



# Great Lakes Maritime Research Institute

A University of Wisconsin - Superior and  
University of Minnesota Duluth Consortium

## WebGIFT-GL: Expanding Access to the Great Lakes Geospatial Intermodal Freight Transportation (GL-GIFT) Model

### *Final Report*

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# R·I·T



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## Executive Summary

The Great Lakes Geospatial Intermodal Freight Transportation model (GL-GIFT), developed under prior funding from the Great Lakes Maritime Research Institute (GLMRI), the U.S. Department of Transportation Maritime Administration, and others, has proven effective in understanding the trade-offs and impacts of intermodal freight transportation policy decisions in the Great Lakes/Saint Lawrence Seaway region in the U.S. and Canada. We have used GL-GIFT to analyze (1) economic, energy, and environmental impacts associated with freight movement in the region, including the ability to make tradeoffs among different freight modes (marine, rail, and truck); (2) decisions related to highway and intermodal facility infrastructure development; and (3) decisions and policies aimed at improving maritime transport efficiency in the region. We have conducted route analyses comparing and optimizing various transportation network attributes and vehicle selections, including: cost, time-of-delivery, distance, energy use, and emissions of various vehicle configurations. Our case studies have shown that Great Lakes marine shipping demonstrates certain advantages when compared to landside modes such as trucks and rail.

Unfortunately, GL-GIFT is not easy to use except by trained experts in freight transportation policy and in Geographic Information Systems. Further, users need to install rather expensive hardware and software on their desktop computers and maintain the systems and GL-GIFT data. The new project moved the core capabilities of GL-GIFT from a desktop computing environment to a Web-based platform, making it available to many users via the internet. The new model, called WebGIFT-GL, eases the process of creating analysis scenarios and interpreting the results, and it minimizes the cost of using and maintaining GL-GIFT. WebGIFT-GL is available to any user with a Web browser at <http://webgift.rit.edu/>.

WebGIFT-GL enables policy analysts, regional planning organizations, non-government organizations, shippers, carriers, and others to do basic impact and trade-off case studies specific to their needs. It has an easy to use interface that guides a user through the analysis scenario creation and interpretation of results. Through usability testing and design, we have evolved the user interface and system behavior through three iterations, and we continue to make improvements based on user feedback and new opportunities developed from our evolving desktop-based GIFT-GL. We are continuing to improve WebGIFT-GL in response to on-going user feedback.

There were some technical and project management challenges which we had to overcome. In the middle of the project, we switched Web browser and Web server technology to leverage non-proprietary products where possible. We had issues hosting an externally used production Web application from within the security and policy constraints of a university focused on campus administration needs. We worked hard to provide consistent, capable software development talent using a large number of transient students who graduate and leave for co-op jobs. We were able to overcome these challenges, but not without delay and important lessons learned.

This report provides details on the intuitive user interface design study, the development of a vehicle and facility library, and the overall design, implementation, and support effort.

We are proud and honored to have worked with GLMRI to develop and demonstrate a successful WebGIFT-GL project. We are now working with the Maritime Administration to further enhance WebGIFT and to roll it out to a broader audience.



## **1. Introduction**

In prior Great Lakes Maritime Research Institute (GLMRI) projects, RIT and the University of Delaware developed and demonstrated the value of the Great Lakes Geospatial Intermodal Freight Transport (GL-GIFT) model – an innovative, dynamic, network optimization model for analyzing: (1) the economic, energy, and environmental impacts associated with Great Lakes freight movement, including the ability to make tradeoffs among different freight modes operating in the Great Lakes; (2) decisions related to various highway and intermodal facility infrastructure development; and, (3) decisions and policies aimed at improving maritime transport efficiency in the Great Lakes. GL-GIFT allows users to conduct route analyses based on various network attributes, including: cost, time-of-delivery, distance, energy use, and emissions. Our case studies have shown that Great Lakes marine shipping demonstrates certain advantages when compared to landside modes such as trucks and rail.

This new project moved the core capabilities of GL-GIFT from a desktop computing environment to a Web-based platform so that it will be available to many users via the internet. We have developed user-friendly interactions to support case study definitions, data management and sharing, and analysis. We have made this new tool, called WebGIFT-GL, available to GLMRI affiliates and other selected users. With on-going support from the US Department of Transportation Maritime Administration (MARAD), we are continuing to enhance and support WebGIFT-GL.

This report captures the effort to specify, design, implement, and deploy WebGIFT-GL, and it captures key results and lessons learned on this project.

## **2. Project Objective: Availability and Ease of Use of GL-GIFT**

GL-GIFT has proven valuable in understanding the environmental, economic, and energy trade-offs across freight transportation modes in the Great Lakes region. Our prior years' projects used the desktop-based tool to perform case studies of (1) containerized freight movement between Montreal, Quebec and Cleveland, Ohio and (2) high-volume bulk (in this case, coal) movement. In the first study GL-GIFT helped us understand, for example, that the type of vessel used impacts the thresholds for the selection of marine over rail transport for the least CO<sub>2</sub> impact, and how these vessel choices compared against rail and truck transport on environmental and time-of-travel factors. In the second study we found that intermodal routes that combine rail transport for land-side segments with transfer to marine routes for segments that can cover significant distances (such as the Great Lakes or coastal short-sea routes) could lead to significant operating cost savings and reduced CO<sub>2</sub> emissions, as well as other pollutants.

Unfortunately, performing these case studies is time consuming, sometimes confusing, and requires detailed multimodal freight transportation practice and policy expertise to properly set up the cases and interpret the results. Further, the policy analyst would need GL-GIFT installed and configured on their local computer, requiring significant software license costs (for ArcGIS) and installation and continuous update and maintenance of large data sets that model the water/rail/road transportation network, intermodal transfer facilities, and variety of vessels, trains, and trucks available. Feedback from workshops and coursework using GL-GIFT also

indicated that users need a basic competency in using ArcGIS to take full advantage of GL-GIFT.

Our goal in the WebGIFT-GL project was to make core GL-GIFT functionality available to a broad range of users via Web-based access and intuitive user guidance. We want to enable policy analysts, regional planning organizations, non-government organizations, shippers, carriers, and others to do basic impact and trade-off case studies specific to their needs. Although WebGIFT-GL does not provide all the functionality that an advanced analyst might require, it provides the necessary functionality to perform environmental and economic trade-off analysis of multi-modal freight transportation between origination and destination pairs. For more advanced users, we continue to develop and enhance the desktop-based GL-GIFT. We will continue to move functionality developed for GL-GIFT to WebGIFT-GL, as appropriate.

Through a limited initial roll-out and trial use, we have gathered information on the costs and feasibility of providing WebGIFT-GL as a service to government, non-government and non-profit organizations. We are now working with the US Department of Transportation Maritime Administration (MARAD) for a broader roll-out aimed at increased acceptance and use.

### **3. Project Tasks and Summary of Accomplishments**

The WebGIFT-GL project was structured with the following tasks. For each task we summarize the accomplishments here and provide details in the next section.

#### **Task 1: *GL-GIFT Model Update***

We have updated and validated the GL-GIFT geospatial models of the highway, railway, waterway, and intermodal facilities in the Great Lakes and St. Lawrence Seaway region. This includes incorporating the 2010 National Transportation Atlas Database (NTAD), the STEEM international waterway network from our partners at the University of Delaware, and adding delay buffers around railyard, port, or truck terminal facilities where freight is delayed due to freight handling. We have also provided a library of vehicle/vessel performance data models that capture the emissions, energy, economic cost, and time impact of freight movement.

#### **Task 2: *WebGIFT-GL Software Requirements Definition***

This task elicited, specified, and validated requirements of WebGIFT-GL. It included end-user functionality as well as system requirements (performance, security, etc.) and support requirements (system administration and support). The core functional requirements are captured in Appendix A of this report.

#### **Task 3: *WebGIFT-GL User-Computer Interface Design and Usability Assessment***

Since a key objective of developing WebGIFT-GL is to make GL-GIFT functionality easier to use by non-experts, user-computer interface design was essential. We developed and evaluated the usability of a number of user interface options and designed the WebGIFT-GL user interface based on these results. There were challenges due to the limitations of Web browser-based user interfaces and the technology supported by ESRI's ArcGIS Server (ArcGIS is the underlying Geographic Information System on which WebGIFT-GL is based).

**Task 4: *WebGIFT-GL Design and Development***

Design and development of WebGIFT-GL was the main task of this project. Based on the existing desktop-based GL-GIFT, new WebGIFT-GL software requirements, and the user-computer interface design developed in Task 3, we selected appropriate implementation technologies and designed and developed WebGIFT-GL. The limitations of browser-based user interfaces and the complexity of Web-based application services were challenges, as were the difficulties of using students as designers and developers.

**Task 5: *WebGIFT-GL Software System Test and Acceptance Test***

Incremental versions of WebGIFT-GL have been deployed and tested for over six months. Although we did not get the volume and diversity of user testing that we wished for, we did gather experience that improved the user-computer interface, system administration and support, and system security management.

**Task 6: *WebGIFT-GL Limited Deployment, Training Workshop, and Trial Operations Support***

We had planned for a trial operation of WebGIFT-GL with end-users evaluating the system. This task was accomplished through the development of a user manual and training materials. We also employed the system within our development teams and demonstrated and discussed its use with potential users in the GLMRI affiliates, MARAD, and the Genesee Regional Transportation Council.

**Task 7: *Quarterly and Final Reports***

We provided quarterly progress reports and annual reports to GLMRI. This report serves as the project Final Report.

**4. Project Results**

The next sections detail the work performed in the above tasks and the results of that work. This includes the user interface design study, the vehicle and facility cost factor set library, and the system design, implementation, and support of WebGIFT-GL.

**4.1. User Interface Design**

The target users for WebGIFT-GL are transportation analysts in a metropolitan or regional planning office, freight shippers and receivers working to understand the trade-offs in carrier and mode choices, and freight carriers seeking to balance environmental, economic, and social impacts of freight transportation. To use WebGIFT-GL to perform basic intermodal trade-off case studies, the user must be familiar with the basics of geographic information systems (GIS) and intermodal freight movement. However, they need not be expert GIS users and freight policy analysts who would use Desktop GIFT-GL. For those advanced users, we are continuing to develop and enhance Desktop GIFT-GL. WebGIFT-GL provides a subset of GIFT-GL functionality that is more intuitive. WebGIFT-GL is targeted at “advanced novices.”

The following sections first illustrate and explain the current WebGIFT-GL user interface, then present the user interface design study that led to the current user interface design.

## 4.2. Current WebGIFT-GL User Interface

When first starting WebGIFT-GL, the user is presented with the screen in Figure 1. (Note: this user interface is as provided in June, 2012, which is version WebGIFT v3-alpha.) The map represents the Great Lakes region with major highways and railways as yellow lines, waterways as blue lines, and intermodal transfer facilities as yellow triangles. These are GIS layers overlaid on a base map showing an aerial image of the region (from the ArcGIS on-line Basemap database). Zooming in to a medium resolution image, such as Figure 2, separates the landside transportation network into major highways, minor highways, and rail lines. A higher-resolution image, such as Figure 3, allows the user to see details, such as a transportation route using a railyard for inter-mode transfers.

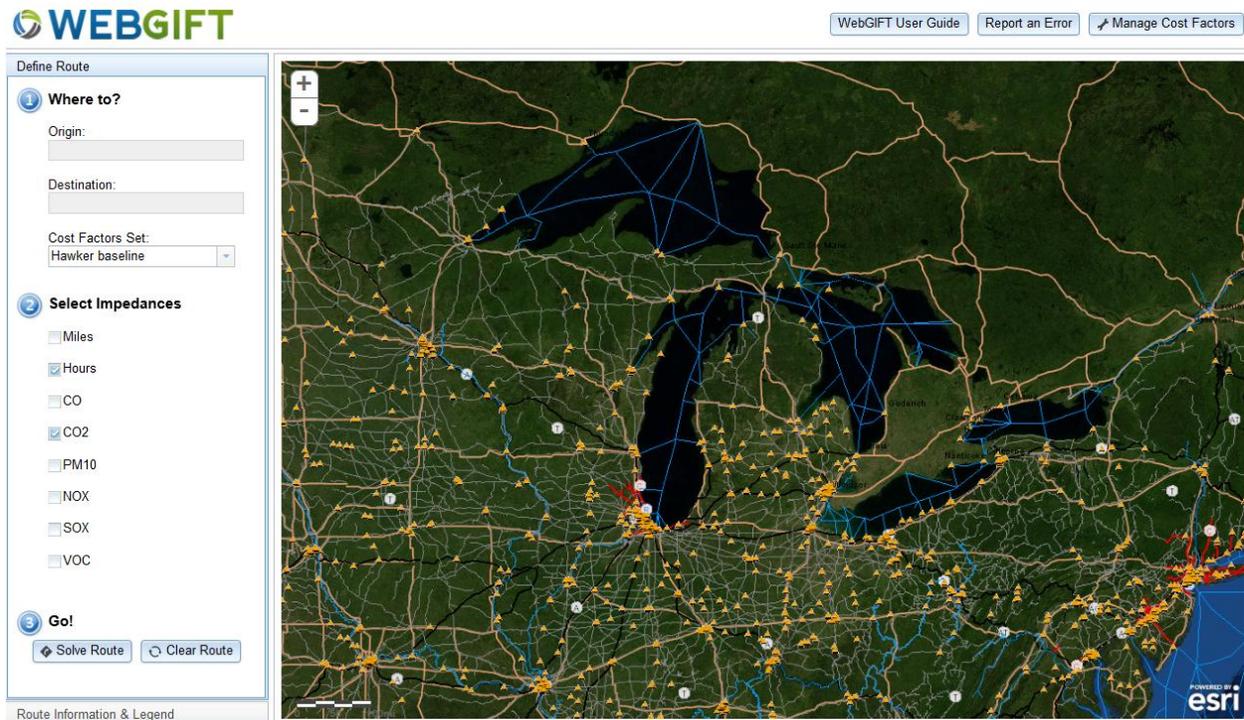
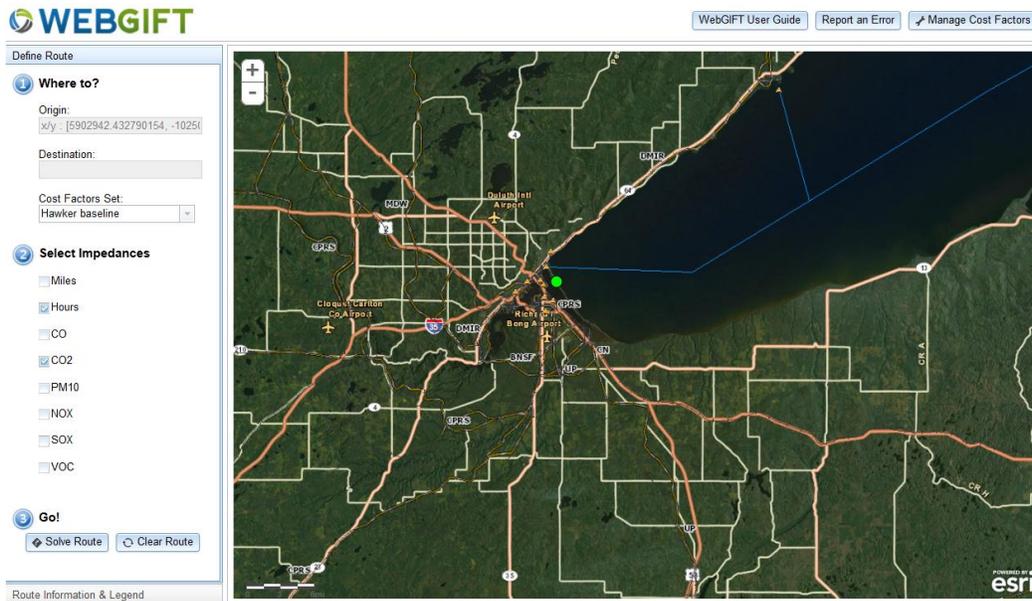
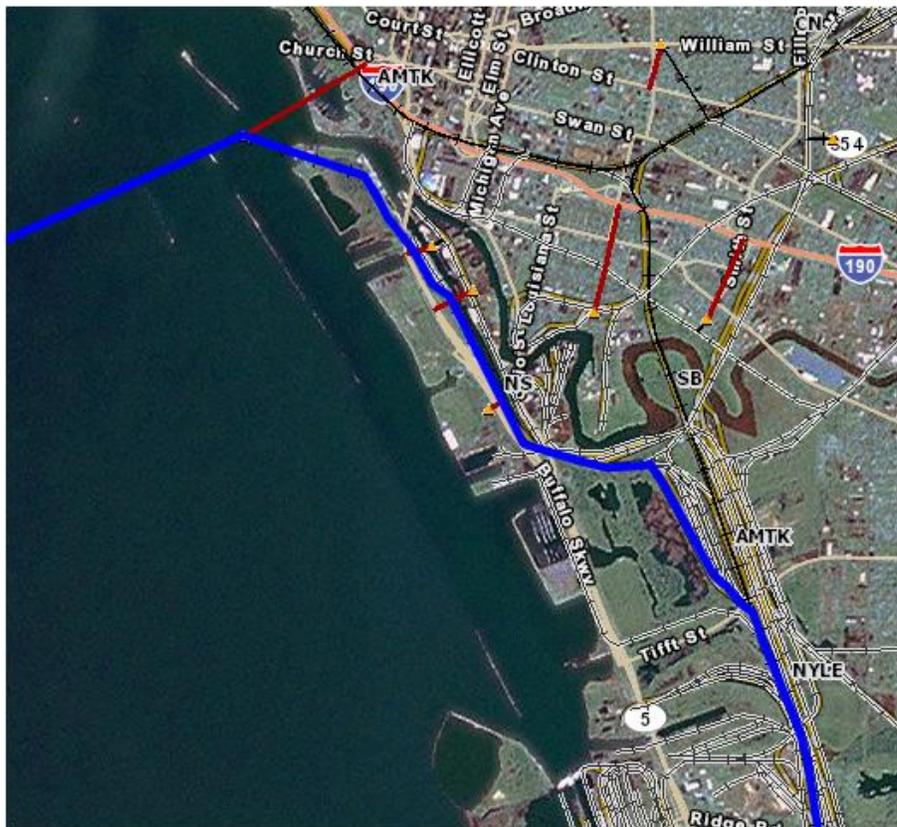


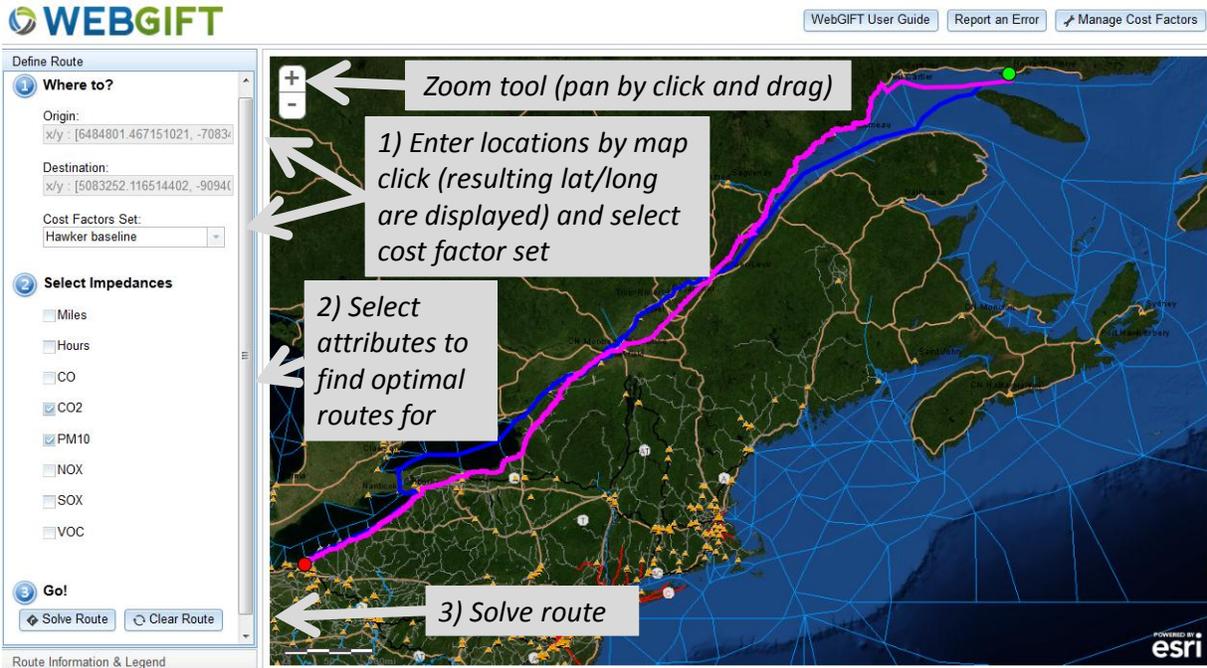
Figure 1. The start-up user interface screen for WebGIFT-GL (WebGIFT v3-alpha)



**Figure 2.** A medium resolution map shows major highways (orange), minor highways (beige), rail lines (hashed orange and white), and water routes (blue) (WebGIFT v3-alpha)



**Figure 3.** Detailed view showing the transfer from water to rail in the Port of Buffalo, NY. (WebGIFT v3-alpha)



**Figure 4. Steps to define and solve optimal routes (WebGIFT v3-alpha)**

On the left side of the initial user interface screen (see Figure 4) is a multi-step process to guide the user in configuring WebGIFT-GL with what routes to solve for. First the user interacts with the map, panning and zooming to select origination and destination locations. The user can select from known multi-modal transport facilities, which are indicated on the map as orange triangles (railyards and truck terminals) and purple dots (ports). Next, the user selects what attributes to optimize for the routes (a minimal time route, a minimal CO<sub>2</sub> route, etc.). Finally, the user selects the “Solve Route” button to launch the route solver on the WebGIFT-GL Web server. The route definition information is sent across the internet from the browser-based user interface to the WebGIFT-GL server (residing at RIT), which solves for the designated routes. This often takes a while because of the size and complexity of the search space (see Figure 5). It takes a similar amount of time on Desktop GIFT-GL, so the delays are not due to internet traffic.

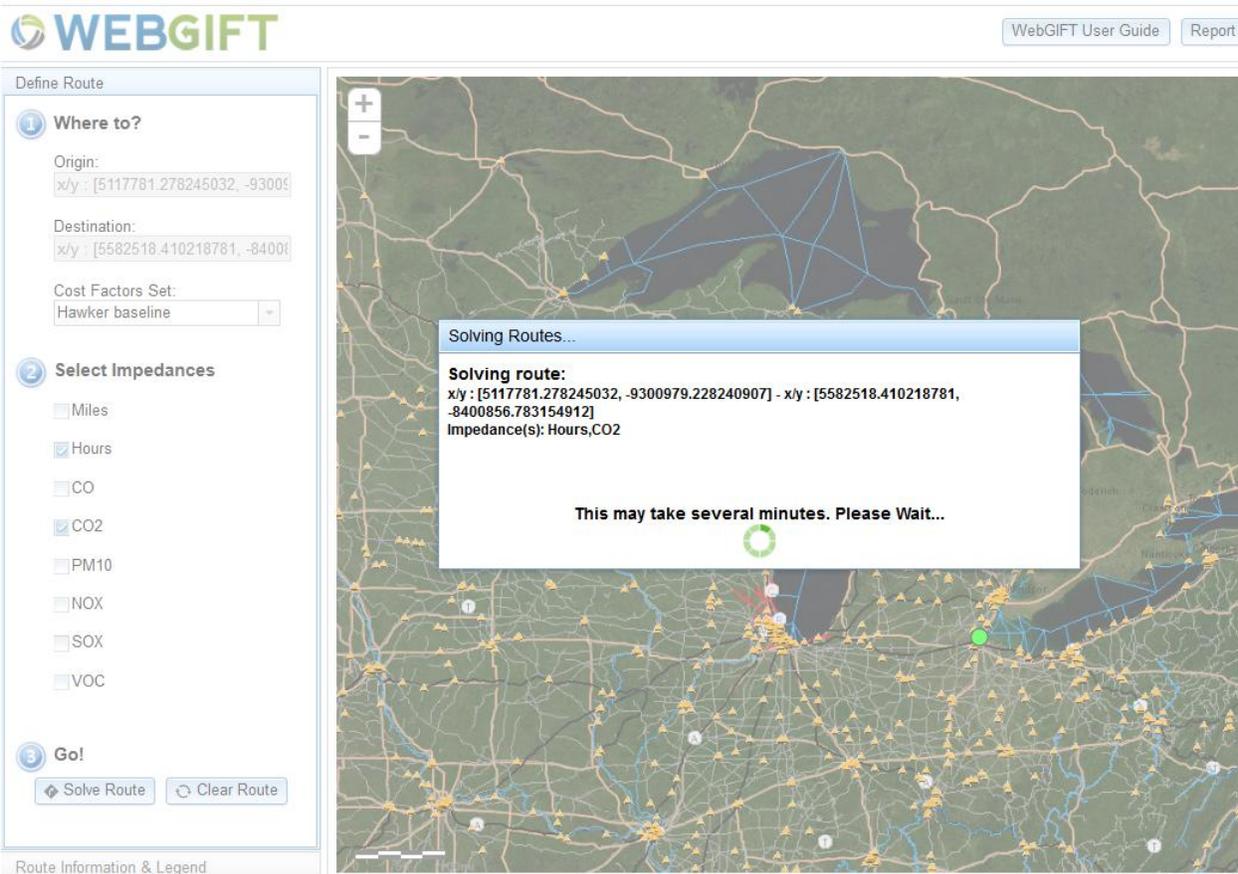


Figure 5. A screen showing that the route solver is processing (WebGIFT v3-alpha)

Once the solver finds the specified optimal routes, the WebGIFT solver server sends the route path and summary performance data for display in the Web browser (see Figure 6). The route color and route data are color-coded to aid matching a route with its corresponding data, as shown in Figure 6 and Figure 7. The summary statistics give the total length, energy, and emissions associated with each route. The directions give segment-by-segment details of the route taken, including intermodal transfers. Zooming into the routes gives a geospatial representation of the optimal routes, as shown in Figure 8.

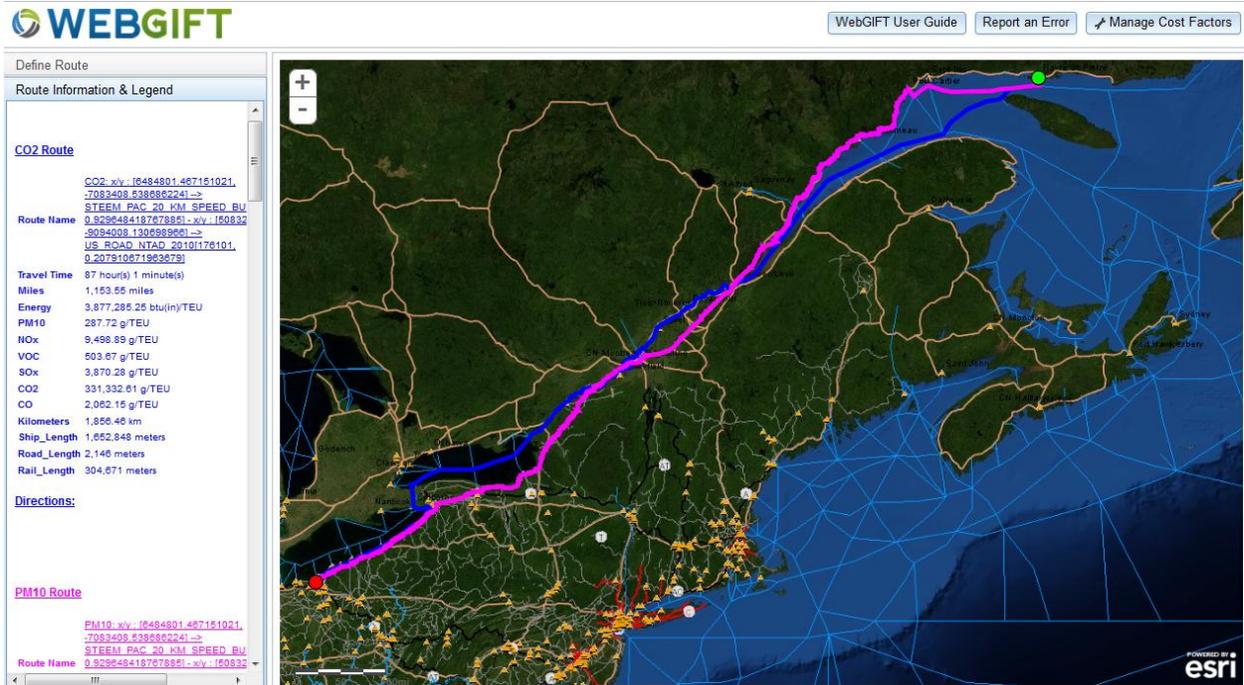


Figure 6. Alternate routes from entry to the St. Lawrence Seaway, destined for Cleveland, OH. (WebGIFT v3-alpha)

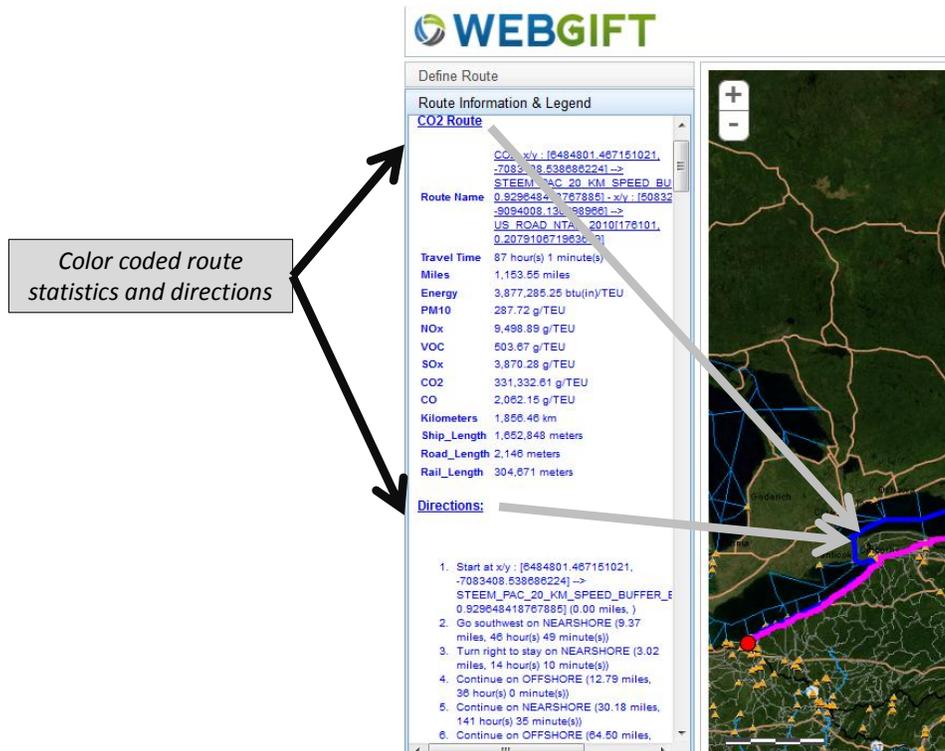


Figure 7. Route statistics and direction information are color coded with the geospatial route color (WebGIFT v3-alpha)

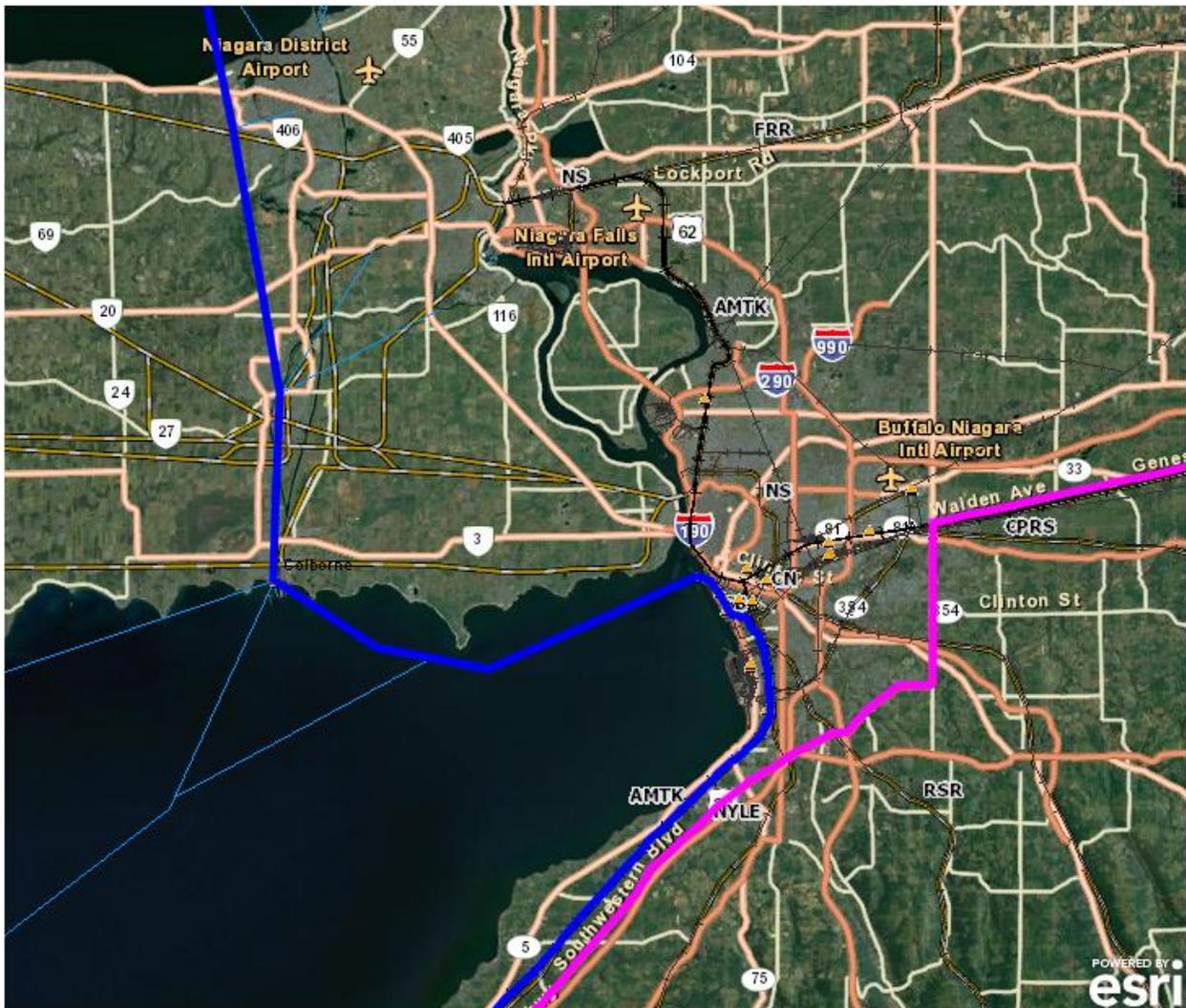


Figure 8. Moderately-detailed view showing alternate marine route (in blue) through the Welland, Ontario, Canal and a rail route (in pink) through Buffalo, New York. (WebGIFT v3-alpha)

### 4.3. User Interface Design Studies

Before we settled on the user interface design features just described, we developed proof-of-concept and design trade-off prototypes. This section describes that effort and the findings. Ongoing research and feedback from WebGIFT-GL use is continuing to improve the user interaction design.

### 4.4. User interface technologies

At the beginning of the project, ESRI, the vendor of ArcGIS, was encouraging the use of Adobe's proprietary Flash products for the browser-side implementation. Flash was expected to become a *de facto* industry standard product available on any Web browser, but when Apple, Inc., announced that it would not support Flash on its mobile platforms (iPad, iPhone, iPod), the industry fell back on non-proprietary, standardized, browser-side technologies, most notably, JavaScript, the JavaScript Object Notation (JSON), and REST (REpresentational State Transfer) protocols for access to server-side functionality. ESRI followed suit and improved their support

for JavaScript and integration with the ArcGIS server using Web services based on JSON and REST.

In spite of project challenges from having to adapt to quickly changing Web technologies, the effort of transforming GL-GIFT from the ArcGIS Desktop platform to the ArcGIS Server platform and a Web browser also gave us opportunities to define a more usable interface design that is understandable by “advanced novices” familiar with the basics of geographic information systems and intermodal freight movement. When we were still using Adobe Flash technologies, we prototyped some user interface design approaches and assessed their usability by advanced novices (version WebGIFT v2). We developed further prototypes and the current user interface using JavaScript technologies (version WebGIFT v3-alpha). The following sections highlight the needs and possible approaches learned from this prototyping effort.

### **Color coding routes**

There is a need to indicate to the user which routes optimize which attributes (for example, least-CO<sub>2</sub> route compared to least-time or least PM10 route, as in Figure 6). This also highlights one of our initial design trade-offs. As shown in the discussion of the WebGIFT-GL user interface, above, there is value to side-by-side comparison of the trade-offs of routes taken for alternate optimization factors. Figure 9 shows a prototype of this display, which is useful for single-mode routes. However, as Figure 10 shows, there is also value in color coding the modes taken for a given multimodal route. Figure 10 shows a route that starts on a rail segment and ends on a marine highway segment. These route segments are color-coded with route statistics showing the emissions and other contributions of each modal segment.

There is a challenge in selecting appropriate colors. Coloring truck routes red and marine routes green may imply that marine routes are more environmentally “green” than truck routes. WebGIFT-GL is not trying to imply these judgments, rather, it is providing trustworthy data with which the users can develop their own understanding and decisions.

In our current implementation, we chose to use color coding to compare alternate least-cost routes. We have chosen colors which are “culture neutral” (magenta, blue, etc. rather than red, yellow, or green). We are investigating other symbology to denote modes, such as dashed lines for waterways, cross-hatched lines for railway, etc. We are also investigating ways to meet the need to provide a detailed statistics display that allows users to compare least cost routes and to also see the contribution of each mode on multimodal routes.

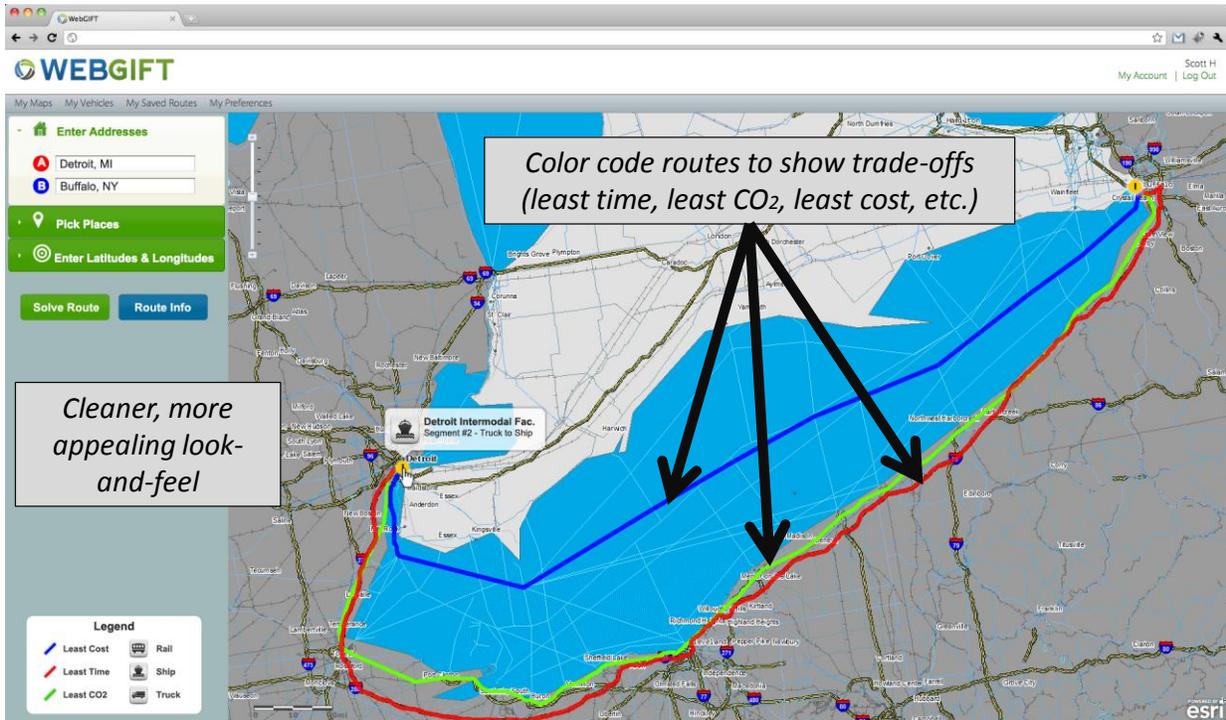


Figure 9. A visual comparison of the different routes and modes taken, comparing least cost (blue color - marine), least time (red color - truck), and least CO<sub>2</sub> (green color – rail) (WebGIFT v2)

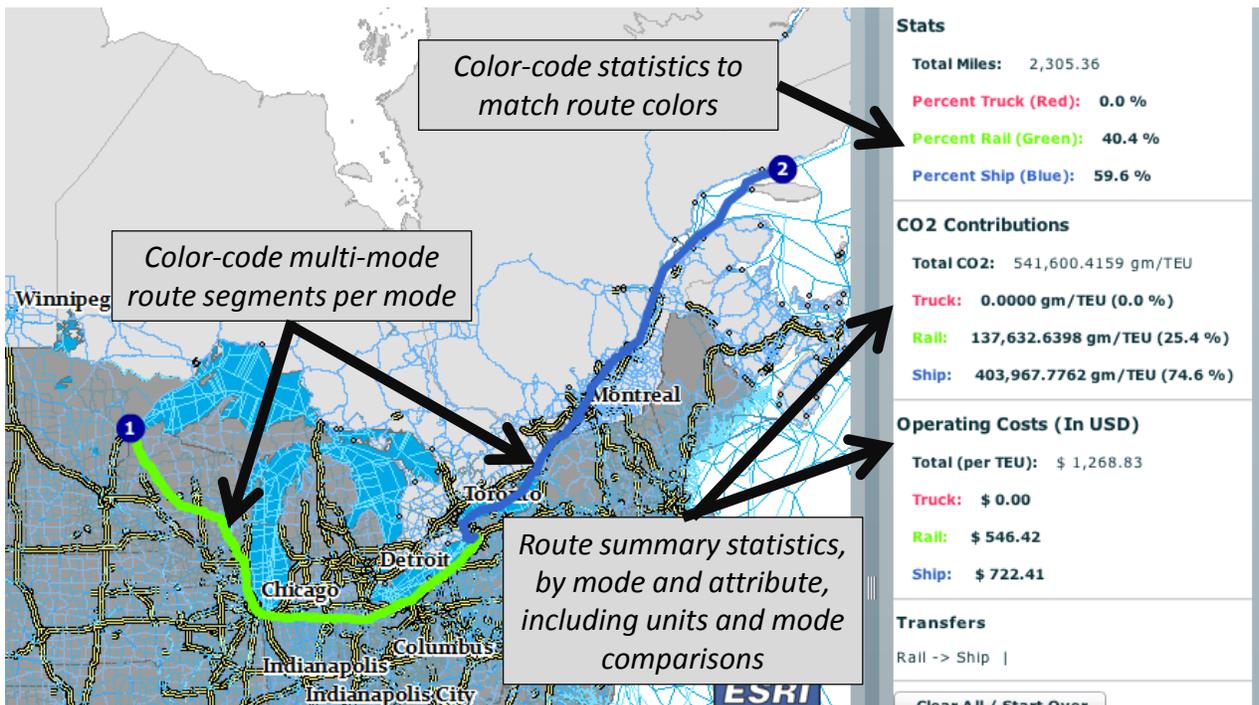


Figure 10. A screen snapshot of a WebGIFT-GL prototype showing a multimodal route from Duluth, Minnesota, to the inlet of the St. Lawrence Seaway. The first segment (in green) is on rail, and the second segment (in blue) is on a marine route. To the right are summary statistics for the route. (WebGIFT v2)

## Overall display options

To address the overall usability and understandability of the user interface, we prototyped a number of display options. Figure 11 shows one such display mock-up. Based on analysis and user feedback, we found that we need to provide

- Guidance to the user on what steps to take to perform a case study analysis,
- More detailed route data for trade-off analysis and understanding the route details,
- Vivid visual contrast between solved routes and the underlying base map and,
- Intuitive icons with text hints (“tool tips”) to explain their purpose.

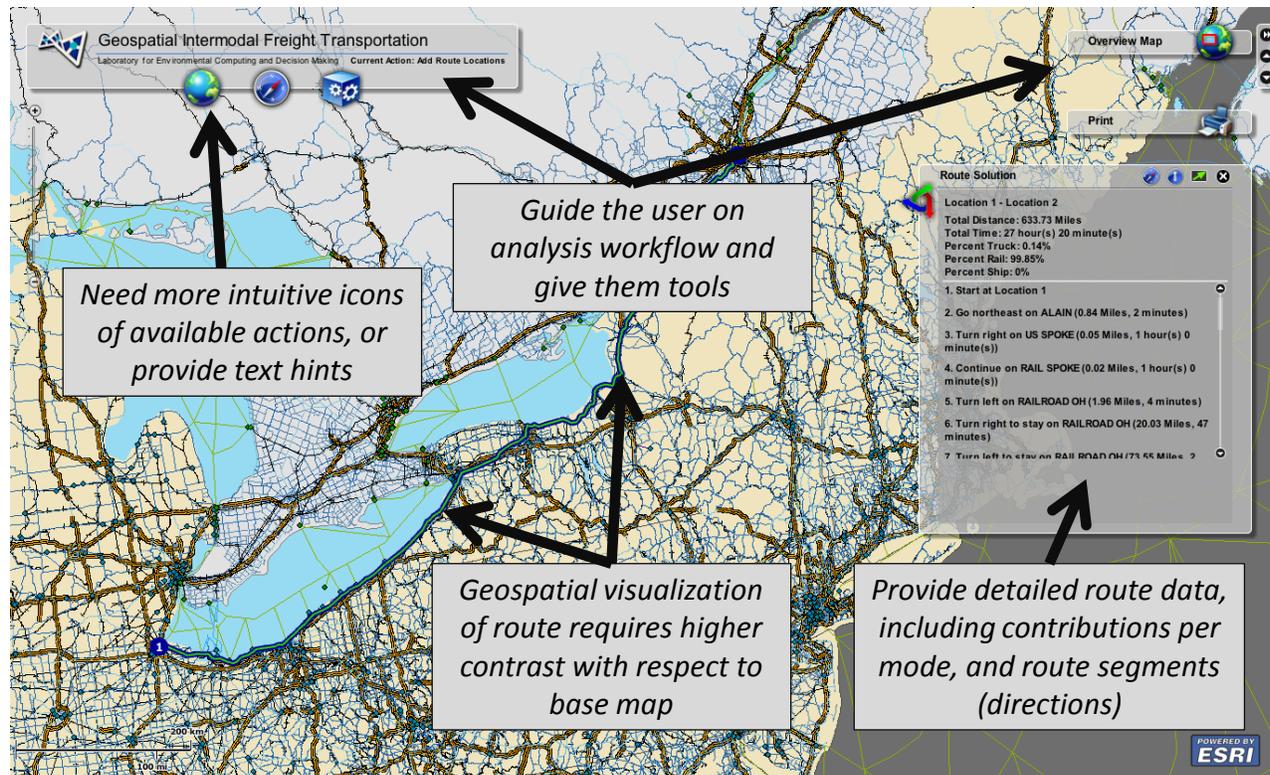


Figure 11. A user interface mock-up showing some of the design issues and trade-offs. (WebGIFT v2)

## Entering route origin and destination (O/D) pairs

There are a number of ways available to indicate locations for route origin and destination. In each case, the results must be a pair of latitude and longitude coordinates to send to the route solver server. Figure 12 illustrates a user interface mock-up to test these various ways to indicate route origin and destination to the route solver.

One way to indicate locations is to pan and zoom the map to find a desired location, then click on the map. Often, the location the user clicks will correspond to a known intermodal transfer facility (shown with an orange triangle in Figure 1 and elsewhere). ArcGIS Network Analyst “snaps” a clicked location to the nearest transportation network feature (a road, rail, or waterway

segment). This is problematic if the point snaps to a location that the user does not desire. There needs to be feedback to the user to ensure that the snapped location is the desired location. Further, the snapping process is computationally time consuming.

Another, and perhaps more intuitive, way to enter locations is to enter street addresses. This involves “reverse” geocoding – turning the address into latitude/longitude coordinates. This is problematic if the street is not known in the geolocator, if the geolocator cannot snap the location to a nearby network feature, or if the geolocator snaps to a feature that the user does not desire. Again, there needs to be interaction with the user to ensure that their desired location is selected.

A third way to enter locations is to select from a predefined list of known locations that have previously been snapped to the network. We have taken the US Department of Transportation’s database of Commodity Flow Survey (CFS) locations and snapped them in the network. In the prototype, we provide a pick list of these locations for the user to choose from (see Figure 13). Unfortunately, these locations are arranged alphabetically rather than geographically, and they often include only the name, not the location, of the facility. Further, there are over 100 locations in the continental US. There needs to be some location organization and user interaction to manage this list of locations. Also, the users need to be able to add their own custom locations to the list.

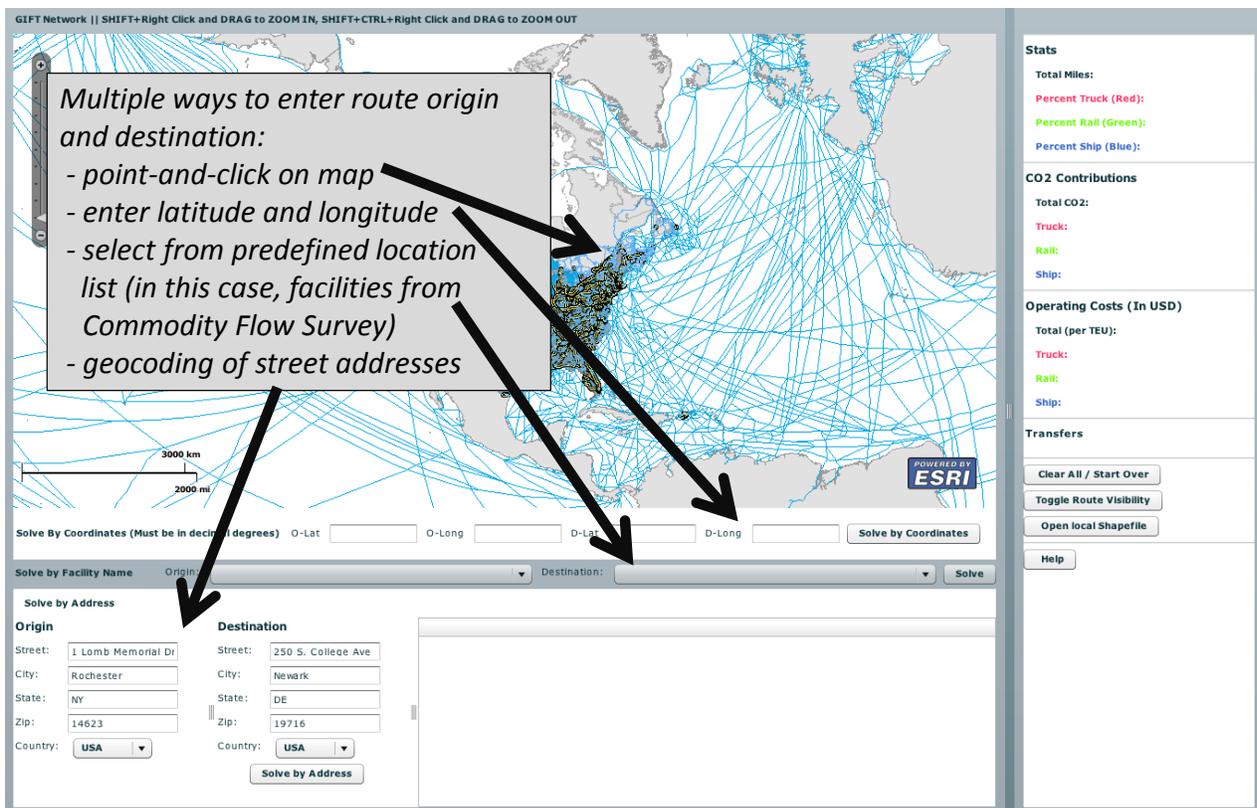
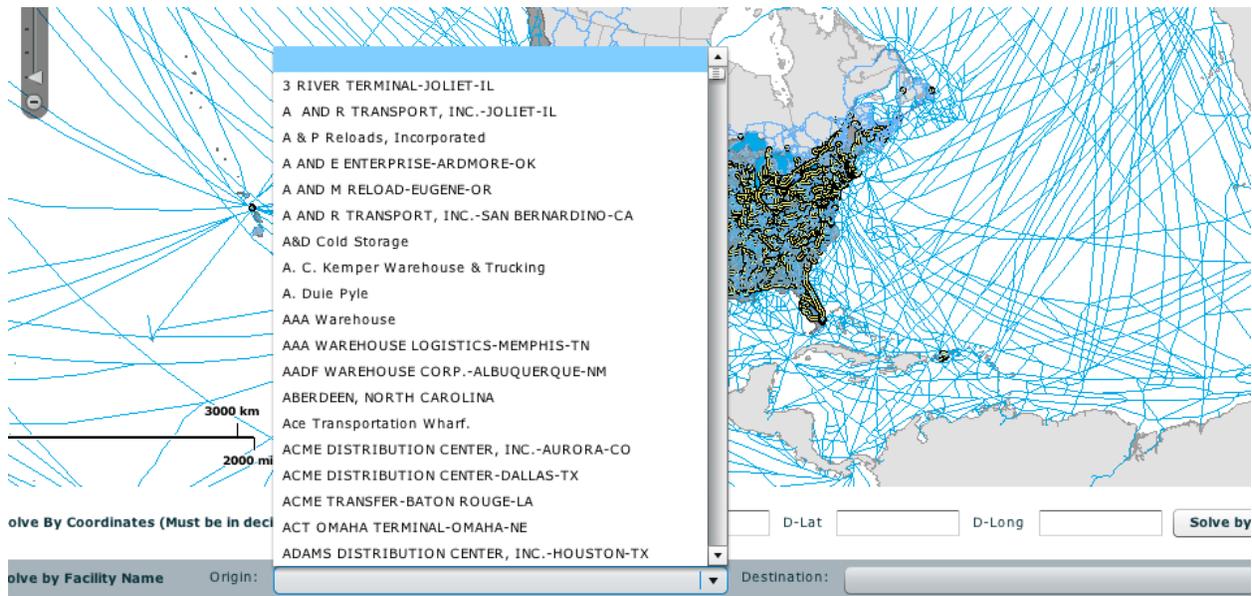


Figure 12. There should be multiple ways to enter the route origination and destination locations (WebGIFT v2)



**Figure 13. A pick list of predefined locations, based on Commodity Flow Survey intermodal facilities (WebGIFT v2)**

### Guidance on User Workflow

As Figure 14 suggests, WebGIFT-GL needs to provide the user with simple, understandable guidance on what to do and when and how to do it. For example, panning and zooming the map is important to select desired locations and to understand the geospatial details of the computed routes. The zoom bar in Figure 14 seems intuitive, but the key strokes for zooming and panning the map is awkward in this prototype.

We also found that at low and moderate zoom resolutions, geopolitical information (town names, political boundaries and names, etc.) plus moderate geographic features (rivers, major roads, etc.) provide the user with the context of where they are on the map, but at high, close-up resolutions, aerial imagery of the features such as railyards, minor roads, streams, etc., provide more information and context for understanding route details. Figure 15 illustrates this.

Another observation shown in Figure 15 is that providing detailed segment-by-segment data provides useful information for comprehending and comparing routes, but the raw information is hard to use. Pre-defined analytics, such as the mode-by-mode contributions in Figure 10, could provide the user with a rich base of usable, actionable information for route and mode trade-off analyses.

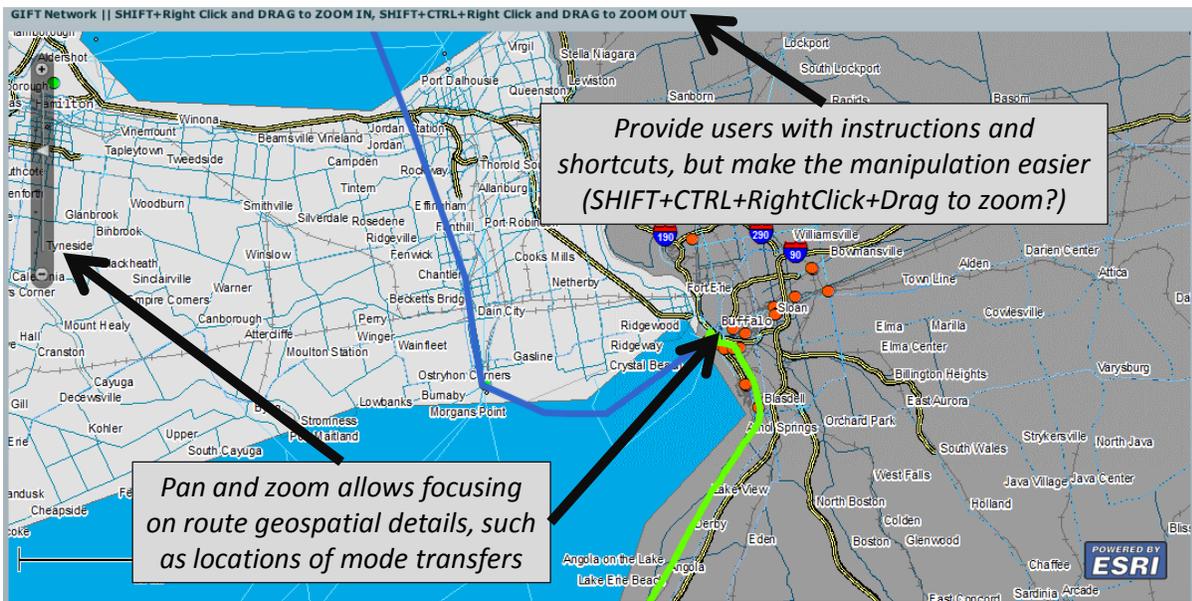


Figure 14. Zooming into the map allows the analyst to visualize the freight being transferred from rail to water at the Port of Buffalo, New York, then traversing through the Welland Canal from Lake Erie to Lake Ontario. (WebGIFT v2)

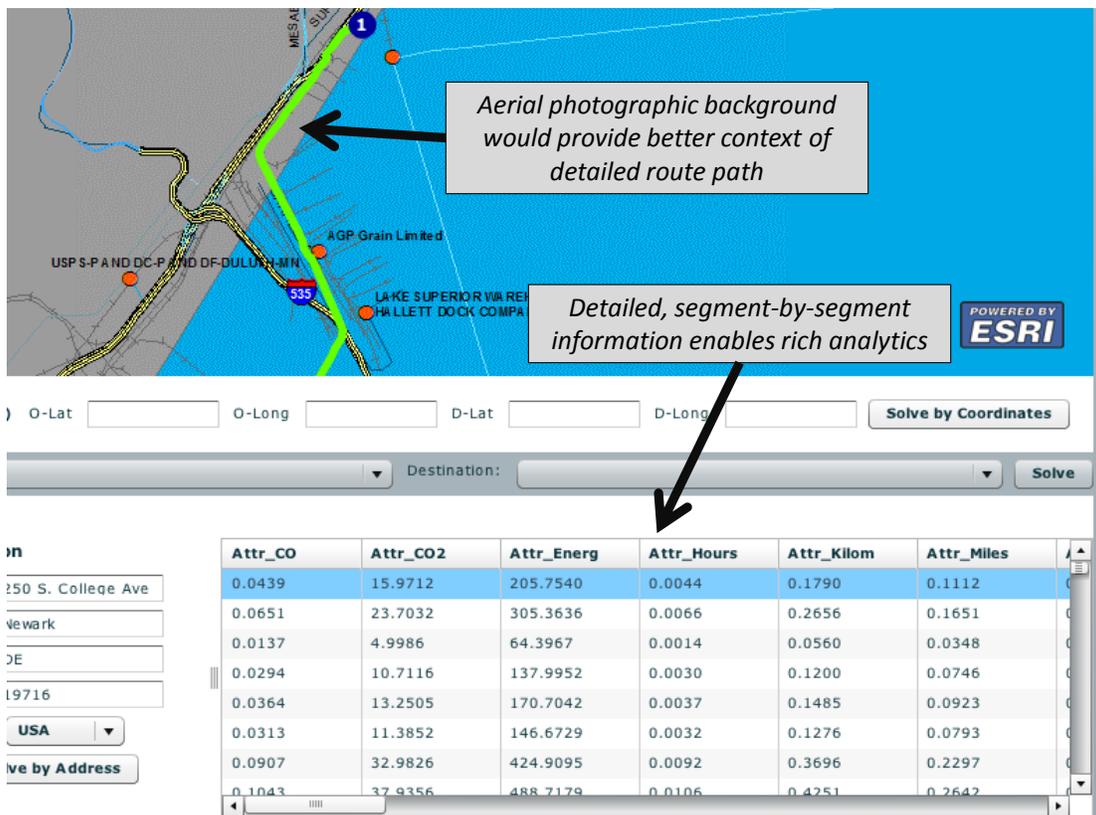
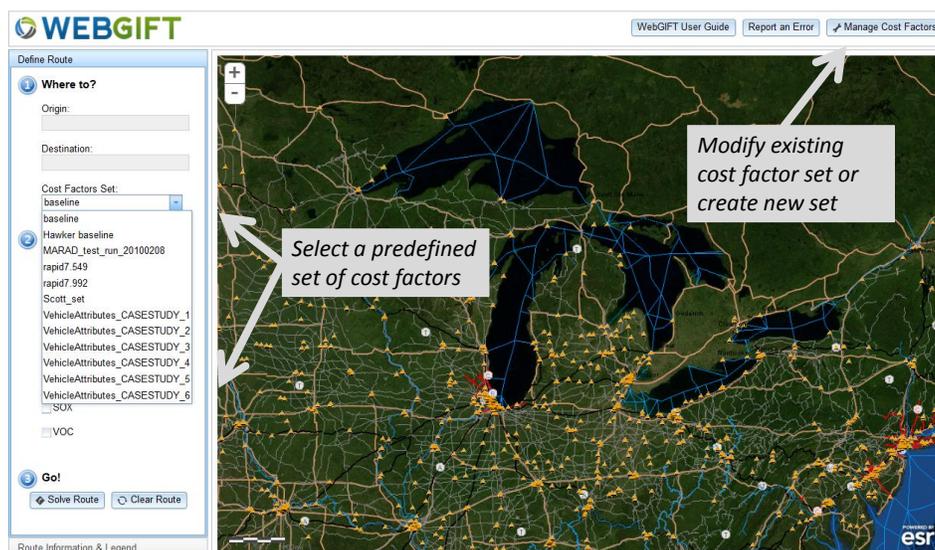


Figure 15. Detailed, segment by segment information of a route is available, allowing detailed analytics for energy, environment, and economic trade-off case studies.(WebGIFT v2)

## 4.5. Vehicle Library and Cost Factors

A core part of GIFT are the cost factors: the rate at which criteria pollutants are emitted, energy is consumed, and distance is covered (speed) by a given vehicle (truck, train, or marine vessel) or by equipment involved in intermodal facility transfers. These cost factors are selected or modified as part of defining a route (see Figure 16). The user can also manage (modify or copy/create new) cost factor sets, as in Figure 17 and Figure 18.

We developed a library of emissions and energy cost factors representing the types of trains, trucks, vessels, and intermodal transfer facilities expected in the Great Lakes region and elsewhere. These cost factors were derived from our Intermodal Energy and Emissions Calculator (<http://EmissionsCalc.rit.edu>), which was developed under separate funding, and from literature reviews in our previous GLMRI GL-GIFT projects. The Calculator computes the energy and emissions for a given configuration of engines, fuel, load, and other factors. Figure 19 shows the user interaction using the Intermodal Energy and Emissions Calculator to define cost factors for a given vessel, train, or truck in an analysis scenario. The user can select, modify, or create a new vehicle and manually enter its computed emission values into WebGIFT-GL using the interaction of Figure 18. We are working to integrate the Energy and Emissions Calculator more directly into WebGIFT-GL so that the user need not manually enter the emissions rates. Instead they would simply select a configuration of truck, train, and vessel for a given route analysis, and the route solver would use these values in solving for optimal routes and their corresponding energy, emissions, and times.



**Figure 16. Select predefined cost factors for route analysis, or modify existing cost factor set or create a new set. (WebGIFT v3-alpha)**

Actions	Name	File Name
<a href="#">Manage</a>   <a href="#">Copy</a>	baseline	baseline.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	Hawker baseline	Hawker baseline.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	MARAD_test_run_20100208	MARAD_test_run_20100208.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	rapid7.549	rapid7.549.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	rapid7.992	rapid7.992.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	Scott_set	Scott_set.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	VehicleAttributes_CASESTUDY_1	VehicleAttributes_CASESTUDY_1.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	VehicleAttributes_CASESTUDY_2	VehicleAttributes_CASESTUDY_2.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	VehicleAttributes_CASESTUDY_3	VehicleAttributes_CASESTUDY_3.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	VehicleAttributes_CASESTUDY_4	VehicleAttributes_CASESTUDY_4.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	VehicleAttributes_CASESTUDY_5	VehicleAttributes_CASESTUDY_5.xml
<a href="#">Manage</a>   <a href="#">Copy</a>	VehicleAttributes_CASESTUDY_6	VehicleAttributes_CASESTUDY_6.xml

Figure 17. A list of cost factor sets with a user interaction to modify them or create new sets (WebGIFT v3-alpha)

The screenshot shows a table with the following columns: Vehicle, Cost Factor, Value, and Units. The 'Value' column contains input fields, all of which are currently set to '0'. The 'Units' column lists units such as 'gm/TEU-mile'. The table is organized by vehicle type: Trucks, Rails, Ships, and Ship\_Spoke. Below the table are 'Save' and 'Back to List' buttons.

Annotations on the right side of the image:

- Can define and save cost factor sets**: An arrow points to the top of the table.
- Emissions rates for each mode**: An arrow points to the 'Value' column for the 'Truck' and 'Rail' sections.
- Emissions rates for mode transfers**: An arrow points to the 'Value' column for the 'Ship' and 'Ship\_Spoke' sections.

Figure 18. The values of a given cost factor set can be modified by users to represent their specific trucks, trains, marine vessels, and intermodal transfer costs. (WebGIFT v3-alpha)

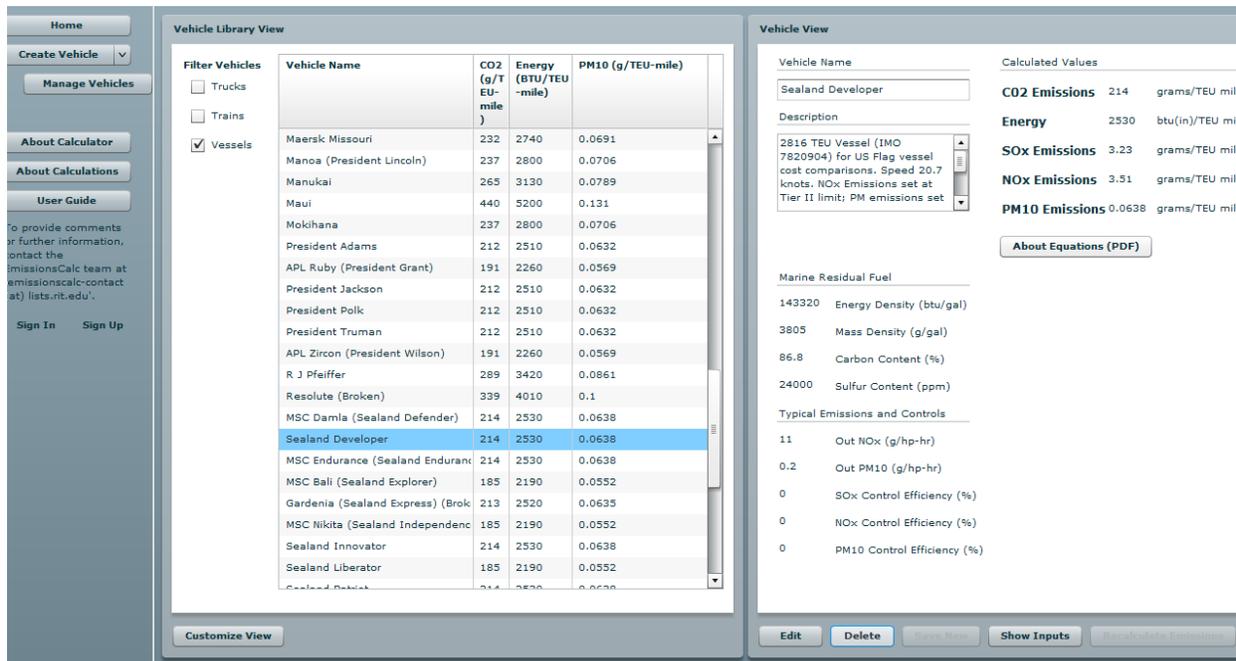


Figure 19. Energy and emissions calculator showing vessel library and calculated emissions and energy for a selected vessel (EmissionsCalc version 1)

#### 4.6. Updated GL-GIFT Geospatial Model

We updated the geospatial model underlying GL-GIFT and which also underlies WebGIFT-GL. We updated the highway, railway, waterway, and transfer facility data in the Great Lakes and St. Lawrence Seaway region to include the following:

- Validated and updated locations of intermodal transfer facilities
  - Including a mapping of all Commodity Flow Survey (CFS) locations to nearby facilities
- NTAD (National Transportation Atlas Database) 2010 highway, railway, waterway, and transfer facilities for U.S.
- Highway, railway, waterway, and transfer facilities for Canada
- Integrated model of the international shipping lanes (STEEM from University of Delaware)
- Dwell buffers – regions around a railyard, port, or truck terminal where freight transport is delayed even though it does not change mode.

Figure 20 shows the WebGIFT-GL base map for the Great Lakes region. We continually update the geospatial model as new data becomes available, so WebGIFT-GL and GL-GIFT will provide the best available data.

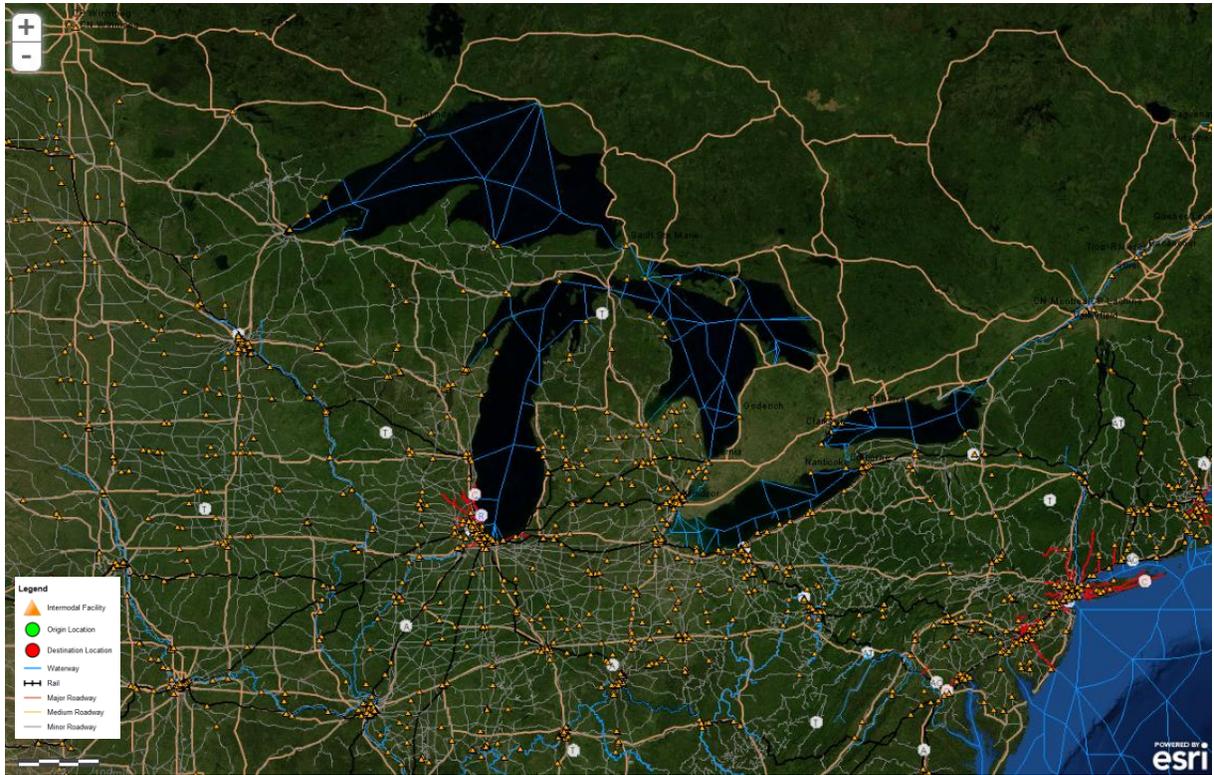


Figure 20. WebGIFT-GL base map showing highway, railway, and waterway segments, plus intermodal transfer facilities (WebGIFT v3-alpha)

#### 4.7. User Management and Scenario Management

In its current form, WebGIFT-GL is available for anyone to use (<http://WebGIFT.rit.edu> or <http://WebGIFT.lecdm.org>). Overall, this is good and desired, but we need a way to limit users' ability to modify and create new cost factor sets, and we need a way for users to save solved routes and recover them for later analysis. To this end, we have created a user management system to support registration, login, logout, and password recovery, but we have not yet integrated that capability into the WebGIFT-GL system.

Once basic user management is integrated, we will work to provide user groups. Users will be restricted to using and managing cost factor sets and routes within their registered groups. We will also work to provide saving and recovering route data—what we call analysis scenario management. This will involve creating ways to meaningfully name and organize routes and store the full route information for detailed analysis.

#### 4.8. WebGIFT-GL Software Requirements, Design, and Implementation

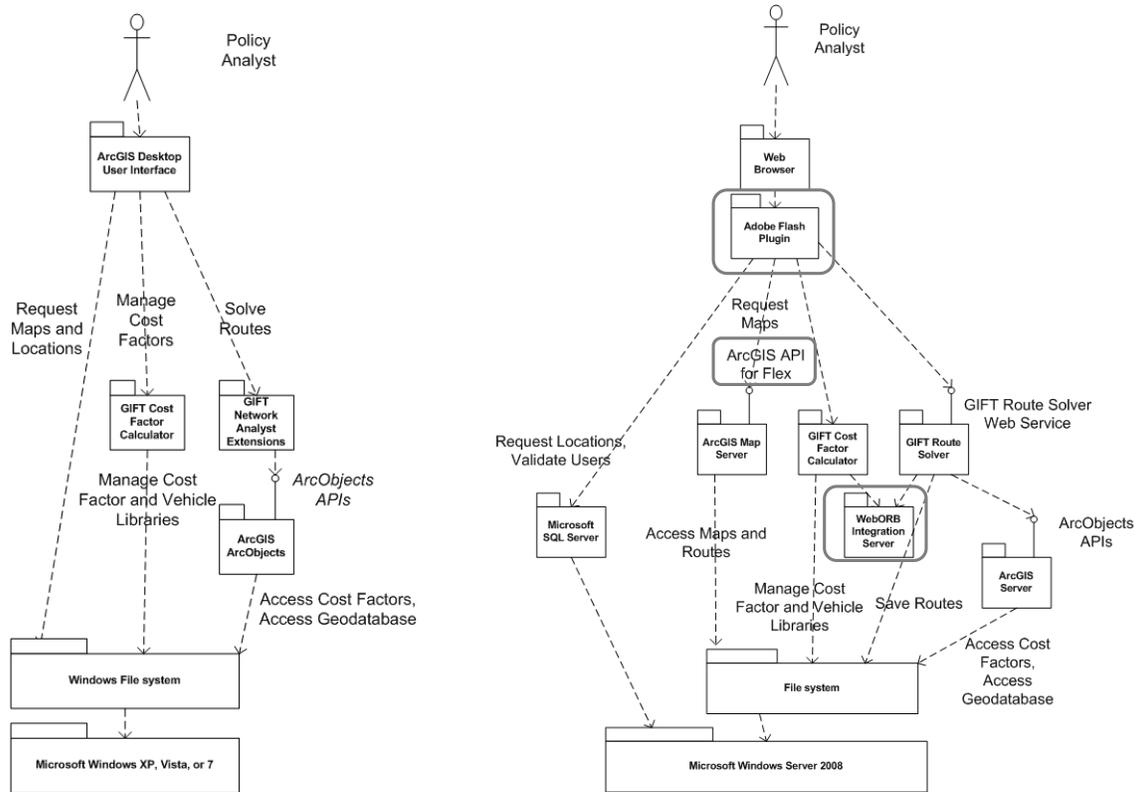
The bulk of our effort, and the most challenging tasks, were specifying, designing, and implementing WebGIFT-GL. The requirements specification effort was straightforward because we had the Desktop GL-GIFT system to refer to for functional requirements. Appendix A summarizes these requirements. The challenge was in re-implementing that functionality in a

Web-based environment, using ESRI ArcGIS Server, Microsoft Server with .NET, and Web browser technologies.

Figure 21 illustrates our first approach, showing the Web-based software components used. This approach used Adobe Flash and Flex technologies, as described in the User Interface Design Studies section. We also used MidnightCoder’s WebORB product to make ArcGIS functionality available across the Web

(<http://www.themidnightcoders.com/products/weborb-for-net/overview.html>).

While these technology choices would have served to meet our functional requirements, we would become dependent on proprietary, licensed technologies for Adobe Flash and Flex and for WebORB. As noted in the section on user interaction design prototypes, ESRI began providing better support for non-proprietary technology for the Web browser in their support for JavaScript and JSON. So, our current implementation of WebGIFT-GL, shown in Figure 22, re-implements the user interface functionality to use JavaScript and JSON. We are still dependent on ESRI’s proprietary ArcGIS products and Microsoft’s proprietary C# and .NET products, but these are widely adopted and supported technologies and our academic licensing provides these at zero or reduced cost.



*Desktop GL-GIFT*

*WebGIFT-GL based on Adobe Flash, ESRI ArcGIS API for Adobe Flex, and WebORB (WebGIFT v2)*

**Figure 21. Reimplementing Desktop GL-GIFT on Web-based technologies adds significant technical complexity.**

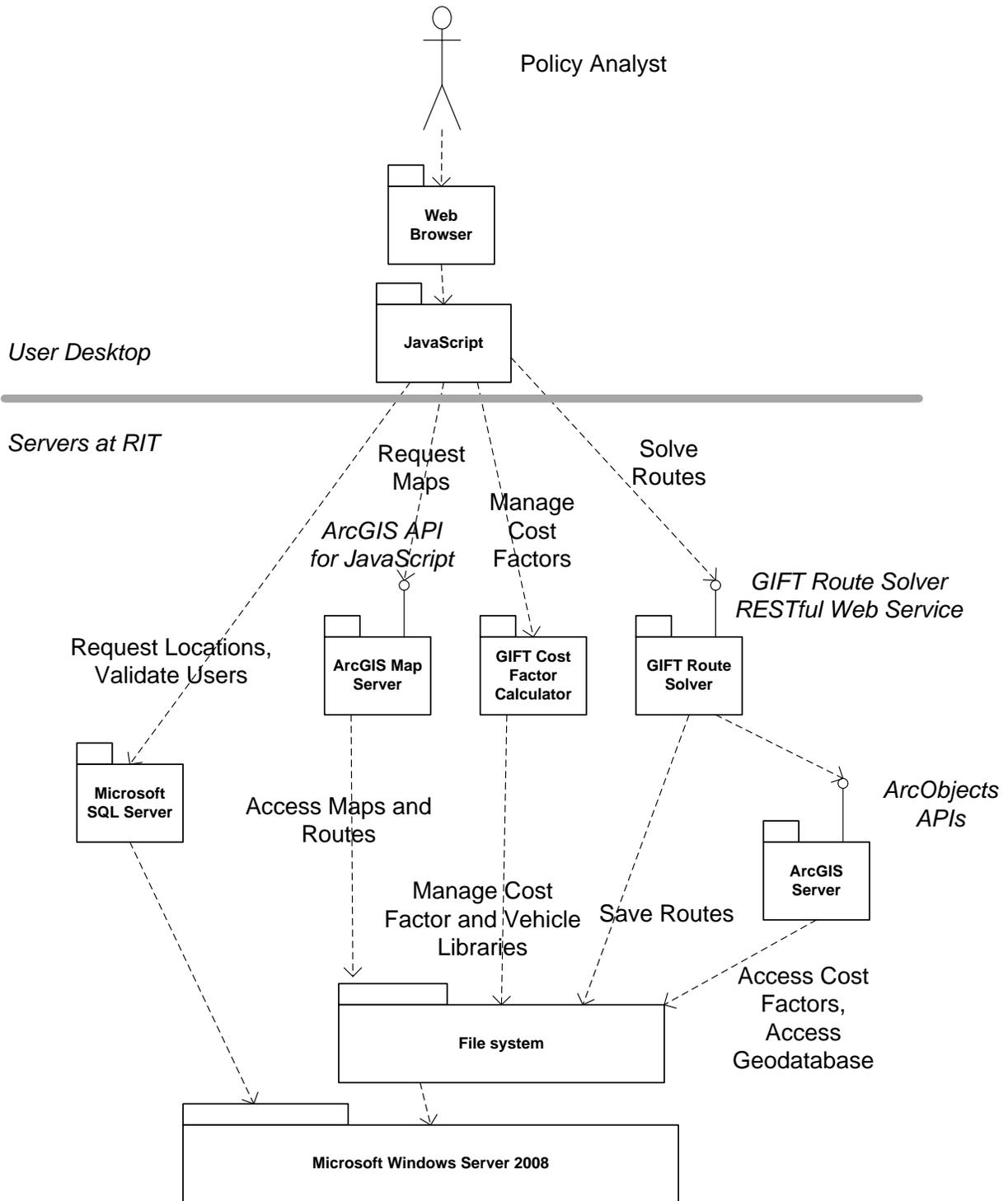


Figure 22. The current implementation of WebGIFT-GL (WebGIFT v3-alpha)

## 4.9. Development and Support Challenges

As noted, the bulk of our work, and the most challenging aspects, were specifying, designing, and implementing WebGIFT-GL. The increased technical complexity of a Web-based system compared to the desktop-based GL-GIFT was an expected challenge. Deciding to change Web-browser programming technologies set us back, but we believe it was the right long-term decision.

Two areas that were not necessarily surprises, but were unplanned challenges, were hosting a Web-based application in an academic setting, and relying on students for development and on-going maintenance. The next sections discuss those challenges.

### Web-based Applications in an Academic Computing Environment

A commercial enterprise hosting a Web-based application would (or, at least, should) have an established computing infrastructure and system administration support. RIT has these, but they are targeted for internal operations, not for external customers and users. This is an issue faced by most colleges and universities. Policies of availability, pricing, security, etc. are often not appropriate for providing a production-worthy Web application such as WebGIFT-GL to external users. In response, we provided our own computing infrastructure and Web application execution environment, and we took on the task of system administration and support. Even so, we still needed to operate within the constraints (especially security policy constraints) of an academic setting. We learned that this is more difficult and man-power intensive than we had expected, but we were able to meet WebGIFT-GL user needs.

### Students as Developers, Maintainers, and System Administrators

A commercial enterprise developing and maintaining a Web-based application would have a staff of dedicated, full-time, experienced application developers and a development environment with the software tools and methods for full-scale development projects. In contrast, in our academic research lab, the primary developers are students and faculty using a mix of loosely integrated tools and *ad hoc* development and system administration methods. Students (and faculty) are not necessarily experienced in the latest technologies and tools, they have many other responsibilities that distract them from the project (course work, job search, etc.), and students turn over rapidly as they graduate or take time for co-op jobs. On the other hand, students are eager to learn and deliver, they work well together, and they love to build working, useful systems.

In response to these challenges,

- We set up separate virtual machines for development, staging (system integration and test), and production,
- We set up a project management environment based first on Redmine (<http://www.redmine.org/>) (abandoned when it failed to meet security requirements) then on Atlassian tools (<http://www.atlassian.com/>),
- We held weekly status meetings where each person reported progress, plans, and barriers to progress,

- We set up system administration tools and responsibilities to support developers (“Development Operations”),
- We required informal design documentation and unit tests, and documentation of how to use technologies, tools, and administration methods,
- We aggressively recruited top undergraduate and graduate software engineering students who were able to commit to at least six months of 10-hours/week of effort, and we made sure there was overlap between those 6-month windows to ensure proper hand-off of tasks and results. Where possible, we hired students for full-time work as a co-op student,
- We assigned responsibilities based on experience with a tool or technology (areas included Web client-side programming in Flash and JavaScript, server-side programming with .NET and C# and ArcGIS programming interfaces, database development, and system administration).

In researching what software development and project management practices are appropriate for multi-disciplinary, academic-based research projects, we found little to guide us. As a result, we have started a research project focused on software engineering for computational science and engineering research projects.

### **On-Going System Administration and Maintenance**

On-going WebGIFT-GL system administration and maintenance will be a continuing task. Keeping a Web-based system technologically up-to-date and secure is a non-trivial but not overly challenging task. In addition, as users provide feedback on WebGIFT-GL use or find defects in system behavior, we will need software developers to implement needed changes. We will also need staff to provide user guidance and support in their effort to learn and productively use WebGIFT-GL. We have developed a user guide and a set of developer and system administrator guides. Even so, better user tutorials, training materials, workshops, and one-on-one support would significantly enhance the adoption and use of WebGIFT-GL. These on-going efforts need a source of on-going funding to sustain them.

## **5. Summary and Conclusions**

WebGIFT-GL is an important software system that allows for easy, comprehensive, and reliable analyses of multi-modal and intermodal freight transportation for the Great Lakes region. The model provides users an opportunity to explore the energy, environmental, economic, and time-of-delivery tradeoffs associated with alternative routes and modes, as well as the opportunities for goods diversion or port construction in the region.

As discussed in the body of this report, we faced a variety of obstacles in producing the software – most of which were met and successfully overcome. We have also worked to conduct test cases and to identify areas where future research activity is needed. In summary, we believe this project was a great success, minimizing (for the user) the complexity of a full GIS while retaining much of the desired GL-GIFT functionality and will provide a springboard for interesting and important research in the future.

## 6. Potential Economic Benefits of the Research Results

These spatial modeling tools will provide great value to the Great Lakes region, as well as regional and national transportation planners. With WebGIFT-GL, planners and decision makers have easy access to comprehensive and complex software that can evaluate tradeoffs associated with freight transportation in their region. Aside from the reduction of analytical costs this software brings, it also brings opportunities to explore the economic impacts associated with enhanced GL freight flows. For example, WebGIFT-GL can be used to identify economically optimal shipping routes or port locations that would provide significant economic, environmental, or energy savings compared to alternative highway transportation. The emissions estimates may also be useful to environmental agencies, planners, and consulting groups interested in ecological and human health impacts of Great Lakes freight movement. We intend to continue to use WebGIFT-GL to conduct case studies to highlight and uncover these benefits.

## 7. Dissemination of Study Results

We continue to disseminate our study results in a variety of ways. First, we have been actively using our University News Service to “spread the word” regarding WebGIFT-GL. Second, we have been coordinating with the U.S. DOT (MARAD) regarding a “roll-out” of a national WebGIFT model; this roll-out will likely occur in the September/October 2012 timeframe. Third, we are working on several academic papers and conference presentations (regional and national) that will highlight the uses of WebGIFT-GL for analytical purposes. We are using WebGIFT-GL as a demonstration tool in university GIS and Environmental Science courses. And finally, we are using WebGIFT-GL in a case study environment to explore the impacts of shipping across the lakes vis-à-vis highway trucking alternatives. These case studies also have the potential to serve as key components to advanced coursework at other colleges and universities engaged in environmental and transportation research.

One Master’s thesis and two Master’s projects were defended and published. The thesis is on the use of GL-GIFT to study opportunities and policy impacts on intermodal freight transportation in the Great Lakes region. The two projects capture the results of the WebGIFT prototype development and analysis.

- Bryan Comer, *Sustainable Intermodal Freight Transportation: Applying the Geospatial Intermodal Freight Transport Model*, Masters of Science Thesis, Science Technology and Public Policy, Rochester Institute of Technology, November, 2009.
- Udayan Sharma, *WebGIFT – Geospatial Intermodal Freight Transportation Model on the Web: Building Web-Based Services Supporting Transportation Policy Analysis*, Master’s of Science Project Report, Information Technology, Rochester Institute of Technology, November, 2009.
- Matthew K. Walter, *WebGIFT: A Geospatial Intermodal Freight Transportation Model on the Web: Using ArcGIS Server and ArcSDE to Implement a System for Transportation Policy Analysis*, Master’s of Science Project Report, Information Technology, Rochester Institute of Technology, December, 2009.

In addition, the following papers were published:

- Hawker, J.S. Comer, B., Corbett, J.J. Ghosh, A. Korfmacher, K., Lee, E.E. Li, B., Prokop, C., Winebrake, “An Integrated Model to Study Environmental, Economic, and Energy Trade-Offs in Intermodal Freight Transportation,” 2010 International Environmental Modelling and Software Society (iEMSs) 2010 International Congress, Ottawa, Canada, July, 2010.

- Comer, B.S., Corbett, J.J., Hawker, J.S., Korfmacher, K., Lee, E.E., Prokop, C., Winebrake, J.J., “Marine Vessels as Substitutes for Heavy-Duty Trucks in Great Lakes Freight Transportation,” *Journal of the Air & Waste Management Association*, 60 (7), July 2010, pp. 884-890.

The following presentations were made:

- Scott Hawker presented previous Great Lakes GIFT work as part of a GLMRI panel at the Marine Community Day event in Cleveland, Ohio, on February 11, 2010.
- GIFT and WebGIFT were presented at an Innovation Showcase in Washington, DC on August 4<sup>th</sup>, 2010. This was sponsored by Senator Gillibrand from New York.
- Presented current project status at the September, 2010 GLMRI Affiliates Meeting.
- Presented WebGIFT to Maritime Administrator (MARAD) David Matsuda on September 7, 2011, and August 16, 2012.

## Appendix A – WebGIFT Core Functional Requirements

1. Display base map for current geodatabase model (H)
  - 1.1. Center display on Great Lakes region (M)
  - 1.2. Manage clutter – zoom in to see details (M)
2. Select origination and destination
  - 2.1. Click on the map (H)
  - 2.2. Select from pre-defined list of locations (M)
  - 2.3. Enter Lat/Lon (decimal degrees) (M)
  - 2.4. Enter street address and reverse geocode (L)
3. Select emissions and energy cost factors
  - 3.1. Select from pre-defined sets (H)
  - 3.2. Modify an existing set (H)
  - 3.3. Set emissions and energy rates for (H):
    - 3.3.1. Impedances: CO, CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub>, BTU, PM<sub>10</sub>
    - 3.3.2. Truck, train, vessel, transfer facility
4. Select impedances to minimize (H)
  - 4.1. CO, CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub>, BTU, PM<sub>10</sub>, time, distance
5. Solve one route for each impedance selected (H)
  - 5.1. Display route on map
    - 5.1.1. Color-coded plus key to differentiate routes
  - 5.2. Display analytic data for each route
    - 5.2.1. Total accumulations for all emissions/energy factors (H)
    - 5.2.2. Total miles per mode (M)
    - 5.2.3. Total number of transfers (M)
6. Save route data (TraversalResult, graphic) for further analysis (M)
7. Authenticate users
  - 7.1. Only registered users can save route data and browse existing route data (H)
  - 7.2. Log who is using the system (H)
    - 7.2.1. Log what routes they are analyzing (M)
8. Manage users (H)
  - 8.1. Add, modify, delete user ID and data
    - 8.1.1. Data: name, affiliation, email address
9. Support system administration and maintenance (H)
  - 9.1. Error logs, start-up, shut-down, install