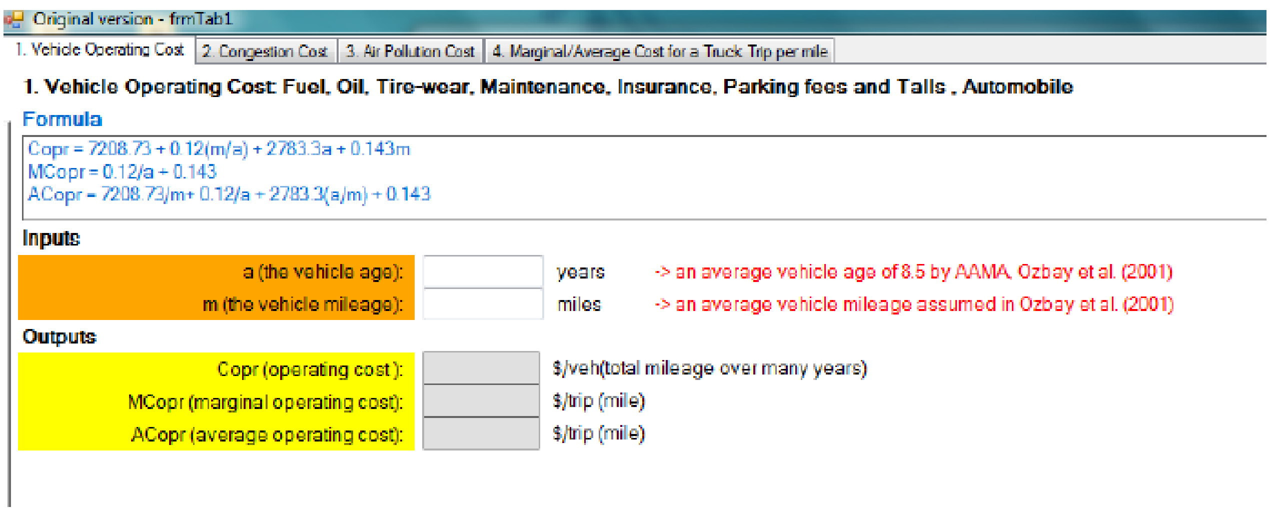


Figure 5-2 Vehicle Operating Cost Sheet

In this form the user specifies the vehicle age and the vehicle mileage (if different from the default value that appears on the screen once the vehicle age is specified. Based on this information the model estimates the total, marginal and average vehicle operating cost. The second sheet is the congestion cost model, as shown in Figure 5-3.

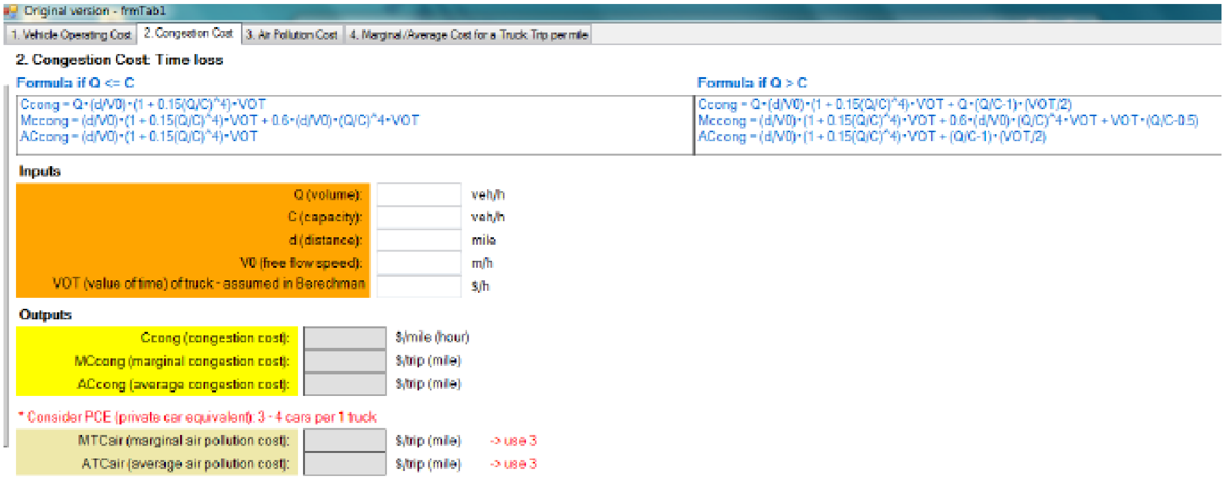


Figure 5-3 Congestion Cost

In this form the user specifies the volume and capacity of the roadway segment being analyzed, as well as the distance, the free flow speed, and the value-of-time. A different model is used depending on whether volume on the roadway segment exceeds capacity or not. Based on the specified input, the monetary equivalent of the time lost because of congestion is estimated, as total, average or marginal cost. The third sheet is the air pollution cost model, as shown in Figure 5-4.

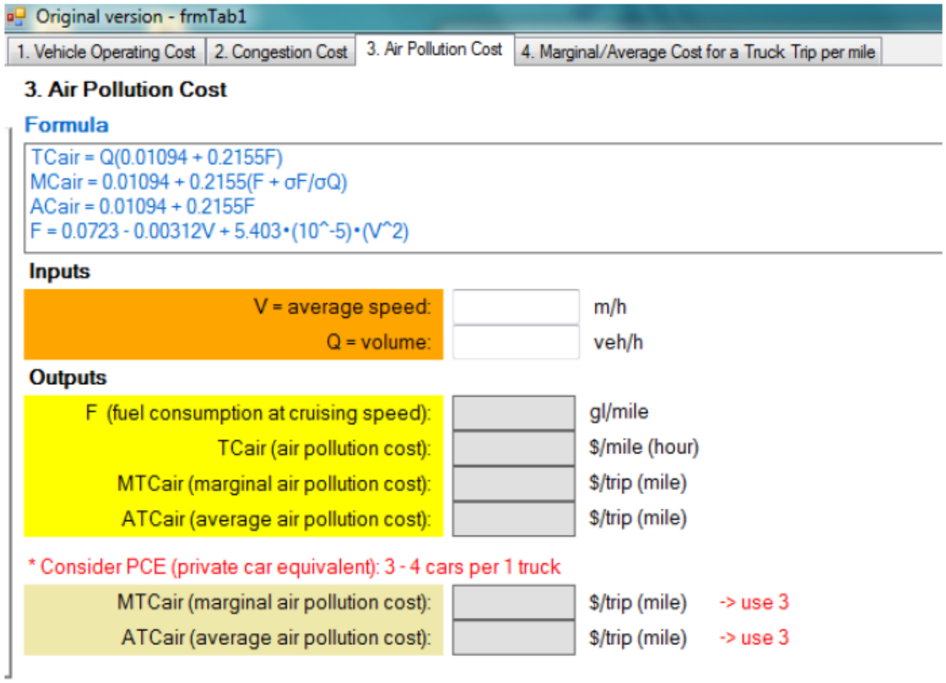
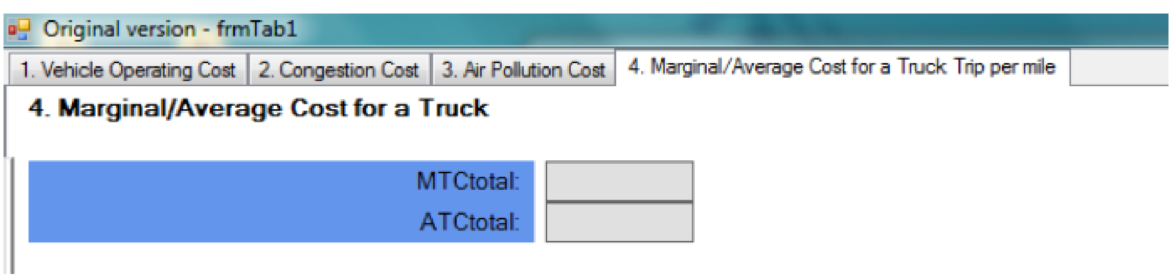


Figure 5-4 Pollution Cost Model

In this form, the user specifies the average speed for the traffic conditions and the volume of traffic. The model produces estimates of the total, average and marginal air pollution cost.

The fourth sheet produces a summary of the costs, as marginal and average cost per truck.



6. REMOTE SENSING AND GEOSPATIAL DATA APPLICATIONS

6.1 Introduction

This research report addresses the application of advances in commercial remote sensing and spatial information technologies for achieving faster, smarter and more cost effective planning for marine highways. The research study shows remote sensing imagery using satellite and aerial platforms, airborne laser scanning and thermal scanning. It enables the collection of broad area and detailed physical (spatial) data rapidly and on a repetitive basis, integrating remote sensing data with Geographic Information Systems (GIS) and facilitating the rapid analysis of spatial planning for routing and infrastructure assessment for marine highways.

High-resolution images from commercial remote sensing provide new capabilities for examining the infrastructure condition of waterways from port-to-port and verifying infrastructure conditions and the flow of freight from various freight diversion modeling scenarios. The advances provide new tools for national examination of waterways currently unused that have the potential for marine highway operations. Remotely sensed images, in combination with the near port freight and drayage analysis studies, help to determine critical factors needed for improving freight traffic flow and drayage at ports for marine highway planning.

Very High Resolution remotely sensed satellite imagery provides an unparalleled capability for studying, monitoring, forecasting and managing natural resources and human activities on national and global scale. GeoEye Inc, a partner in this study, has set geospatial industry standards for high resolution commercial satellites and operates an extensive constellation of Earth-imaging satellites, mapping aircraft and an international network of ground stations. These resources, coupled with a vast imagery archive and advanced imagery-processing capabilities, have provided an efficient, cost-effective way to obtain invaluable geographic information for marine highway decision-making process. The imagery offers spatial resolution of 0.41-meter panchromatic and 1.65-meter multispectral.

In this study, a relatively undeveloped port on the James River, Hopewell, was identified in a hypothetical scenario as new location for diverting freight from highway to marine highways. The diversion demonstrates the application of both remote sensing and computer modeling technique. TransCAD modeling, an analytical approach, was applied to estimate diversion of freight and road traffic conditions. The model produces estimates of commodity flow on the highway segments and quantifies the benefits of diverting freight traffic from highways to waterways, in any given segment of the freight diversion from highway to waterway.

The analysis of remote sensing imagery serves as basic tools for planning marine highway operations at new and emerging port areas, for creating a new port infrastructure or expanding port capability for upgrading port operations. The 3-D imagery of port regions is generated by combining geocoded imagery, Digital Elevation Models (DEM) and GIS mapping information. It is applied to meet port planning needs for both route expansion and infrastructure reconstruction. The examination of 3-D imagery shows that the lower Route 10 in Hopewell would offer a more favorable condition for road expansion to handle freight flow increase. In ports planning, remote sensing data also helps in land/cover change detection in local area. The imagery archive facilitates land use and infrastructure planning and local change detection at or near port areas. Images acquired at different times have been used for local infrastructure change detection for both Port of Hopewell and Port of Norfolk. For the past ten years, based upon remote sensing imagery, the layout of Hopewell's port shows little change while Port of Norfolk experienced massive infrastructure reconstruction including a container yard and parking lot. Coupled with GIS technique, remote sensing imagery also provides an expedient way to update topographic vector route network for more accurate modeling and local planning. The route network around two distribution centers has been updated for future use.

6.2 Importance of Remote Sensing Image for Port Area and Region Wide Analysis

Remote sensing derived imagery information offers specific advantages for examining and verifying infrastructure condition of waterways from port-to-port and monitoring freight flow.

- The Synoptic view identifies various waterway and surface features in their spatial relation to each other.
- Repetitive coverage of waterway and port infrastructure provides temporal information for change detection analysis.
- Remote sensing provides accessibility to gather information in remote land and water areas, where a precise land survey is not feasible.
- Remote sensing rapidly collects information about a large area, saving considerable time for the permitting process and environmental assessment.
- High resolution remote sensed images provide more accurate information for mapping, and monitoring natural resources and human activities.

6.3 National Imagery Archives for Marine Highway Analysis

Current and historical geospatial imagery from GeoEye provides timely and vital insight for marine highway applications. A wide range of imagery products collected by the consolidation of high-resolution satellites and aerial systems would match specific resolution requirements and geospatial interests. In marine highway analysis, high-resolution imagery facilitates port planning, the examination of the infrastructure condition, and verification of infrastructure condition from various freight diversion modeling scenarios.

The source of imagery in this study comes from two Earth-imaging satellites, IKONOS and Geoeye-1. GeoEye set geospatial industry standards with the launch of IKONOS, the world's first sub-meter commercial satellite. IKONOS is the world's first commercial satellite able to collect panchromatic images with 82-centimeter resolution and multispectral imagery with 4-meter resolution. The more than 300 million square kilometers of imagery that IKONOS has collected over every continent is being used for national security, military mapping, air and marine transportation, and by regional and local governments. GeoEye-1 is equipped with the most sophisticated technology ever used in a commercial satellite system. It offers detailed spatial resolution by simultaneously acquiring 0.41-meter panchromatic and 1.65-meter multispectral imagery. The detail and geospatial accuracy of GeoEye-1 imagery further expands applications for satellite imagery in marine highway application (Figure 6-1).

SATELLITE FEATURE	GEOEYE-1	IKONOS
Resolution	.50-meter	1-meter
Spectral range (pan)	450-800 nm	526-929 nm
Blue	450-510 nm	445-516 nm
Green	510-580 nm	505-595 nm
Red	655-690 nm	632-698 nm
Near IR	780-920 nm	757-853 nm
Pan Resolution at nadir	.41 meters	.82 meters
Pan Resolution at 60 elevation	.50-meters	1.0 meter
Multi-spectral Resolution at nadir	1.64 meters	3.28 meters
Swath width at nadir	15.2 km	11.3 km
Launch date	06-Sep-08	24-Sep-99
Life Cycle	7 years	Over 8.5 years
Revisit Time	3 days at 40° latitude with elevation > 60°	3 days at 40° latitude with elevation > 60°
Orbital Altitude	681 km	681 km
Nodal Crossing	10:30 AM	10:30 AM
Approximate Archive size (km2)	View Archive	View Archive

Figure 6-1 Satellite Features for GEOEYE-1 and IKONOS

GeoEye's Imagery Sources collect high-resolution satellite and aerial imagery from around the globe each day. GeoEye stores all available satellite imagery in its large imagery archive which can be accessed through GeoFUSE, an imagery search and discovery platform. Built on the familiar and ubiquitous Google Maps™ API and Esri® ArcGIS™ Server technologies, Online Maps makes it easy zoom to a place on the globe and locate available GeoEye imagery. The customers can browse the image catalog archives, quickly and easily locate and preview imagery.

The GMU consortium used GeoFuse for collecting imagery from the imagery archive. Figure 6-2 is an example applying GeoFuse for image selection along the Richmond-Norfolk barge route. Each gray box in Figure 6-2 represents one available remote sensing image scene. GeoEye also provides the capability to acquire new imagery on demand.

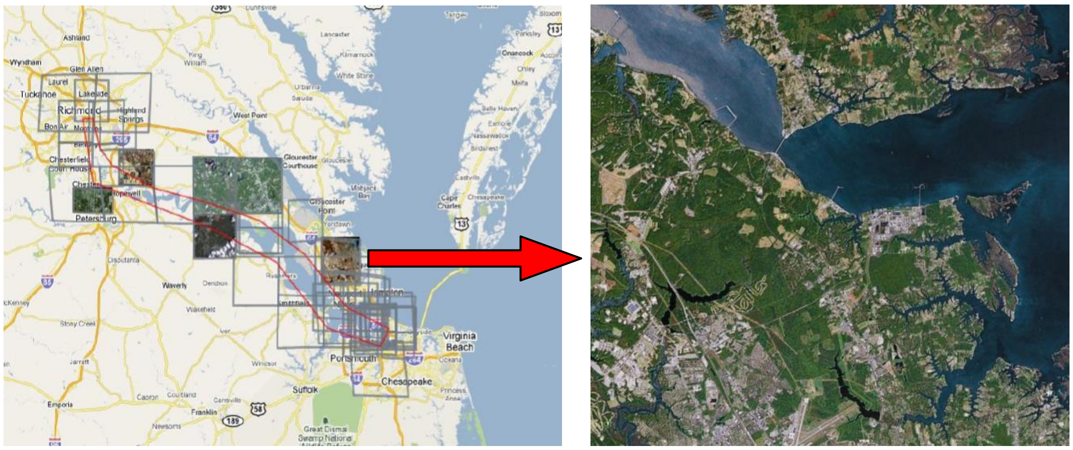


Figure 6-2 GeoEye Imagery Data Base Matrix in Richmond-Norfolk Barge Route and View of One Image Matrix

6.4 Remote Sensing Image Mosaic

As an expedient method of earth observations, remote sensing technique has the capability to provide timely massive spatial information. In transportation applications, remote sensing technologies have gained increasing attention in recent years. The key driving forces behind the use of remote sensing include the rapid data acquisition speed and comparatively lower cost, and growing demands for more accurate, comprehensive, and updated data.

Due to limited coverage of each scene of satellite imagery, for study of transportation applications that require large study area, there is a need to stitch together a number of remote sensing images to obtain thorough understanding about connectivity between different traffic modes. The image mosaic provides much more spatial information than image alone, enhancing image resolution and field of view, and allowing researchers to access to information of areas around hot spots.

This image mosaic is generated with proprietary algorithms which were particularly suited for marine highway study. In order to obtain a seamless mosaic, the individual satellite images were orthorectified using a block adjustment procedure. Additionally, tie points were defined for the transition zones (overlaps) between the neighboring scenes. By spectral optimization and mosaicking, adjacent images have been optimized with respect to their coloring and were combined into a homogeneous and seamless satellite image mosaic (Figure 6-3).

Figure 6-3 Image Mosaic for Norfolk area

In highway and road sector, image mosaic facilitates the examination of existing road network condition and provides valuable information for new road design and upgrade. Coupled with GIS techniques, image mosaic helps in analyzing ground appropriateness to locate and construct roads. In this study, mosaic has been applied in Port of Hopewell to support decision-making for road expansion in port areas. Because of traffic increase at Hopewell, estimated by TransCAD modeling, the roads connecting the highway and Port of Hopewell are suggested for upgrade to 4/6 lanes for incoming increase in truck flows in this area. In GIS system, road network is usually presented in the form of polyline. Due to rapid construction of roads, previous geospatial transportation database in fast developing regions is likely to be outdated. The mosaic can be used as a base map for on-screen digitizing. The update of existing road network based on satellite image mosaic will provide up-to-date information of current road condition, making it possible to better serve communities with respect to transportation geospatial data. Many different transportation models have been developed to manage road network geospatial data.

With new updated road network information, these models can provide more accurate simulation results and comprehensive response to transportation problem.

In waterway and port study, image mosaic provides a tool to examine the infrastructure condition of waterways from port-to-port, evaluate regional infrastructure conditions, and examine the freight shift in different transportation modes. Composed of high resolution images, the image mosaic facilitates national examination of waterways currently unused that have the potential for marine highway operations. The mosaic also provides a quick and broad view of port access and waterway connectivity which plays an important role in marine highway operations. Combined with other information, such as near port freight and drayage analysis studies, the images help to determine critical factors needed for improving freight traffic flow and drayage at ports for marine highway planning. When image mosaic is overlaid with digital elevation model, a 3-D terrain model is created which provides an opportunity for quantitative characterization of land surface in terms of digital terrain information and also helps in examination of existing infrastructure condition and location selection for new infrastructure construction.

6.5 Remote Sensing Application for Scoping of Marine Highway Infrastructure at New and Smaller Ports

Both short and long haul marine highway routes were selected by the GMU research team for validating analytical tools in comparing advantages of moving freight by waterways versus highways:

1) A short haul route in the Commonwealth of Virginia between the Port of Richmond and Norfolk (Port of Virginia); and
2) A long haul route along the Atlantic seaboard, from the Port of New Bedford, MA, to Port Canaveral, FL with an intermediate stop at the Port of Virginia.

The detailed short haul route map between the Port of Richmond and the Port of Virginia is shown in Figure 6-4. Interstate I-64 runs East–West through central Virginia from West Virginia via Covington, Lexington, Staunton, and Charlottesville to Richmond. From Richmond, Interstate 64 continues southeasterly through Newport News and Hampton to the Hampton

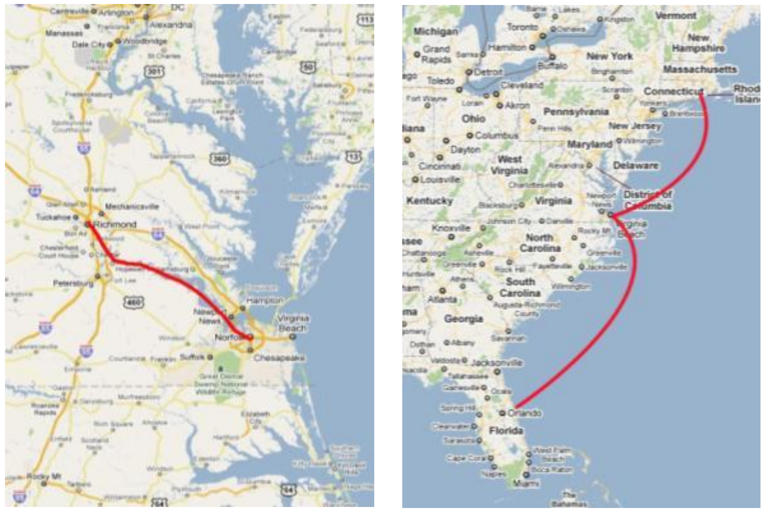


Figure 6-4 Selected Short Route and Long Route

Roads Bridge-Tunnel, and then through Norfolk and a small portion of Virginia Beach to end in Chesapeake. According to Department of Transportation, more drivers are using the eastern half of I-64 from Richmond to the port of Virginia, increasing congestion and producing freight bottlenecks.

The James River is a marine highway alternative to I-64. The river is navigable from Richmond to Norfolk. To take advantage of this alternate route, the Port of Virginia authorized the James River Line, LLC, to establish an operational barge freight service running between the ports of Richmond and Norfolk. The service began in 2008 and provides several trips per week using a tug and barge service, carrying standard shipping containers between the two ports. This service is already credited with relieving some congestion, and also providing a more environmentally friendly alternative for moving cargo between the two port locations.

As part of the short haul study, the GMU study team decided to include a hypothetical scenario identifying another relatively undeveloped port location along the James River to demonstrate the application of both remote sensing and computer modeling technologies for diverting freight to marine highways. The remote sensing results were applied in port selection, route analysis, and existing congestion assessment.

The purpose of selecting a new and underused port for marine highway is to show the effectiveness of expedient planning of marine highways using remote sensing and spatial information methods. The hypothetical scenario selects a likely new port location on the James River that could potentially handle a 30% diversion of freight from highway to the new port. Remote sensing imagery on the following five new port locations along the I-64 corridor were examined to select a suitable new port for handling freight diversion to marine highways (Figure 6-5): Hopewell, Jamestown, Yorktown, Newport News and Portsmouth.

Port Location:	**Hopewell**	**Newport News**	**Portsmouth**	**Yorktown**	**Jamestown**
Port Name:	Port of Hopewell	Port of Newport News	Port of Portsmouth	Port of Yorktown	Jamestown Harbor
Port Authority:	City of Hopewell	Virginia Port Authority	Port of New Hampshire		Jamestown Harbor Master
Address:	300 N. Main Street Hopewell, VA 23860 United States	25th St. & Warwick Blvd. Newport News, VA 23607 United States	New Hampshire Division of Ports and Harbors	Yorktown, VA United States	Jamestown STHL 1ZZ St. Helena
Latitude:	37° 18' 23" N	36° 58' 50" N	43° 5' 15" N	37° 13' 27" N	15° 55' 27" S
Longitude:	77° 16' 29" W	76° 25' 54" W	70° 46' 11" W	76° 28' 23" W	5° 43' 14" W
UN/LOCODE:		USNNS	USPSM	USYKW	SHSHN
Port Type:	Seaport	Deep water Seaport	Seaport	Seaport	Pier, Jetty or Wharf
Port Size:	Small	Large	Medium	Small	Small

Figure 6-5 Five Possible New Port Locations

Newport News: The 140.64 acre Newport News Marine Terminal (NNMT) is the Port of Virginia's main break-bulk terminal. The facility boasts 42,720 feet of direct rail access/rail track provided by CSX. With 3,480 feet of total pier space serviced by four cranes, direct cargo loading on and off ships to and from the CSX break-bulk rail service, covered storage, container storage, and accessibility from 3 major Virginia roadways.

Port of Portsmouth: The 219 acres Portsmouth Marine Terminal has 3,540 feet of wharf, 3 berths, and 6 cranes; PMT is able to handle container, break-bulk and RO/RO cargo. The port has direct access to both CSX and NS railways, and will soon connect to the Commonwealth Railway.

Yorktown: Based on satellite image, no short sea shipping infrastructure could be found in Yorktown. The port would need significant new infrastructure to handle marine highways.

Jamestown: The Jamestown is one of three locations comprising the Historic Triangle of Colonial Virginia, along with Williamsburg and Yorktown. Based on imagery, the small size of Jamestown harbor limits the harbor freight capacity.

Hopewell: Hopewell is a waterfront community located at the confluence of the James and Appomattox rivers. It is approximately 24 miles southeast of the capital city of Richmond and accessible by both I-295 and I-95. Hopewell port ranks 147 among 150 US ports in terms of total trade tonnage.

Cargo volume at U.S. ports, 2004, short tons.

Rank (by total trade)	Port name	Total trade	Foreign imports	Foreign exports	Foreign total	Domestic total
147	Hopewell, Virginia	986,826	4,963	353,215	358,178	628,648

The GMU study team selected the Port of Hopewell as an example of an underdeveloped port that could have potential growth for marine highway services. Hopewell is a relatively undeveloped port, but offers prospects for further development. By contrast, Jamestown is a historic site with no developable waterfront, Yorktown is a US Naval support facility, and Newport News is hemmed in by urban development.

6.6 Comparison of Richmond Port and Hopewell Port

Port of Richmond is known as the Richmond Deepwater Terminal. It is located on the James River in Richmond, Virginia, 100 miles from Cape Henry and approximately 78 miles north of Newport News, Virginia. The Port is Central Virginia's domestic and international multi-modal freight and distribution gateway on the James River serving waterborne, rail and truck shippers throughout the Mid-Atlantic States.

The Port handles containers, temperature-controlled containers, bulk, break-bulk, and neo-bulk cargo. It is the western terminus for commercial navigation on the James River and is four miles south of the central Richmond Business District. Major export/import cargoes at port of Richmond include chemicals, pharmaceuticals, forest products, paper, machinery, consumer goods, frozen seafood, produce, campers, steel, steel products, stone, tobacco leaf, aluminum, project cargo, vehicles, boats, wire coils, wire rods, and pipe.

Port of Richmond is also a competitive candidate as a diversion point to handle freight diversion to marine highways. It has its own advantages:

- Port of Richmond has excellent distribution and transshipment location with strong local export/import support.
- The Dynamic transportation gateway is adjacent to I-95 with easy access to I-64 and I-85, air and major rail services.
- There is weekly Container-on-Barge service from Hampton Roads to Richmond, via the 64 Express.
- Foreign Trade Zone # 207 at Richmond International Airport saves businesses money and time on goods sourced abroad.

Compared to Port of Hopewell, there is no doubt that Port of Richmond has advantages in terms of port scale, cargo storage and shipping ability. However, Hopewell is preferred as a new port for freight diversion in that:

Port of Hopewell has excellent location: it is centrally located on the East coast, in an area that has excellent, multi-modal transportation infrastructure. It is close to I-95 and has quick northeast highway access to I-64 via I-295.

Port of Hopewell is located on the James River only 30 miles downstream from Richmond. However, the river route between Richmond and Hopewell is narrow and curved. If Hopewell is chosen as a diversion point other than Richmond, the stretch of waterway could be avoided and shipping time will be saved.

The hypothetical scenario proposed by the GMU team is to identify another relatively undeveloped port location on the James River to demonstrate two key advantages of both the remote sensing and computer modeling technologies being developed. Hopewell is preferred over Richmond as a diversion point and as an attempt to develop a template that can be used to facilitate the selection of other desired port pairs

6.7 Developing Imagery Analysis Tools for Quantitative Identification of Freight Flow in Selected Highway

Efficient and robust object detection in large-scale high-resolution remote sensing imagery has been drawing the attention of the vision community for the last few years. In particular, automatic detection and counting of cars or trucks in high resolution satellite images has been an active research topic as a result of many transportation applications. Research on this topic is motivated by different fields of application. Traffic-related data play an important role in urban and spatial planning. Therefore, an algorithm that automatically detects and counts vehicles in high resolution images would effectively support traffic-related analyses in transportation planning. Furthermore, because of the growing amount of traffic, research on truck detection is also motivated by the strong need to automate the management of traffic flow by intelligent traffic control and traffic guidance systems.

For this marine highway study, the main interest is in truck traffic flow on major highways. Automatic and quick detection and counting trucks has been studied. The approach of truck detection is based on a thresholding process--a method of image segmentation. During the thresholding process, individual pixels in an image are marked as "object" pixels if their value is greater than a given threshold value (assuming an object to be brighter than the background) and as "background" pixels otherwise. This convention is known as threshold above. Typically, an object pixel is given a value of “1” while a background pixel is given a value of “0.” Finally, a binary image is created by coloring each pixel white or black, depending on a pixel's labels.

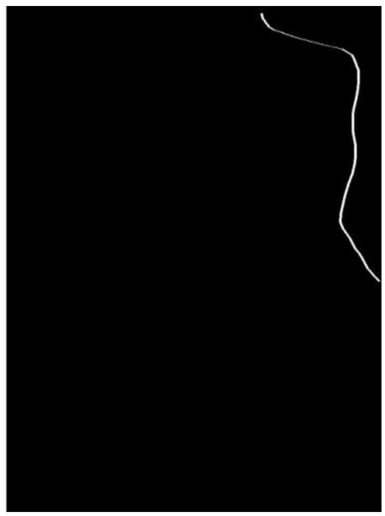
The key parameter in the thresholding process is the choice of the threshold value. Several different methods for choosing a threshold exist; a threshold value can be chosen manually or computed automatically. A simple method would be to choose the mean or median value, the rationale being that if the object pixels are brighter than the background, they should also be brighter than the average. In a noiseless image with uniform background and object values, the mean or median will work well as the threshold, however, this will generally not be the case. A more sophisticated approach might be to create a histogram of the image pixel intensities and use the valley point as the threshold. The histogram approach assumes that there is some average value for the background and object pixels, but that the actual pixel values have some variation around these average values.

To accurately distinguish between trucks and the highway, the thresholding image processing should not be applied to non-highway areas including residential areas, bare soil, farm land, or vegetation. Therefore, highway corridors are extracted from remote sensing images based on U.S. Highway shapefile *before* thresholding is applied. U.S. Highway shapefile is published by Federal Highway Administration which is a digital vector storage format for storing geometric highway locations and associated attribute information. Within GIS tool, buffer zone (highway area) is generated based on highway center polyline. To ensure full highway coverage, a buffer radius was set equivalent to width of the highway. As a result, highway pavement can be treated as a uniform background getting darker color than truck body which reflects sunlight and gets brighter color.

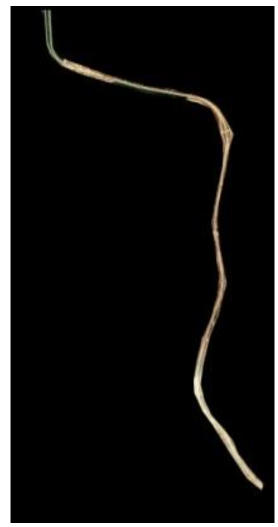
Highway pavement pixels and truck body pixels were sampled to generate histograms for intensity of each of two object pixels. Then, valley point is used as the threshold to separate highway and trucks. But, in some cases, brightness of truck body and highway pavement on image would change according to the time the image was acquired, causing difficulties in threshold selection and truck extraction. Sometimes, noise pixels will show in truck extraction results because of interference with highway ground signals, lines, car shadows, and trees that have similar intensity as truck body. Image filters or manual interventions are necessary as a final step to remove all noise pixels.

1. Extract highway area from remote sensed image based on U.S. highway shape file

Remote sensed image of Port of Virginia

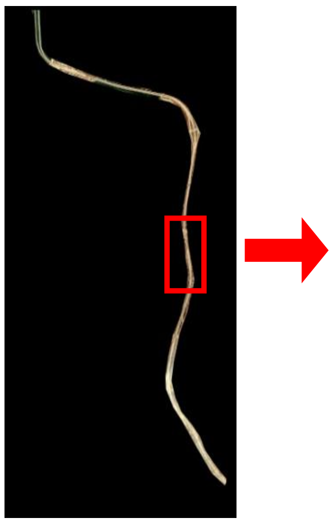


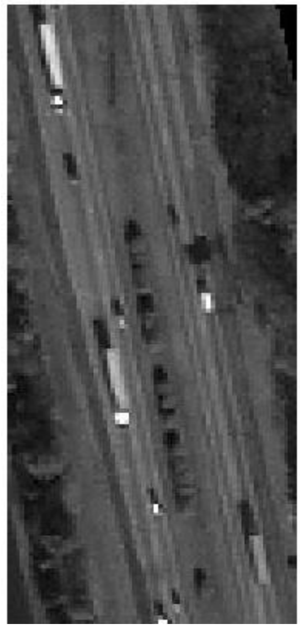
Highway coverage generated from highway shapefile



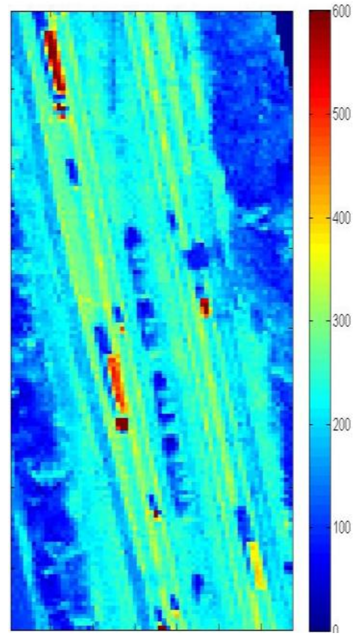
Extracted highway area

2. Sample highway pavement pixel and truck body pixels separately and generate histogram for intensity of each of two object pixels



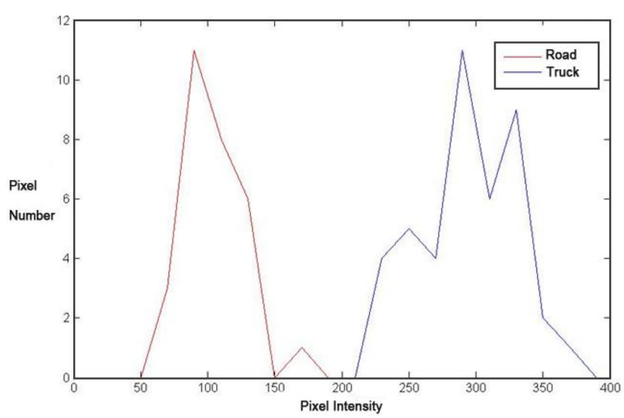


Gray scaled study area



Histogram expanded image

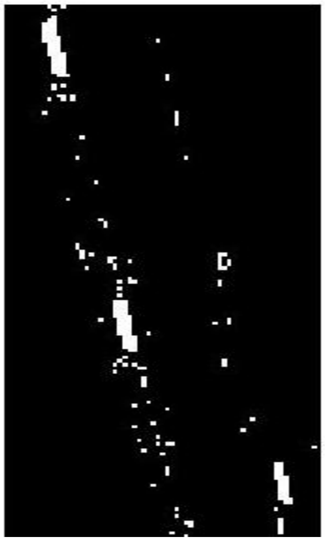
3. An initial threshold (T) is chosen based on valley point of histogram of the pixel intensities of highway pavement and truck body.



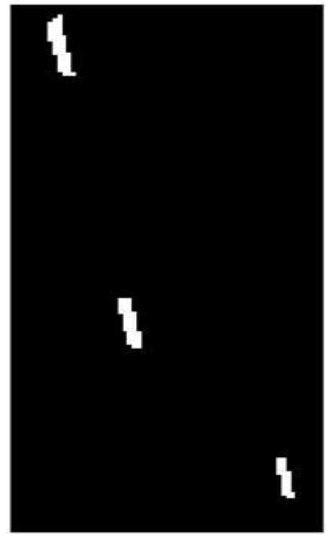
4. The image is segmented into object and background pixels as described above, creating two sets:

   G1 = {f(m,n):f(m,n)>T} (truck pixels)
   G2 = {f(m,n):f(m,n)<T} (highway pixels)
   (f(m,n) is the value of the pixel located in the mth column, nth row)

5. Detect truck intensity-like pixels and filter out noise pixels



Truck intensity-like pixels



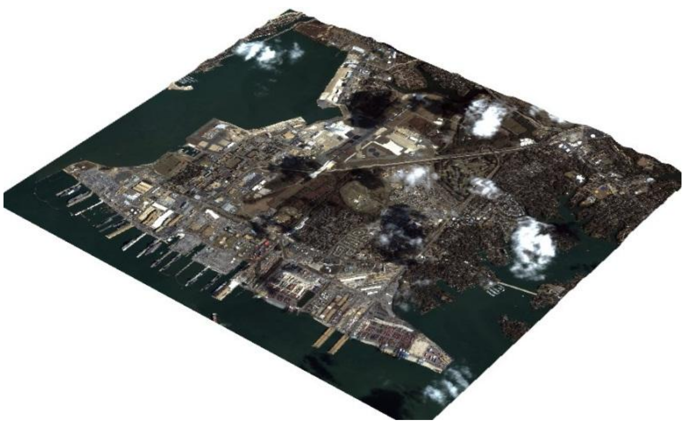
Filter out noise getting truck pixels

Using the above approach, we can detect freight trucks on highways and count their numbers. However, because satellite scanning time is fixed, we could only examine trucks on designated highway sections at one snapshot image. So, though the analysis process is operational, we lack adequate time-scaled imagery to effectively use the methodology to detect congestion patterns along selected highway sections.

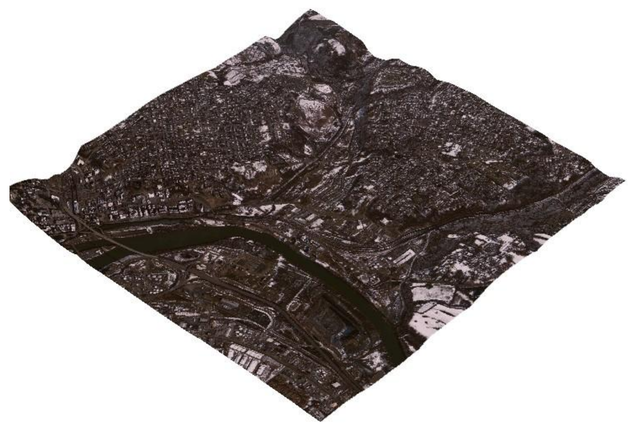
6.8 Near Port Route Planning by Applying 3-D Digital Surface Model

High resolution satellite imagery from satellite sensors combined with the GIS (Geographic Information Systems) have gained popularity among planners, developers and engineers for regional infrastructure planning of urban land management. The 3-D imagery shows the feature of landscape and indicates the elevation of natural features of the terrain. It is generated by overlaying different sources of data: satellite imagery, Digital Elevation Models (DEM) and GIS mapping information. The 3-D imagery of port regions helps in both marine highway route development and strategic planning of new ports.

3-D imagery has been used in the analysis study to estimate planning needs for route expansion to handle increasing freight flow at newer ports. The 3-D imagery has been created for both Port of Hopewell and Port of Norfolk. The modeling results show that, with the 30% truck volume on I-64 diverted to the Port of Hopewell, the traffic volume of highway routes connected to Hopewell increase in varying degrees (Figure 6-6). Upper town segment (Route 10) show an increase of about 50,000 trucks annually. Congestion will therefore increase in the upper town segment of Hopewell. A further examination of 3-D imagery shows that the lower Route 10 would offer a more favorable condition for road expansion to handle freight flow increase. Among three routes considered, route 156 seems to offer the least cost-effective alternative for road infrastructure expansion to handle the diversion.



Norfolk digital surface model



Richmond digital surface model

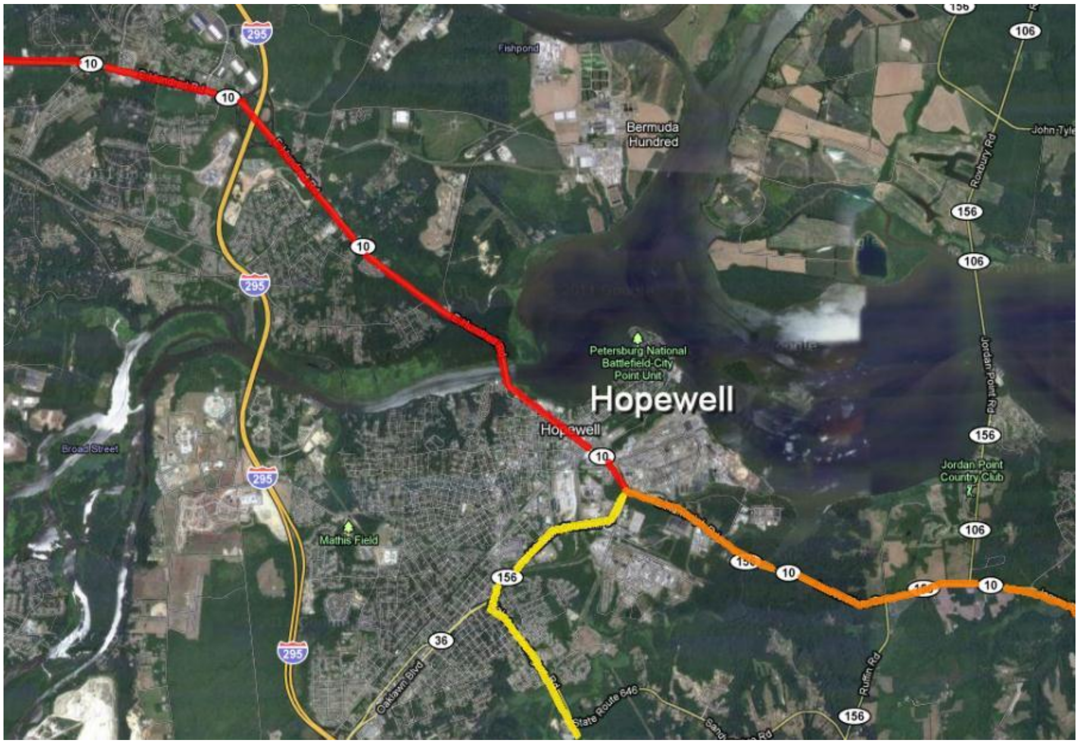


Figure 6-6 Traffic Increase in Hopewell Area

There are two lanes each way for most of Route 10 and 156. The Route 10 corridor west of Interstate 295 has three lanes each way. Future safety and mobility improvements are being planned by VDOT for Route 10 east to I-295 and for Route 156 connecting Hopewell city. These improvements include the expansion of the existing four lane roadway to a six lane divided route which would serve well for handling freight flow to marine highway using the Hopewell port (Figure 6-7).

Figure 6-7 Routes in Hopewell Area

Overlaying a geo-coded image on digital elevation model (DEM) has the potential to provide a base for port infrastructure planning and decision making. A DEM is a digital model or 3-D representation of a terrain's surface, created from terrain elevation data. 3-D views from Digital Elevation Models provide an opportunity for quantitative characterization of land surface in terms of digital terrain information. In this study, 10m resolution DEM in Hopewell area was obtained and overlaid with corresponding remote sensing imagery to realize 3-D visualizations using ENVI, consumer-oriented, remote sensing software which provides an intuitive user interface and flyby images experience (Figures 6-8, 6-9).

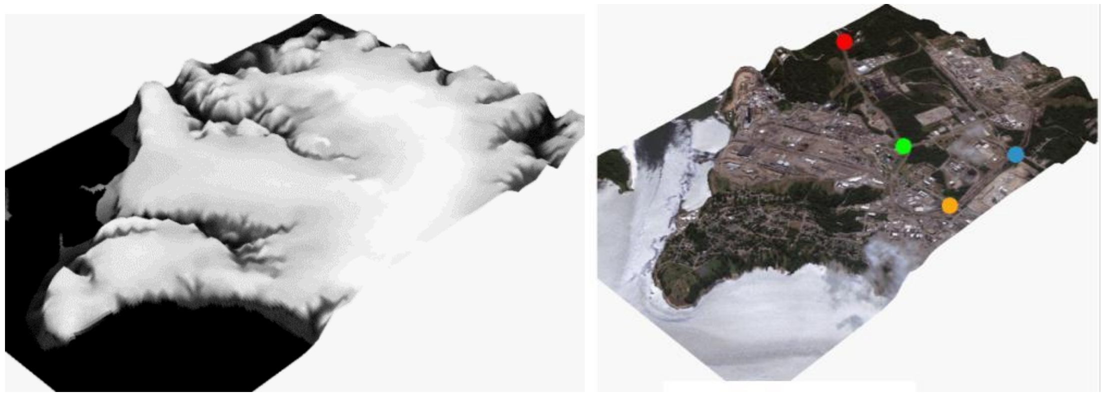


Figure 6-8 Hopewell DEM and Digital Surface Model

Figure 6-9 Use Hopewell Digital Surface Model to Detect Route Condition

6.9 Port Planning

Imagery analysis serves as basic tools for planning marine highway operations at new and emerging port areas, for creating a new port infrastructure or expanding port capability for upgrading port operations. At the Port of Hopewell, modal linkage connects two different modes of transport, potentially permitting efficient movement of cargo and commodities.

The imagery information collected thus far serves as a feeder for selecting the most suitable mode of loading between the two options: The lift on–lift off (Lo-Lo) port loading operation, or the Roll on–Roll off (Ro-Ro) Operation. Based on the access routes and port layout, a RO-RO operation in which the loading and unloading operation is conducted by horizontally moving equipment to a vessel, was determined to be most cost effective set up for marine highway operation at the port. To carry out RO-RO operations at the Port of Hopewell, the port will need to be equipped with a loading ramp that permits the movement of cargo handling equipment and other vehicles (trucks, forklifts, straddle carriers, tractors, etc.) between the access zone and the vessel. In order to improve port processing, the expansion of dockside zone (Red Zone in Figure 6-10) of existing Port of Hopewell is necessary.

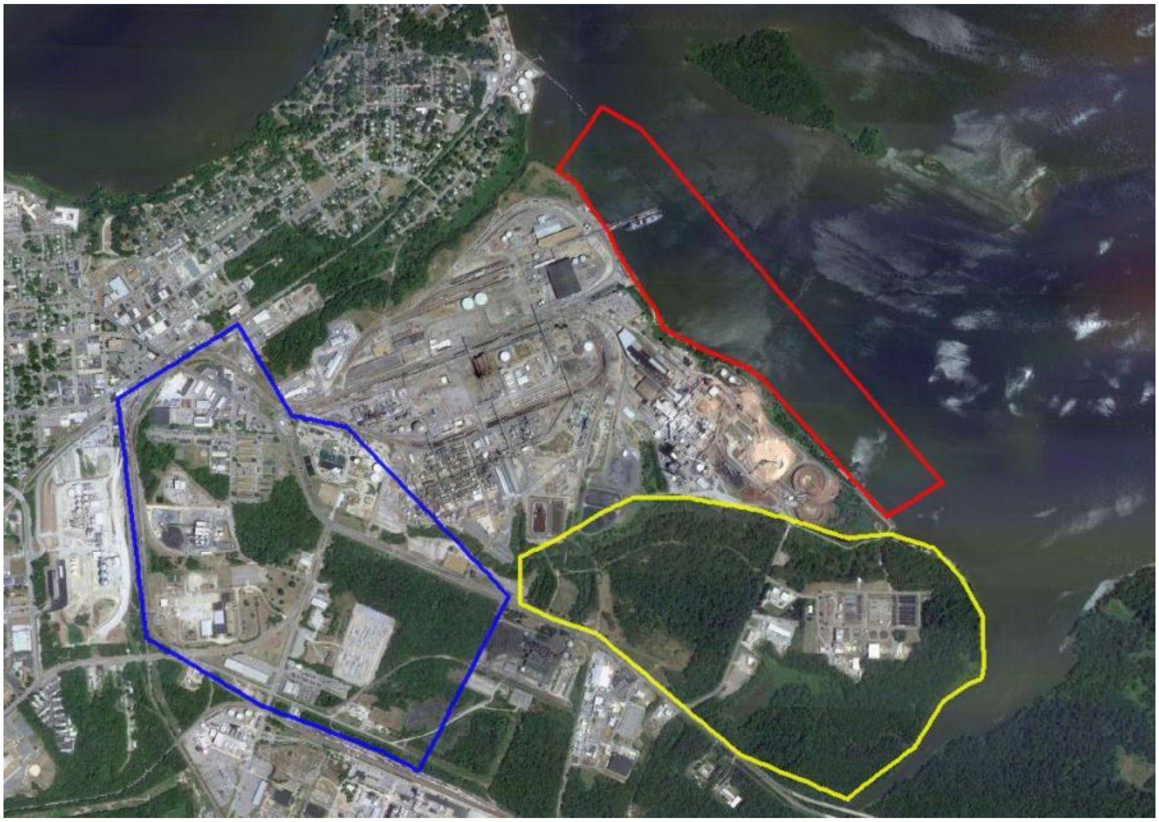


Figure 6-10 Port of Hopewell

For more efficient cargo uploading and unloading to vessels, Ro-Ro operations, construction of more berths and cargo terminal would be needed to maintain optimal waiting time for the vessels for loading. Even a proportionally small but persistent increase in the traffic of a port area may very quickly cause congestion, increasing expected congestion of Route 10 and 156 (Blue Zone). VDOT is currently planning to widen the routes in this area to relieve expected port traffic congestion. The identified potential bottlenecks based on imagery include E Randolph Road and S Hopewell Street (Figure 6-11).

Figure 6-11 Junction of Route 10 and 156 Is an Expected Congestion Area

6.10 Applying Land Cover Study for Marine Highway Ports Planning

Satellite remote sensing data and GIS facilitated land use and change planning was applied to transportation needs at and near port areas. Coupled with the ready availability of historical remote sensing data, the reduction in data cost and increased resolution from satellite platforms, remote sensing technology appears poised to make an even greater impact on planning agencies and land management initiatives involved in monitoring land-cover and land-use change at a variety of spatial scale.

Satellite remote sensing data is available at several spatial, spectral, and temporal resolutions by using the appropriate combination of bands to bring out the geographical and manmade features for detecting local land cover and changes. Remote sensing information, in concert with available enabling technologies such as GPS and GIS, can form the information base upon which sound planning decisions can be made, while remaining cost-effective. Based on remote sensing images, ground objects are classified in the Hopewell port area (Figure 6-12) and for comparing it with the Port area in Norfolk (Figure 6-13). The images, acquired at different times, contribute to an examination of transportation and regional growth in these areas. The layout of Hopewell port has barely changed during last decade while Port of Norfolk experienced infrastructure reconstruction including a container yard and parking lot (Figure 6-13).

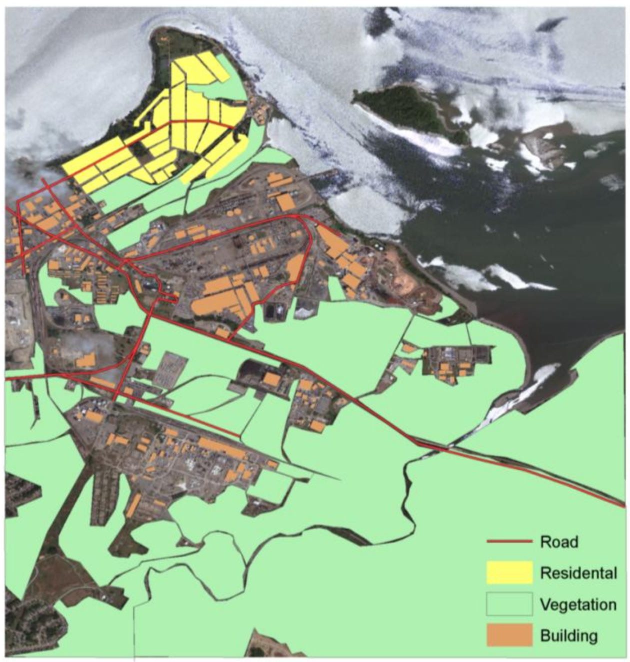


Figure 6-12 Land Cover Classifications in Hopewell, 2009

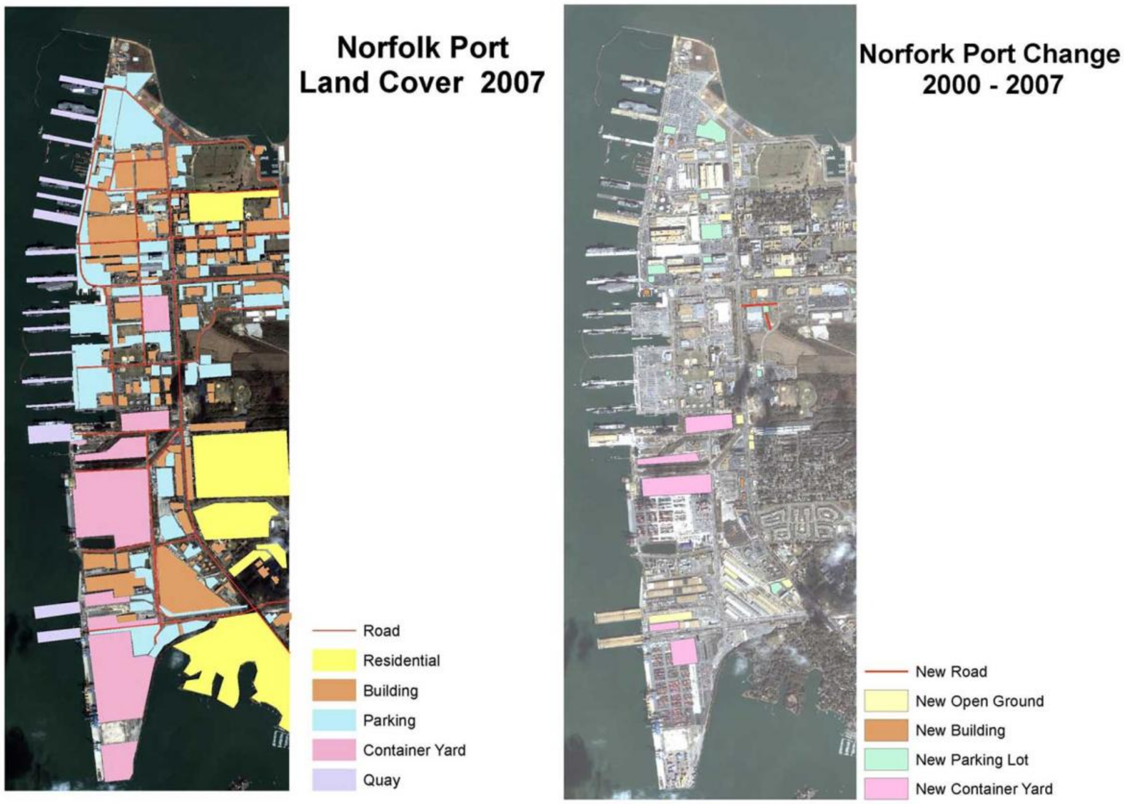


Figure 6-13 Land Cover Classifications for Port of Norfolk and Port Change from 2000-2007

Vector data layers for each object is generated for the purpose of updating existing road vector data used in modeling software. The vector data could also be used for further application in the modeling process to simulate the flow of container traffic in and around a port area.

6.11 Locating and Analyzing the Impact of Freight Distribution Centers Using Remote Sensing Images

Storage sites near port sites provide expedient connectivity to port locations for seamless marine highway operations. In addition to making good use of existing land in the port area, the patch of land east of the Port of Hopewell has the potential for warehouse construction to expand storage area.

The composite imagery provides an expedient tool for analyzing the potential need for locating storage sites to handle marine highways in and around the port. Freight Analysis Framework estimates commodity movements by truck and the volume of long distance trucks over specific highways. The network is used to disaggregate interregional flows from the Commodity Origin-Destination Database into flows among localities and assign the detailed flows to individual highways. It is based on geographic distributions of economic activity rather than a detailed understanding of local conditions.

6.12 Connectivity Planning Between Storage Sites and Port Sites for Marine Highways

GIS map overlay and local route digitalization serves to analyze freight flow to and from distribution centers for marine highway operations at ports.

For example, in the Virginia area under consideration, Cross Global Transport provides multi-port container service capabilities to and from Norfolk, VA; Savannah, GA; Houston, TX and Port NY/NJ. Figure 6-14 shows the connectivity between Cross Global distribution center in Virginia and nearby ports. In this study, the local routes networks at two Cross Global distribution centers in Virginia have been updated using satellite images.

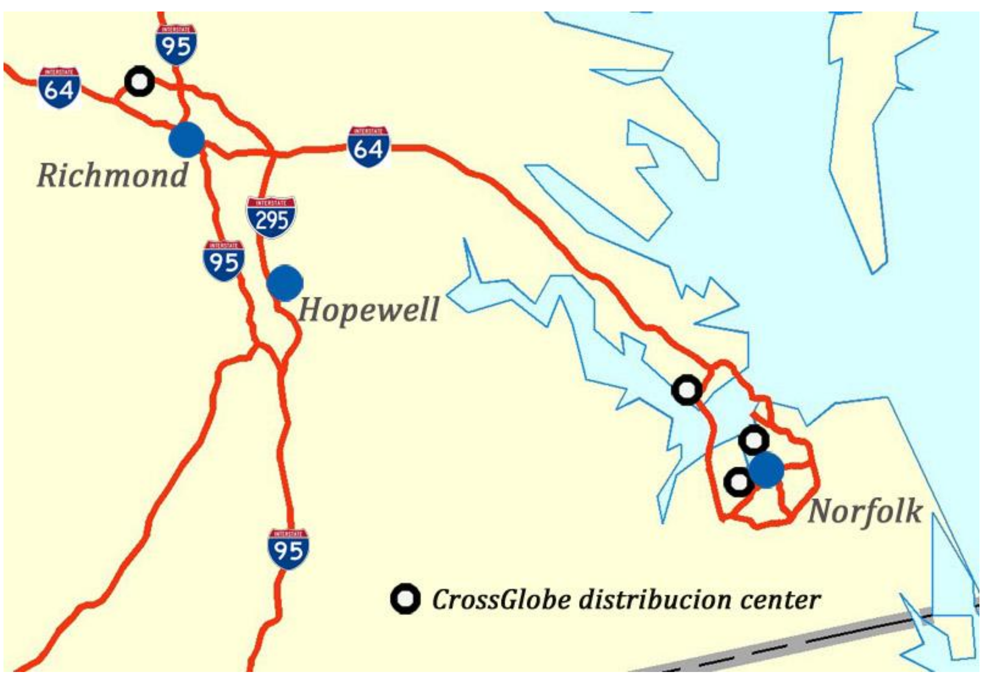


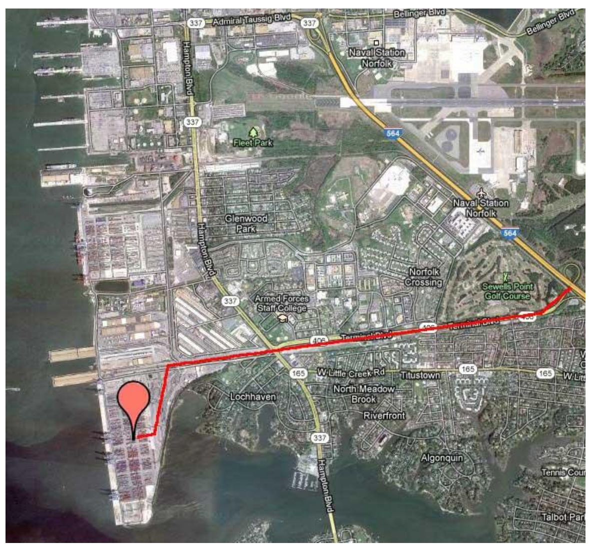
Figure 6-14 Connectivity Between Distribution Center and Nearby Ports

Integrating Flow from Distribution Center at Norfolk

This distribution center is strategically located on the dock at Norfolk International Terminal (NIT) and offers cost effective and expedited service to and from the port and their facilities.

The Norfolk distribution center is a multi-commodity distribution center with a high warehouse capacity for handling all modes of freight including break bulk cargo and container drayage. It is equipped with advanced Warehouse Management Systems (WMS) and scanning systems for rapid cargo transfer and storage.

Storage sites play an important role in intermodal system. The connectivity among ports, storage sites, and highway use is what most concerned the research team.



The connection between Norfolk distribution center and highway I-564

As shown below, the Freight Analysis Framework network at Norfolk was updated using the latest satellite image.

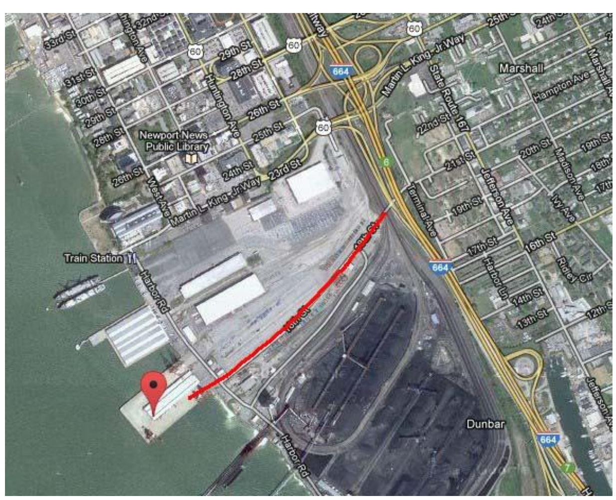
Original FAF network at Norfolk

FAF network updated with satellite imagery

Crossglobe Group Distribution Center at Newport News

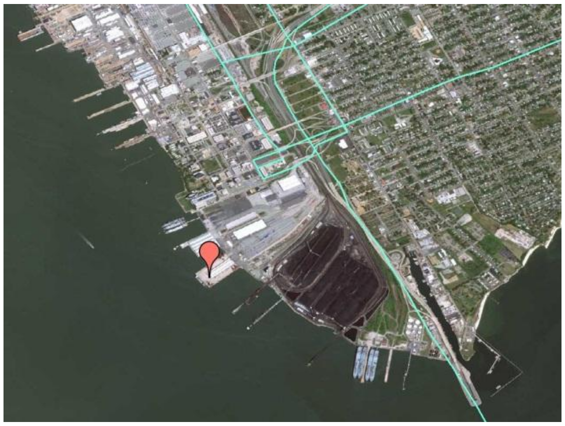
At the Port of Virginia, The CrossGlobe Group has partnered with the Virginia Port Authority (VPA) and Virginia International Terminals (VIT) to manage world-class distribution facilities in Newport News Marine Terminal and immediately outside Portsmouth Marine Terminal.

The distribution center is utilizing company owned trucking, trailer and special intermodal chassis equipment designed to transport over-weight and heavy import and export containers, which cannot be carried by most transport carriers. This capability provides import and export customers flexible transportation and payload options.

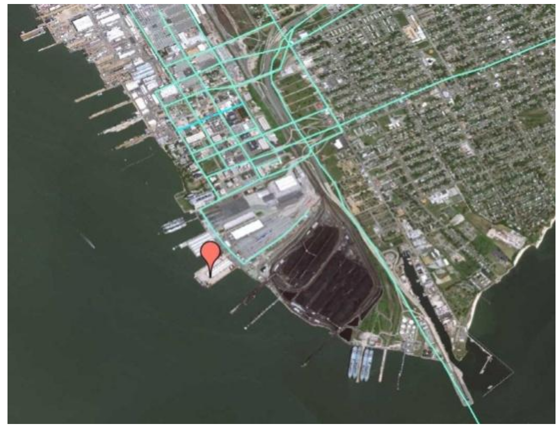


The connection between Newport News *distribution center and highway I-664*

The Freight Analysis Framework network at Newport News was updated using latest satellite image.



Original FAF network at Newport News



Updated FAF network

6.13 Conclusion

Among many transportation applications, marine highway planning is now able to take advantage of satellite imagery for a variety of aspects. The advances in remote sensing provide a new potential for quick examination of infrastructure condition of both waterway and highway network and comprehensive layout planning for port areas. In this study, remote sensing, coupled with Geographic Information System (GIS) and modeling analyzes, provide quantitative information for first line decision-making, thereby optimizing the whole planning process. Additionally, the study focus was on the short haul route between the Port of Richmond and Norfolk (Port of Virginia).

To alleviate congestion problems on I-64, the marine highway provides an alternative freight transport route in the navigable James River parallel to highway I-64. A number of ports were considered as options for diversions of truck flows to the James River waterway in the middle point between Richmond and Norfolk. Among five alternative port options, the Port of Hopewell was chosen for performing a hypothetical analysis--diverting freight to relieve traffic on a longer stretch of I-64. Additionally, the hypothetical selection presented an opportunity for evaluating remote sensing applications for effectiveness in first, selecting suitable smaller and less developed ports for marine highways, and then, how well these applications support the redesign of a candidate port.

The hypothetical scenario set by the GMU team proposes diversion of 30% of existing truck flows on I-64 to the port of Hopewell on the James River. Existing conditions and the hypothetical scenario for both truck flows and Vehicle Miles Traveled (VMT) were compared. The results show traffic congestion relief on I-64. Both truck flows and Vehicle Miles Traveled were reduced significantly. However, based on modeling results, the extra truck traffic flowing to Hopewell would require port expansion and improved access roadway infrastructure.

High Resolution satellite imagery, local digital elevation models, coupled with GIS tools, was applied to guide port development needed to increase port capacity, upgrade port operation, and expand access roads.

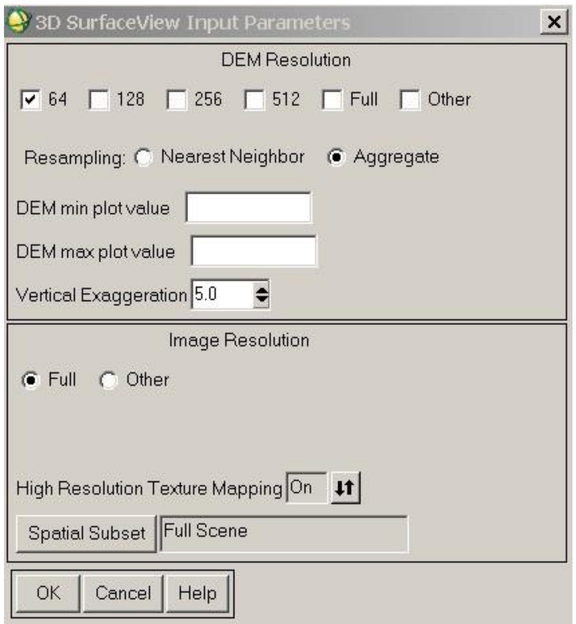
Satellite imagery has proved to be a powerful tool to provide information for studying, monitoring, and managing infrastructure for marine highways. The results demonstrate a new potential not only for national examination of waterways currently unused but also for investigating port infrastructure development needs and local road network planning.

6.14 Some Usage Guidelines

3-D Digital Surface Model Generation

When high resolution satellite imagery is overlaid with Digital Elevation Models (DEM), 3-D digital surface is generated. The 3-D imagery shows the feature of landscape and provides topographical information for ground objects.

The 3-D digital surface model is created and visualized by ENVI's 3-D SurfaceView window. Envi, developed by Exelis VIS, is a consumer-oriented, remote sensing software application which is widely applied to process and analyze geospatial imagery. 3-D SurfaceView can be selected in “Topographic” from the ENVI main menu bar. Once it is opened, an image file is selected to input and optional Spatial Subsetting can be performed, then click OK. The 3-D SurfaceView Input Parameters dialog appears. Many parameters can be controlled in parameters dialog including: DEM resolution, image resolution, resampling methods and vertical exaggeration. Then, 3-D SurfaceView overlays input image with DEM to generate 3-D digital surface model. If both files are geo-referenced, then ENVI uses only the part of the image that overlaps with DEM.



3-D SurfaceView Input Parameters

The 3-D SurfaceView in ENVI can do the following:

- Display the surface data as a wire-frame, a ruled grid, or as points.
- Drape the surface data with a gray scale or color image, and overlay it with region of interests and vectors.
- Rotate, translate, and zoom in and out of the surface in real time using the mouse cursor or the 3-D SurfaceView Controls dialog. The cursor is also linked to your draped image allowing cursor locations, values, and profiles to display from the 3-D view.
- Define a flight path (interactively or with a drawn annotation). Flight path can be animated to produce 3-D fly-throughs of your data. Both vertical and horizontal view angles can be controlled to fly through data at a constant height above the surface or at a constant altitude.
- Use perspective controls to place the visual perspective in the 3-D SurfaceView and rotate the surface around that perspective.

Land Cover Study for Port Areas

The combination of satellite imagery and GIS technique for land cover, land use and its changes is a key to many diverse applications such as environment, agriculture and transportation. Although many land cover types such as vegetation and bare soil can be unsupervised identified based on spectral signatures obtained from training samples, in this study, for more accurate ground objects classification, different infrastructure types are artificially identified based on high resolution imagery.

Different classes are created and presented as format of shapefile layers in ArcGIS platform. Shapefile, a popular geospatial vector data format for GIS software, spatially describe three types of ground features: points, polylines, and polygons. Each shapefile has an attribute table associated with it. In this study, each infrastructural type is presented by a single shapefile layer. Before the start the process of physically creating a new data layer, the data design issues is need to think about for both the geographic part (point, line or polygon) and the attribute table (information need in the table).

Creating the geographic feature (point, line, or polygon)

After identifying remote sensed image for interested area input as a base map for on-screen digitizing, a new shape file under designated folder can be created in ArcCatalog by using the **File-New** menu. When you choose File-New, you must specify a new shapefile name and feature type (point, line, or polygon). You should also specify a coordinate system by pressing the **Edit...** button. You can specify this either by pressing **Edit**, then **Select**, then choose **Projected**, then navigate to the desired coordinate system. Or you can press **Edit**, then **Import**, then navigate to an existing shape file for which the coordinate system is specified.

Creating the attribute table

The creation of attribute table associated with shapefile is separate from the creation of the shapefile itself. In ArcCatalog, right-click on the new shapefile and choose **Properties**. Then click on the **Fields** tab and add new fields. Each field need a name and other field properties need to be defined.

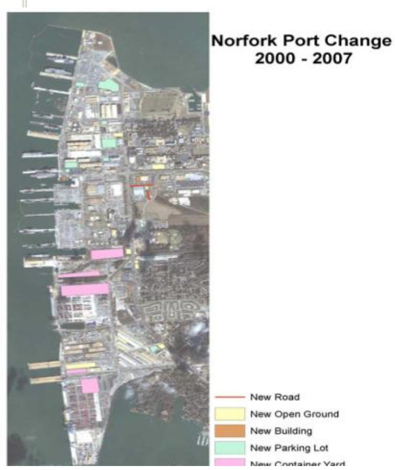
Adding and editing geographic features and attributes in ArcMap

After creating the shapefile it may be added to ArcMap to begin the actual digitizing process.

Once the shapefile is added, make the Editor toolbar visible (choose **View-Toolbars-Editor**).

Follow the instructions in *ArcGIS Desktop Help* or the digital manual for *Editing in ArcMap* - creating new features.

Choose **Edit-Start Editing** to begin creating new features. You can add points, polyline or polygon features depending on shapefile type. For land cover map of Norfolk Port 2007, polygon shapefiles were created for five infrastructure types: residential area, building, parking lot, container yard and quay.



We'll use the polygon feature to demonstrate this process. To create a polygon feature, place the cursor on the map where you want to begin your new feature -- you should see a circle with a cross-hair in it. Click once. Go to the next point that defines a polygon and click again. Continue doing this until polygon almost forms. To close the polygon, double-click on the next-to-last point, or press F2 after the next-to-last point. When a boundary polygon or polyline compete for study area, choose Edit **- Save Edits** and leave editing mode by choosing **Edit-Stop Editing**. Different land cover types are created as a form of shapefile layer in ArcMap. The map would be improved if different land cover classes were properly colored and necessary map elements, such as map title, legend and scale bar, were added. When the landcover map is finished, the map can be exported by choosing **File – Export.**, Map resolution can be adjusted in the Option and quality of the output map can also be controlled before final export Press **Export** when everything is satisfactorily completed - the process will take a few minutes.

Updating Freight Analysis Framework

Freight Analysis Framework estimates commodity movements by truck as well as the volume of long distance trucks over specific highways. The network data files are presented in both ESRI format and TransCAD format. Due to rapid road construction, road network in Freight Analysis Framework is likely to be outdated. As a result, latest satellite image is applied in this study as a base map for on-screen road network digitizing and upgrading.

After both remote sensed image and Freight Analysis Framework are imported into ArcGIS, make sure **Start Editing** is selected to start creating new polyline features on existing Freight Analysis Framework.

Create a new line

1. Select the Line layer in the Create Features dialog
2. Choose the Line Construction Tools Click once to start the Line
3. Click once to add each vertex along new road; double-click to finish the line or right-click and Finish Sketch.

Edit a line

1. Select the Line layer in the Create Features dialog
2. Choose the Edit Tool (Arrow) on the Editor Toolbar.
3. Double-click on the line to modify. The line is now highlighted with the vertices shown.
4. Hit the delete key to delete the line
5. Click and drag a vertex to a new location to move a vertex.

6. Right-click on the line to add a vertex.
7. Mouse-over and right-click on a vertex to delete the vertex.
8. Click anywhere on the map (except on the line) to deselect the line

When polyline features are completely created, choose **Edit - Save Edits** and leave editing mode to finish Freight Analysis framework upgrade.

Original FAF network at Norfolk

FAF network updated with satellite imagery

7. TECHNOLOGY TRANSFER FROM EUROPEAN SHORT SEA SHIPPING PRACTICE

European Countries have over four decades of successful marine highway experience. The European Union (EU) coordinates research and operational program initiatives for Europe. The EU has been funding short sea shipping initiatives over the past three decades. These initiatives have significantly helped the growth and modernization of the European short sea shipping practice and the European freight transportation competitiveness. A delegation of about ten marine highway experts representing several European countries met with about 60 invited participants from stakeholders, operators, state and local agencies and the marine highway community from United States in a technology transfer workshop session in July 2011. The lessons learned and the findings transferable to U.S. practice are the following:

1) The European Union has organized several national outreach centers to help local regions to implement marine highways (short sea shipping) as an alternate mode of transportation. Establishing similar outreach centers within state transportation agencies in United States would significantly help to advance the adoption of U.S. marine highways as an alternate mode of freight transportation using available waterways in U.S.

2) The focus of European transportation short sea shipping and transportation research has been on reducing congestion and improving transportation performance and reliability. Diverting freight from road ways to waterways for bypassing congested urban routes has proven to be highly successful in Europe. The European practice is transferable to U.S. marine highway operations for relieving congestion in freight corridors.

3) Europe has been highly successful during the past three decades in significantly increasing the use of available waterways, thus increasing transportation capacity with lower infrastructure investment, compared with roadway or railroad expansion. Europe transports over 36% of freight through waterways compared with 4% of freight transported in U.S. waterways. Over 75% of usable waterways in the U.S. remain underutilized.

4) The U.S. should make efforts to increase utilization of waterways for freight transportation.

5) Remote sensing and spatial information technologies are deployed in European short sea shipping operations for intermodal planning at ports, precision docking and for reducing in-port time for loading and unloading. Several of these technologies are transferable to U.S. marine highway operations.

6) The advances in E-maritime technologies are mutually transferable. The short sea shipping operations in Europe have a wide network to communicate with intermodal operators, specifically on drayage logistics before arriving at the port. The EU's E-Maritime is interoperable between Member States.

7) Roll On - Roll Off (RO-RO) systems have been the mainstay of short sea freight shipping in European operations for avoiding congestion on urban roadways. Europe has decades of experience in applying and innovating RO-RO systems. The advances in European methods for diverting traffic from congested urban corridors using the RO-RO operational process are transferable to U.S. marine highways.

8) The European Commission is supporting wider application of waterways for achieving increased freight capacity and a modal shift of freight transportation from highways and railways to waterways. The European Union funds and manages several initiatives to promote efficient short sea shipping methods, processes and technologies. The objectives of these initiatives are to integrate short sea shipping in the supply chain system, reduce turnaround time in ports and modernize customs and clearance operations and administrative procedures. Some examples of the initiative are:

<u>The Marco Polo</u> Initiative: The initiative is designed to reduce congestion and improve the environmental performance of intermodal and marine transportation systems. The program is in its second phase. Phase II has wide geographical scope including new connecting intermodal short sea shipping links within Europe and between Europe and other countries. The objective of the program initiative is to achieve the following:

- Overcome barriers in freight transportation for reaching European and international market
- Achieve modal shift of freight to multimodal transportation from roadways to waterways
- Improve cooperation between European countries on freight transportation logistics

Motorways of the Sea Program: The initiative focuses on introducing new intermodal maritime-based operations to manage flow of freight, reduce road congestion, increase freight capacity and relieve over-stretched European roadway systems. The initiative emerged from an idea introduced by the 2001 White Paper on European transport policy, designed on shifting major portions of freight transportation from road network to short sea shipping and combining short sea shipping with other modes of transportation for reducing highway freight congestion. The program improves port communications within intermodal systems and with the European continent and thus strengthens networks between European countries. Salient features of the motorways of the sea program are:

- Increasing accessibility of candidate countries in Eastern Europe to the European market
- Focusing on methods and technologies for reducing road congestion
- Enhancement of coordination between Member States for improving maritime links
- Development of high quality logistic services
- Policy measures for encouraging intermodality in European transport systems.

European Maritime Space without Barriers Program: Unlike freight transport by highways, shipments of goods by sea between the ports of the European Union are treated in the same way as shipments to third countries. Consequently, maritime transport between member States involves many documentary checks and physical inspections by the customs, health, veterinary, plant health and immigration control officials. European Maritime Transport Space without Barriers is a concept for improving the efficiency and competitiveness of intra-EU maritime trade and simplifies the maritime transport process. The initiative proposes to achieve the following:

- Simplify customs formalities for vessels transporting goods between EU ports
- Draw up guidelines for best practices
- Replace and expand "FAL directive" 2002/6/EC (Refers to clearance process)

- Simplify administrative procedures for vessels connecting EU ports.

The Blue Belt Pilot Project: The Blue Belt pilot project was launched by The European Commission and designed to reduce administrative burdens in short sea shipping. Creating a "blue belt" for maritime transport enables operations within the internal market, with minimal administrative burden and facilitates the use of the latest navigation technologies. A new project named Safe SeaNet will apply advanced technologies and make it easier for authorities to distinguish between ships engaged exclusively in internal EU-trade and global trade.

Sustainable Waterborne Transport Toolbox: The tool box under development assists the short sea shipping sector to improve its environmental performance, while maintaining its competitive position. The tool box includes use of alternative fuels such as Liquefied Natural Gas (LNG). The tool box provides guidelines for facilitating integration of short sea shipping into door-to-door logistic chains and fosters innovations for handling future capacity growth.

Development of Multiple Interactive Tools for Marine Highway Management: A European firm from the UK (AECOM) specializing in short sea shipping, has developed a public benefit calculator, a user-friendly online calculator for arriving at the total cost benefits of modal shift to marine highways. The calculator also helps transportation planners with internet based emission reporting software.

E-Maritime Initiative: The EU e-Maritime initiative aims to foster the use of advanced information technologies for the maritime transport sector and stimulate coherent, transparent, efficient and simplified solutions of interoperability between Member States and transport operators.

European River Information Services (RIS) concept: The concept is aimed at implementing information services to support the planning and management of traffic and transport operations. The RIS promises to transform inland waterway transport into a transparent, reliable, flexible and easy-to-access transportation mode. RIS enables compatibility and interoperability for seamless interaction between information services on waterways such as:

- Information on geographical, hydrological and administrative data to monitor a voyage (e.g., water levels, traffic signs, opening hours of locks);
- Traffic information services that display strategic traffic information (spatial information display of vessels and their characteristics over a larger geographical area, including forecasts and analyses of future traffic situations);
- Traffic management for improving the efficiency of vessel traffic;
- Accident services for providing incident data immediately to the rescue and emergency teams;
- Information for transport management including estimated times of arrival (ETAs), data on vessels and the fleet and detailed information on cargo transported;
- Statistics for facilitating the collection and display of cargo data within Member States;
- Automatic waterway invoicing.

<u>The Case of Cargo Flow Imbalances in European Marine Highways</u>: Some European countries are experiencing imbalance in cargo flows and market penetration. These cargo imbalances are caused by: 1) lack of availability of experienced drivers; 2) stricter regulations of driving hours; 3) increased delay times caused by highway congestion; 4) decrease in number of available haulers; and 5) longer waiting time at country's borders caused by congestion and processing time. The marine transportation in Spain offers a typical example for imbalanced cargo flows caused by a high percentage of seasonal agricultural exports from Spain, large differences in market development and imbalances in import and export commodities.

<u>The Dutch and Belgian Waterways</u>: In Europe the main hub of short sea shipping is in Rotterdam, the largest European port. The Dutch and Belgian main waterways locks and bridges are designed for marine highway traffic. Because of congestion in larger ports, a number of smaller ports have been developed with appropriate port infrastructure, similar to Rhine-ports such as Duisburg and Dortmund in Germany. In 2009 the total freight transport by short sea shipping in the Belgian waterways amounted to 1.68 billion tons. The majority of short sea flows take place between partnering ports situated in the Mediterranean (566m tons) and the North Sea (504m tons).

(All presentations from the Workshop are posted on the GMU web site on the DOT project on Remote Sensing and Spatial Information Technologies Application to Marine Highways (eastfire.gmu.edu/Marine_Highway_Freight_System/)