Development of an Intermodal Freight GIS Network Web Interface

Final Report

February 13, 2013

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Introduction

In previously completed research projects funded by the Center for Intermodal Freight Transportation Studies (CIFTS), Vanderbilt University built a nationwide intermodal freight geographic information system (GIS) network. This network was initially built to develop the capability and tools within CIFTS to perform freight analysis and forecasting. The network effort collectively included validation of terminals satellite images, estimation of terminal capacity, design of a unique GIS means to accurately represent terminal dwell and delays, and a methodology for updating the network when terminals are added and when the surface transportation modal networks (rail, road, and water) change.

This research was conducted over several years, beginning in 2006 and consisting of several phases and incremental enhancements. During this time, the GIS technology available to researchers improved significantly, to the point where point to point, multi-modal routing through a standard Internet browser (Internet Explorer, Firefox, Google Chrome, etc.) became feasible. Previous iterations of this work were completed in TransCAD, a transportation planning-specific GIS package. TransCAD’s highway planning modules were modified to perform intermodal freight transportation routing via multiple modes. ESRI, the market leader in GIS, has dramatically improved the capabilities of its network analysis package to the point where it was justifiable to move the intermodal freight network to the ESRI ArcMap and ESRI ArcGIS Server platforms. TransCAD has no comparable Internet GIS platform.

Once the network transition was completed, the network was published using ArcGIS Server and custom JavaScript coding was developed to perform intermodal routing in the Memphis, TN area through an Internet browser. This final report describes this effort. The methodology, datasets, prototype development and usage, as well as conclusions and recommendations for future research are presented in this report.

Methodology

Initial network development began with merging the national rail, highway and waterway networks into a single line layer. Once this was done, researchers verified the existence of container terminal transfer facilities using satellite imagery. Verification was necessary as several logistics companies and transportation carrier headquarters were included in the national public dataset (described later in the data section) as terminals, when in fact, no cargo was actually changing modes at those locations. Additionally, as this network was focused on container shipments, bulk terminals were also excluded. Bulk terminals may be added to the network at a future date, but routing similar shipments (common units) of a container was the most straightforward way of focusing on getting the routing to work properly and realistically. Intermodal links were created that connected all of the appropriate surface modes to the visually-verified container terminal. This way, delays could be coded in each direction on the connector links as well as at each individual terminal. In other words, generic modal combination delays were not required using this design, and a rail to water movement could have a different delay figure than a water to rail movement at a given terminal. Figure 1 shows the conceptual design and the linkage types (RI = rail-intermodal, HI = highway-intermodal, and WI = waterway intermodal).
Following the conversion from TransCAD to ESRI ArcMap Network Analyst, a new method of performing the routing was available to the researchers. This had many advantages over the old method, but there were also some disadvantages. One important benefit was that each mode could remain in its original layer and routing could include delays presented at terminals (point layers) as well as within the line layers. This means that the task of updating the networks was made significantly easier, and no longer required manually merging all three networks into a common line layer. This merging process required the creation of new unique identification number fields and complicated the retention of original network attributes. It should be noted here that new rail, highway and waterway networks are released annually, and the process of manually merging was a very intensive process that took at least a person-week to accomplish. Previously, relevant and similar fields (e.g., tonnages, lengths, speed, time) were in the merged network and joins had to be performed to retrieve the original and modal-specific data (e.g., rail classification, waterway depths). A drawback of using the new network analysis package was that multiple origin-destination combinations could not be routed through the network simultaneously. Routing is performed on a single origin-destination combination, similar to routing on Google Maps and MapQuest online.

As a demonstration of how the routing is performed using the original networks, the following dialog is a screen capture of a network dataset connectivity policy. You can see that there are three connectivity policies, and each mode connects in one while the terminals participate in all three. This separation of modal connections keeps containers from arbitrarily changing modes at railroad crossings, bridges, tunnels and other unrealistic locations.
While there are additional aspects of routing features of Network Analyst that could be discussed here, such discussion is beyond the scope of this final report document. Readers are referred to either contact the author directly, or review the product documentation.

**Data**

The Bureau of Transportation Statistics (BTS), a department of the US Department of Transportation (USDOT) within the Research and Innovative Technology Administration (RITA) maintains a set of nationwide geographic databases of transportation facilities, networks and other relevant infrastructure. These networks are used as a common analysis platform for many national, regional and local freight studies. Each network may be used as a single-mode routing platform, or have additional attributes attached. An example of this is the way the Freight Analysis Framework (FAF) work is produced. Periodically, the commodity flow survey and truck speed surveys, such as the Freight Performance Measures system, are used in conjunction with the BTS national highway network to estimate truck traffic and average speeds along all links. In other projects, Vanderbilt researchers

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commonly use each mode’s BTS network to perform safety and transportation risk analyses, counting the number of accidents along with the appropriate exposure units (vehicle-miles traveled, ton-miles, tons and trips for the highway, rail and waterway networks, respectively).

The intermodal terminals database was the starting point for the terminals used in this project. These are the locations where the containers will be changing modes. Terminals were visually verified using Google Earth satellite imagery to ensure that a significant amount of container transfer activity occurred at each terminal. This included the verification of the presence of gantry and straddle cranes, indicating a container truck-rail terminal. An intermediate project completed by Vanderbilt attempted to estimate the capacity of all terminals using acreage. For this reason, terminal areas that accurately outline each terminal’s property, are included in the network. A screenshot of an actual terminal is presented below.

![Figure 3. Union Pacific Truck Rail Terminal in Marion, AR.](image)

Using these terminal boundaries, digitization of the intermodal links was made easier and more intuitive; in most cases, the actual routes used by trucks entering and exiting the terminal were used.

**Prototype Development**

The general system architecture requires ArcGIS Server, the Network Analyst extension, and a web server (or folder from which html files may be accessed). The ArcGIS Server software is used to publish the network map service geographic layers. As showing all of the layers would be overwhelming (both visually and in required network bandwidth), the streets base layer served by ESRI was used and only the intermodal terminals and terminal area layer was published. The Network Analyst extension makes the route-solving features of the network dataset (the combination of all network and terminal layers)

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available through the map service and Internet. Finally, JavaScript code was written to allow for the selection of route start and end points, barriers, etc.

To demonstrate the feasibility of performing intermodal freight routing, the Memphis, TN area was selected (specifically, a 150 mile by 150 mile area with Memphis at the center). This area is diverse in freight transportation, servicing five Class I railroads and containing a container on barge (COB) facility on the Mississippi River.

The network analyst extension allows for the solution of routes with two or more stops and multiple barriers. In other words, a route may be created that starts at one point, goes through a specified point before finally terminating at the last selected stop (the destination). Additionally, barriers may be placed as points on the line features that prohibit link traversal in calculating the route solution. Through the developed interface, up to 3 routes with barriers may be solved simultaneously.

There are additional features that were left to future releases of the product. These include route driving directions, selection of criteria for routing (e.g., time, distance, and/or other attributes) and the ability to edit terminal and link delays through the browser. For example, one could route to minimize time and change the terminal dwell time to see at which point it becomes more efficient to route through another terminal.

**Results**

This section will demonstrate how the system may be used to determine the shortest intermodal route between two points. The first step is to load the system at: [http://transp40.vuse.vanderbilt.edu/intermodalnetwork/](http://transp40.vuse.vanderbilt.edu/intermodalnetwork/)

The screenshot in Figure 4 shows the initial page. Note that the terminal and terminal area (boundary) layers may be toggled on and off. Additionally, the base layer can be adjusted. The default base layer is streets, but imagery, topographic, light gray canvas and others may be selected inside the “Base Maps” accordion window. Note that routes may only be generated within this initial window. The network features do not extend beyond this window for prototype and establishment of proof of concept purposes. It is anticipated that the next release of this product will be regional or potentially nationwide.
In order to create a route, select the “Add Stops” button on the right side of the page and click on the map in the order in which you wish the route to visit each stop, starting with the origin point. To ensure an intermodal move, it is best to zoom in close to the destination and make sure that the stop is placed on the desired mode (e.g., if the origin is on a highway link, make sure the destination is on a rail or waterway link). Once all of the stops are added, barriers may be placed on the network. Barriers may represent clogged streets, bridges under maintenance, or simply links that the route should not traverse for whatever reason. Click the “Add Barriers” button, click on the map to add the barriers, again making sure to zoom in to place the barrier precisely where it is desired. At this point, a route can be solved by clicking the “Solve Routes” button. Multiple routes may be solved by selecting “Route 2” or “Route 3” from the “select route name” drop-down and the system will solve multiple routes at the same time, giving each solution a different color.

An example solved route (truck to rail movement) is shown in Figure 5.
Zooming in to the City of Memphis (the cluster of terminals), it is apparent that the terminal selected for this movement was the UP Marion facility in Arkansas. The route in to the terminal (moving from East to West) was on highway and the links taken out of the terminal are rail. This transfer is shown in Figure 6.
Figure 6. Truck to Rail Transfer at UP Marion Facility in Arkansas.
A rail to water movement was computed by the system as shown in Figure 7. Note that the shipment origin was in Arkansas, moving upriver on the Mississippi River.

Zooming in to the container-on-barge (COB) terminal just north of Memphis and turning on the satellite imagery base layer, the links which the shipment traversed are visible as shown in Figure 8.
Conclusions and Recommendations for Future Research

This project has clearly established the proof of concept for performing intermodal freight routing using Internet GIS. The bulk of the time spent on this project was converting the TransCAD model to that of ESRI’s Network Analyst. There are several enhancements that will be made to the project in the next iterations. These enhancements and new features include:

- Inclusion of “driving directions” that display in one of the web page sections. Generating driving directions is difficult since the highway layer is the only layer for which the directions make sense. However, the rail and waterway links can be modified so the resulting directions are clear to the average freight practitioner.
- The next iteration of this project will cover at least a regional, and potentially a national, case study area. The Memphis area was selected as a proof of concept since all modes are represented and it was unknown how responsive the system would be with even this number of links. As the server processes the route and not all of the networks are visible (ArcGIS Server typically limits the number of features from a single network to 1,000 and there are hundreds of thousands of rail, highway and waterway links), covering a national area may well be possible.
- This project routed on a single criteria; minimum time. Within the network analyst package, it is possible to route by time, length, or any other attribute (e.g., transportation risk, population). It is also possible to adjust the weights and route via multiple attributes (e.g., minimum environmental impact and time). These challenges will be addressed in the next release, enabling the user to select their desired criteria.
Another enhancement could include enabling users to modify terminal dwell times to see how that affects the route assignment. Temporary values can be stored and there can be functionality added to reset the values to a default. In the future it is hoped that current data may be able to be imported into the system, perhaps from a source such as the Railroad Performance Measures, a website maintained by the American Association of Railroads (AAR), which contains weekly dwell times and line speeds.\textsuperscript{5}

\textsuperscript{5} AAR Railroad Performance Measures Website: http://www.railroadpm.org/, Last accessed February 2013.