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**Transportation Routing Analysis Geographic Information System—TRAGIS, A
Multimodal Transportation Routing Tool**

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INTRODUCTION

Over 15 years ago, Oak Ridge National Laboratory (ORNL) developed two transportation routing models: HIGHWAY, which predicts truck transportation routes, and INTERLINE, which predicts rail transportation routes. Subsequent modifications have been made to enhance each of these models. Some of these changes include population density information for routes, HM-164 routing regulations for highway route controlled quantities of radioactive materials (RAM) truck shipments, and inclusion of waterway routing into INTERLINE. The AIRPORT model, developed 2 years after the HIGHWAY and INTERLINE models, serves as an emergency response tool. This model identifies the nearest airports from a designated location. Currently, the AIRPORT model is inactive.

The Transportation Management Division (EM-261) of the U.S. Department of Energy (DOE) held a Baseline Requirements Assessment Session on the HIGHWAY, INTERLINE, and AIRPORT models in April 1994 to bring together many users of these models and other experts in the transportation routing field to discuss these models and to decide on the capabilities that needed to be added. Of the many needs discussed, the primary one was to have the network databases within a geographic information system (GIS). As a result of the Baseline Requirements Session, the development of a new GIS model has been initiated. This paper will discuss the development of the new Transportation Routing Analysis GIS (TRAGIS) model at ORNL.

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TRAGIS CONCEPT

The concept for TRAGIS is to be a user-friendly GIS-based transportation and analysis model. The older HIGHWAY and INTERLINE models are useful to calculate routes but lack the ability to display a graphic of the calculated route. Many users have had difficulty determining the proper node for facilities and have been confused by or misinterpreted the text-based listing from the routing models. One of the primary reasons to develop TRAGIS is to improve the ease of selecting locations for routing, graphically displaying the route calculated, and to provide for additional geographic analysis of the route.

TRAGIS is written primarily in the Avenue and C programming languages and requires the use of ArcView™ software, which is marketed by Environmental Systems Research Institute, Inc. (ESRI). The development of TRAGIS was done in this method to take advantage of many of the GIS functions available with ArcView. Currently, TRAGIS operates on a UNIX® platform, and with several additional modifications, could operate on a Windows™ platform. Initially, the intent was to develop TRAGIS as a stand-alone Windows application, but it was decided that the ArcView version of the product could be developed more cost efficiently and quickly.

TRAGIS is currently designed to route using the following transportation modes: rail, truck, and waterways. The rail network is used in the initial version of the model is the database currently used in the INTERLINE model. This database was developed for the Federal Rail Administration in the mid-1970's is not a fixed-scale database and has been extensively modified since then by ORNL. The truck database is a 1:100,000-scale database developed from the U.S. Bureau of Census Topologically Integrated Geographic Encoding and Referencing (TIGER) system. Waterway information for the inland waterway systems is based on the 1:2,000,000-U.S. Geodata. Deep-water routes are depicted in TRAGIS as straight-line segments. Dependent upon future funding, it is planned to construct 1:100,000-scale databases for use in the model so that all modes are at a consistent scale.

FUNCTIONALITY OF TRAGIS

One of the features of TRAGIS is to have a consistent user interface in the model between the transportation modes. Functions will be similar for the user when running rail, truck, or waterway routes. Some variations will occur, such as prompts requesting the name of the railroad company to be used when sites are selected for rail routing. Overall, once the user learns to use one portion of the TRAGIS system, it will not be difficult to run other portions of the model.

TRAGIS allows the user to select the origin and destination of a route by two methods: if the user knows the geographic location, the system can be used to zoom in on the site and select the node. Conversely, if the location is not known, the user can select a location

from a list of node names. Using this second method, the program displays a list of state abbreviations from which the user selects a state. Next a list of node names within that state is displayed. The user can scroll through this list and select a node. After selecting the node, TRAGIS labels the selected node with its name. In addition to nodes for nearly every major city and intersection, the TRAGIS database contains hundreds of specialized nodes for locations of nuclear reactors, DOE sites, military installations, and other important destinations.

After an origin and destination is selected, the model is ready to calculate a route based on criteria established by option settings. A standard set of default criteria are active for each transportation mode in the model. Upon calculation of a route, TRAGIS displays the route in the primary display as a bold line. The user can also obtain a text listing of the route and obtain population density information that can be used with the RADTRAN risk model.

Options settings provide a mechanism for the user to change various parameters used by the model for route calculations. Examples of some of the options include adjusting the penalty factors for the mainline classifications for rail routing, using preferred routes for radioactive materials for truck routes, and running alternative routes for the different transportation modes in TRAGIS.

TRAGIS also provides functions for the user to temporarily modify the routing networks. The user can graphically select individual nodes and links or define an area in which all nodes and links are blocked from the network. Individual states can also be selectively removed from consideration. In the rail network, the user can also modify the transfer penalties between different rail systems at interchange locations.

Multimode transport is also a capability of the TRAGIS model. Currently, only rail-water intermodal routing capability is active. To calculate a rail-water intermodal route, the user needs to select the intermodal transportation mode.

EXAMPLES FROM TRAGIS

This section provides some examples from TRAGIS. The first set of figures show an example of a truck route between ORNL and the Idaho National Engineering Laboratory (INEL). First, the user selects the transportation mode. The pulldown menu of Mode has the items Rail, Truck, Water, and Rail-Water for selection. Truck is selected as the transportation mode for this example. Next the user may select the routing options. For this example the HM-164 option for preferred routes of radioactive material is selected. With the HM-164 option, TRAGIS calculates a route following Department of Transportation regulations for the movement of highway route controlled quantities of radioactive material. These regulations specify that the shipment must follow the shortest path to an Interstate highway and then use the quickest route on an Interstate highway, using beltways around major cities. Following this choice, the user selects the Origin item in the Route menu. Figure 1 displays the zoomed-in truck database in the vicinity of

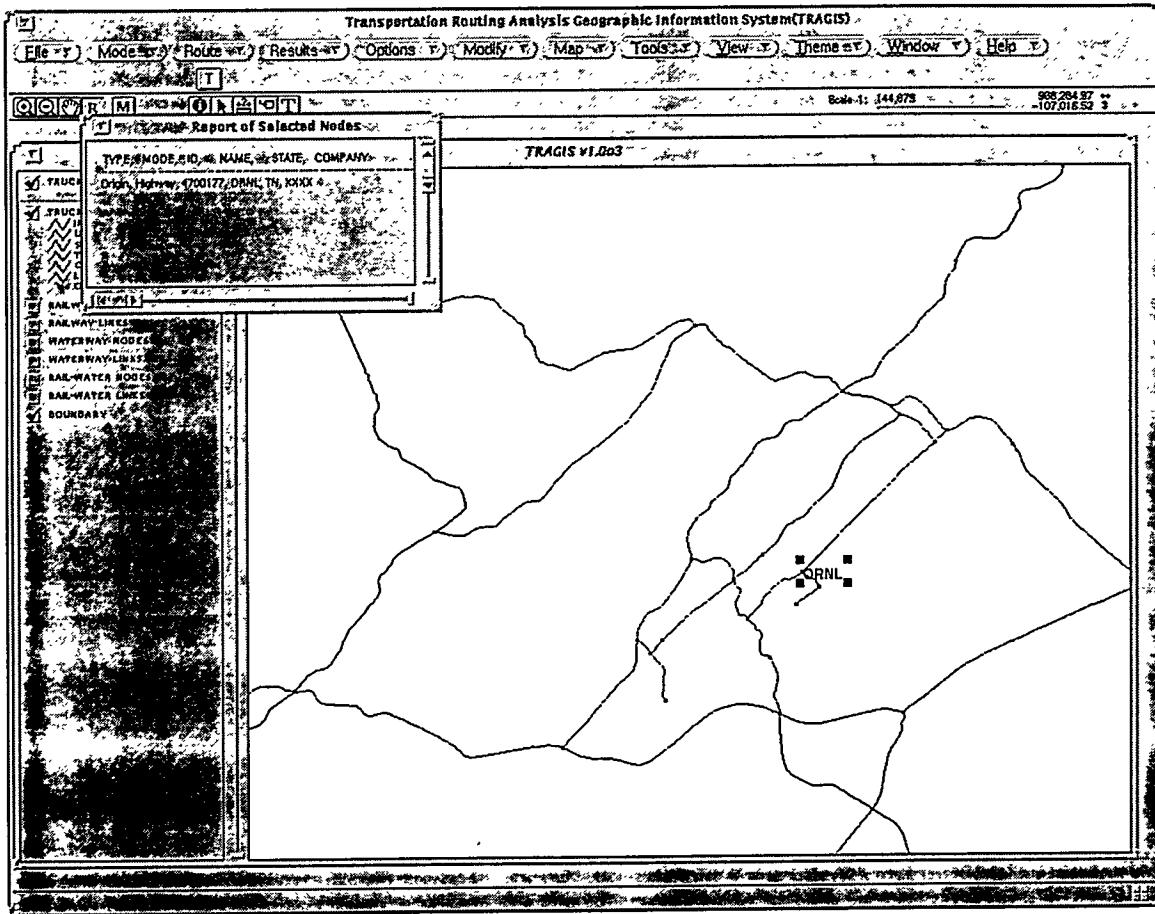


Fig. 1. Example of selecting a node in the truck routing database.

Oak Ridge, Tennessee, with the node ORNL selected. TRAGIS displays the nodes of the database as small dots and the links are displayed in different colors based upon the sign type of the highway. Upon careful examination, over twenty-five nodes can be identified in the vicinity of ORNL, as shown on Fig. 1. Most of the facilities have a node representing their location. Nodes exist at all junctions and other key locations along links. Next a destination, INEL, is selected. After an origin and destination are selected, the route can be calculated using previously defined criteria. After the route is calculated, TRAGIS displays the route, as shown on Fig. 2. The Alternative Routing item in the Options menu is then selected and two alternative routes are calculated. Alternative routes are calculated by penalizing previously used links by a specific amount. The default value for this penalty is an additional ten percent. When the alternative routing option is activated, the user can enter a different value. Figure 3 displays the original route and the two alternatives routes calculated by TRAGIS. A text listing describing the route or population density information about the route can be obtained by selecting the appropriate item from the Results menu.

The next example demonstrates the rail routing capability of TRAGIS. The U.S. has many rail companies providing rail service in different areas of the country. In order to

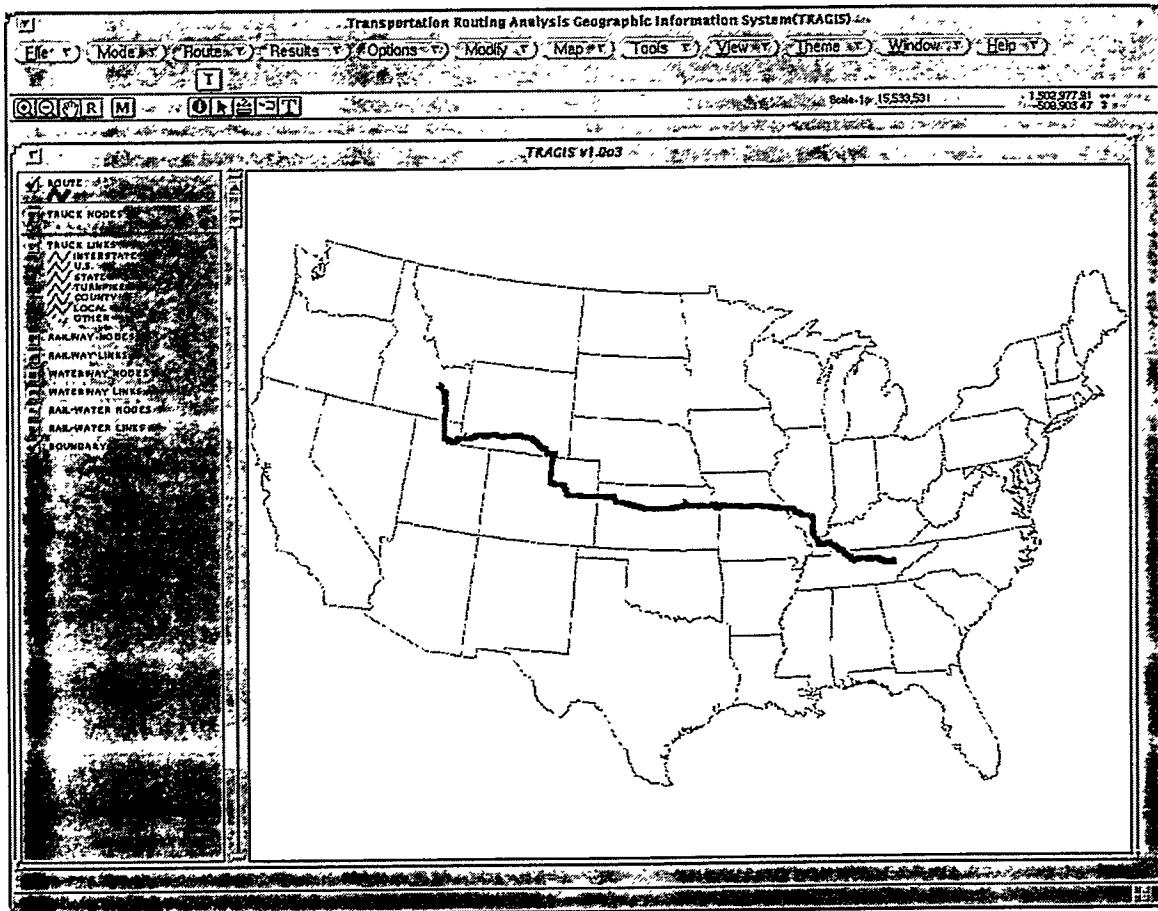


Fig. 2. Example of a truck route from ORNL to INEL.

simulate the actual routing practices of railroads, each company is represented in the TRAGIS database as a separate system. Traffic can be interchanged between rail systems only at locations where transfers are permitted. The TRAGIS database contains these interchange locations and are displayed on the network map with special symbols. Rail routes are calculated to maximize the distance traveled on lines with higher traffic volume. Line segments in the TRAGIS rail database are designated as A mainlines, B mainlines, A branchlines, and B branchlines, with A mainlines representing those lines with the highest traffic volume. A rail route is determined by multiplying the distance of each link by a factor based on the mainline classification of the link. An additional penalty is added to change from one rail system to another. In this example, the origin selected is again Oak Ridge, Tennessee, with CSX Transportation as the originating carrier and the selected destination is Scoville, Idaho, the rail station at INEL, which is served by the Union Pacific Railroad. The alternative routing option is activated, and a total of three routes are calculated between Oak Ridge and INEL. Alternative route penalties are treated differently in rail routing. Previously used links are penalized by an additional twenty percent and the factor for interchange locations used in earlier routes are doubled. Figure 4 shows the three rail routes calculated for this example.

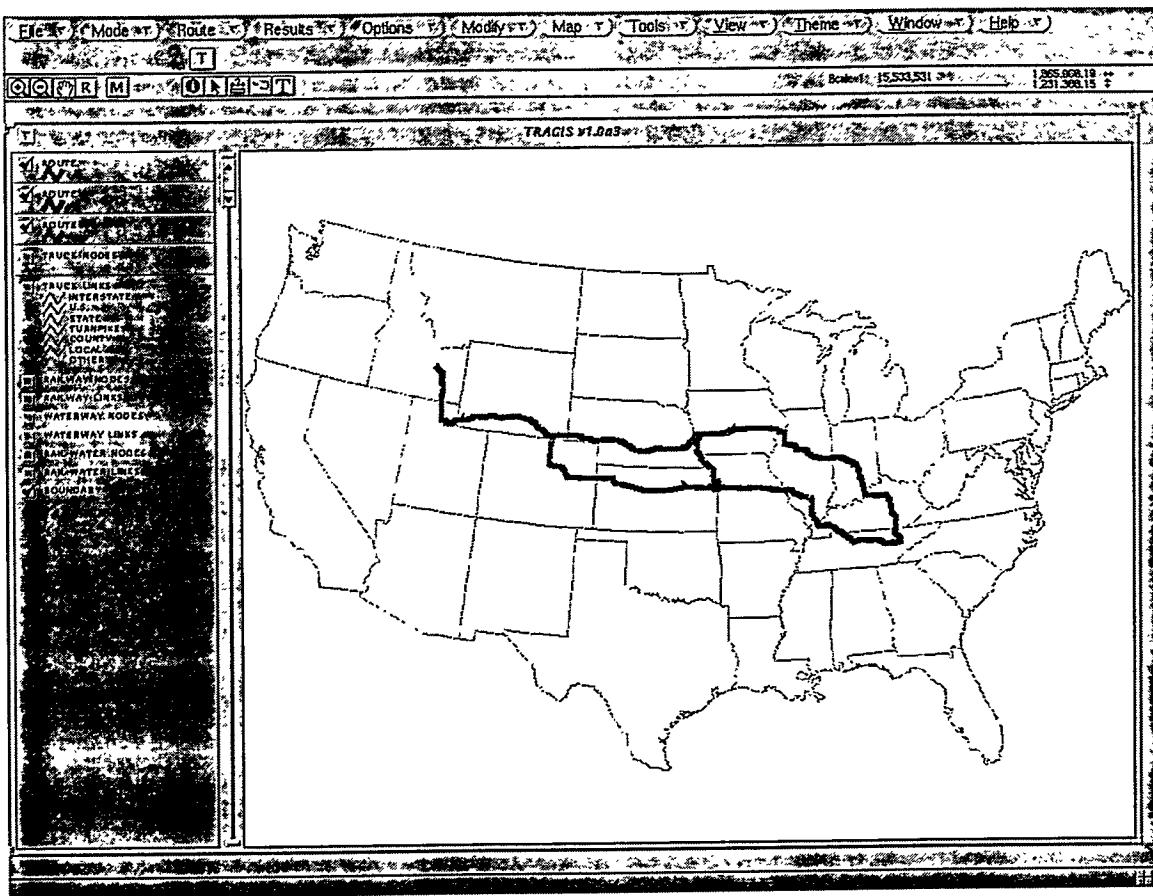


Fig. 3. Example of alternative truck routes between ORNL and INEL.

Waterway routing is also available in TRAGIS. Inland waterways and deep-water routes connecting the Great Lakes, Atlantic, Gulf, and Pacific coasts are included in the database. Lock and dam locations are included at node locations in the database. Currently, waterway routing is based on travel distance. For an example of TRAGIS waterway routing, a barge route between Knoxville, Tennessee, and Houston, Texas, is displayed in Fig. 5. This route follows the Tennessee River from Knoxville to northeastern Mississippi and then uses the Tennessee-Tombigbee Waterway to reach Mobile, Alabama. From Mobile the route follows the Gulf Intracoastal Waterway to Galveston, Texas, and then proceeds to Houston in the Houston Ship Channel. Population density information is also available for waterway routes. Data is calculated based on the centerline of navigation channel. Since many waterways form state boundaries, state by state population density information is not reported in TRAGIS.

FUTURE PLANS

Future development of TRAGIS will include a variety of enhancements, such as adding additional routing functions, intermodal capabilities, emergency responder locations, and airport facilities. Other databases, such as county boundaries, Indian reservations, urbanized areas, and population data will be available to assist the user in the routing

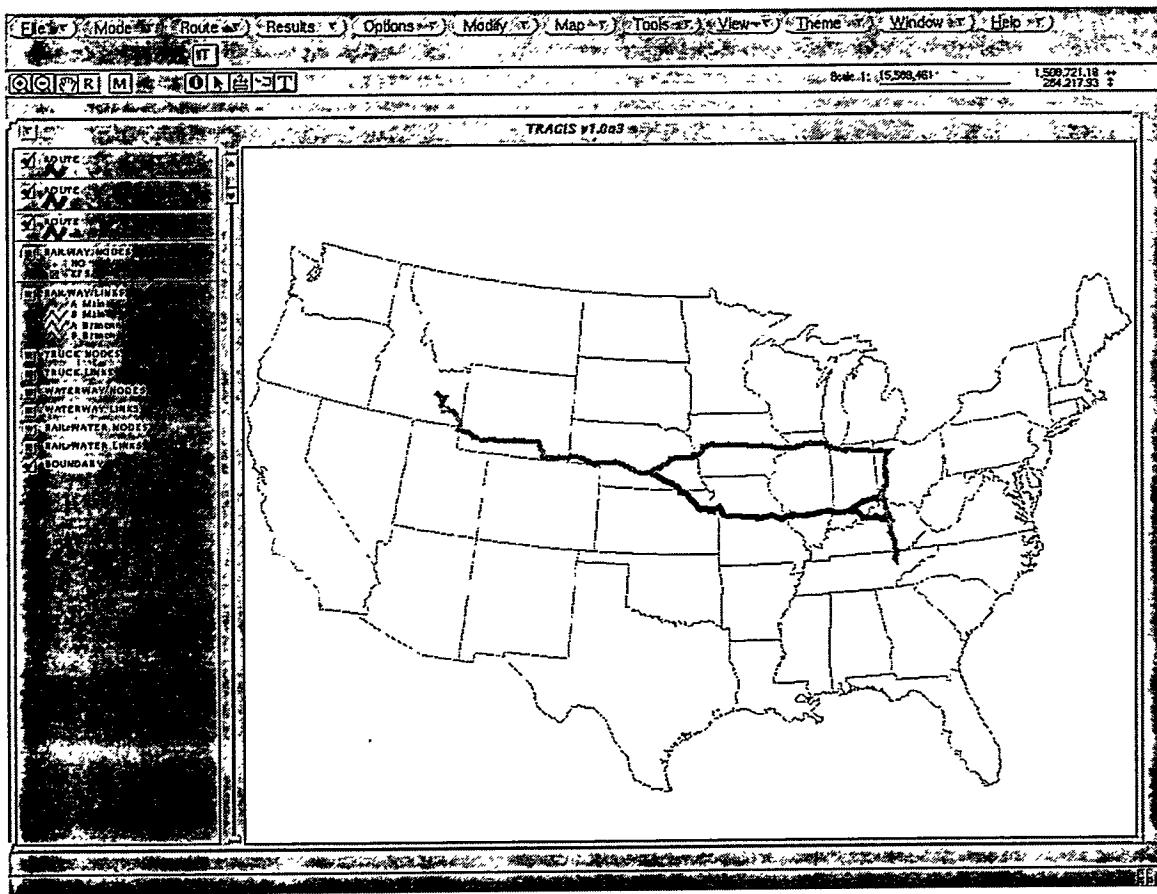


Fig. 4. Example of alternative rail routes between Oak Ridge and INEL.

analysis. Most of these data will be used primarily for display and analysis purposes. Additional data will be added to TRAGIS to enhance its capabilities to perform analysis and to analyze factors concerning environmental justice, emergency response facilities, etc. Users will also have the capability of incorporating their own databases into TRAGIS. Future efforts will also include adapting enhanced network databases into TRAGIS to improve the information that the user can obtain from the system. Also, the development of a stand-alone Windows version of the program is planned for the future.

CONCLUSION

TRAGIS has been developed to serve as a state-of-the-art, user-friendly routing and analysis tool for the DOE community and other interested parties. This model will help DOE perform route analyses for the expected increases in future movements of radioactive and hazardous materials. It will also provide a platform to add additional features to the system in the future.

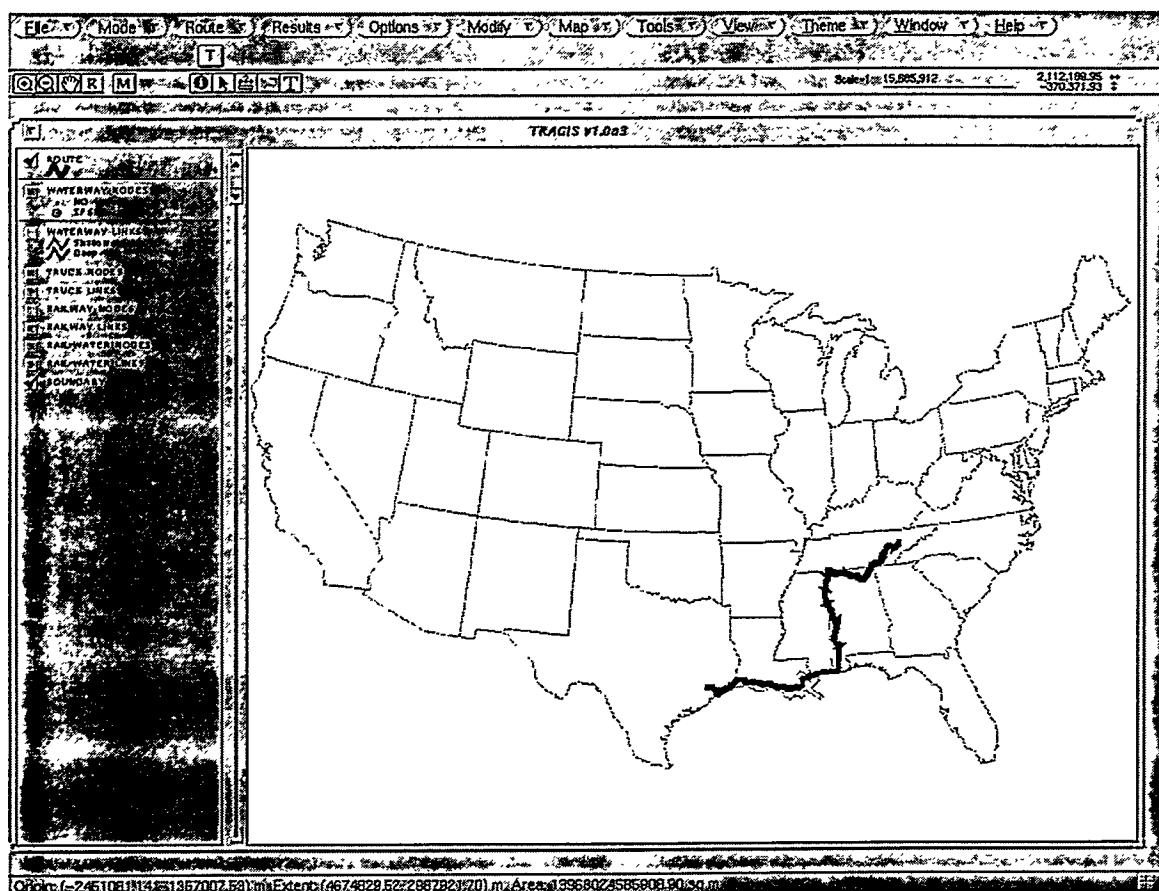


Fig. 5. Example of a barge route between Knoxville, Tennessee, and Houston, Texas.