WebTRAGIS, A Routing Model for the 21st Century

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INTRODUCTION

For nearly a quarter of a century, the Oak Ridge National Laboratory (ORNL) has been involved with transportation route modeling for spent nuclear fuel shipments. The legacy HIGHWAY[1] and INTERLINE[2] routing models, developed with funding from the U.S. Department of Energy, were widely used from the early 1980s until recently to examine and analyze transportation routes in support of National Environmental Policy Act analysis. Both of these models were text-based programs and only provided textual descriptions of routes. Obtaining maps of routes required additional processing of output data and incorporation into a separate user-provided geographic information system (GIS) software program. The need for a GIS-based upgrade was recognized and in the mid-1990s the Transportation Routing Analysis Geographic Information System (TRAGIS) model was developed to replace the original models. The original TRAGIS model was developed to operate on UNIX workstations. However, computing technology advances since the mid-1990s have enabled a web-based application to better serve the user community allowing TRAGIS to evolve into WebTRAGIS[3]. WebTRAGIS is a client-server application where the user interface and map data files reside on the user's personal computer (PC) and the routing engine and its large data files reside on the server. The model uses the Internet for communications between the client and the server. This paper examines the similarities and differences between the WebTRAGIS and the legacy routing models.

PROGRAM DESCRIPTION

The HIGHWAY and INTERLINE models were text based programs that required the users to have some knowledge and experience to efficiently operate the codes. The selection process of command prompts and route endpoints were not readily evident unless the user's manual was available and read. WebTRAGIS is designed with a graphical user interface that allows a user to access nearly the complete functionality of the model without ever having examined the user's manual.

WebTRAGIS is developed to be accessible over the Internet with an easy-to-use Windows interface. The model is deployed as a client-server application. The client portion of the program is downloaded and installed on the user's PC and primarily consists of the user interface software and map data files. Conversely, the routing engine with its large network data files reside on the server. Using the client-server design for WebTRAGIS is useful for several reasons. First, all users are accessing the same version of the routing networks on the server. Next, with access control, all users are registered and can be contacted when updates are made to the model. Finally, this design provides for easier diagnosis of problems that may develop.

The WebTRAGIS client software serves as the user interface for the model. All route parameter settings are established with this portion of the program. After starting WebTRAGIS and logging in, the user interface can display six different screens, which are accessible by clicking on each respective screen's "tab." The initial screen displayed is the "Select Origin/Destination" screen. This screen lets the user select the appropriate transportation mode (highway, railroad, or water) by clicking on the respective

radio buttons. By default, this screen is set to the highway mode. The origin and destination can be selected on this screen by first scrolling through and selecting the appropriate state from a scrollable list. After a state is selected, a list of the nodes within that state is loaded in the node name window. A node then can be selected from this scroll list. The user can also change the route type by clicking on the appropriate selection at the lower portion of this screen. For example, the model defaults the commercial truck routing option. By clicking on the HRCQ route type, the user can select the USDOT preferred routing option. There are other optional routing parameter tabs that display additional mode-specific parameter settings. An additional tab screen "Block Nodes/Links" provides a way for the user to make temporary blocks to the transportation network by restricting traffic from passing through specific nodes, links, or states. After an origin and destination has been selected, the user can click the "Calculate Route" button to have the model calculate the route. When the "Calculate Route" button is activated, the client software creates a small file of all the user-specified route parameters and then transmits this file over the Internet to the server.

The routing engine resides on the server and receives the user-specified route parameters across the Internet. Using the parameter inputs, the routing engine uses the appropriate transportation network and calculates the route and then the server generates output listings as text files. Output files then are transmitted over the Internet back to the client software to display the route information.

Upon receiving the output files from the server, the client software displays the textual description of the route in the "Route Listings" screen. The standard route list is initially displayed, but other listings including a detailed route list and population data are available by clicking the respective buttons at the top of this screen. The "Route Maps" screen provides the mapping capability of WebTRAGIS. The mapping features are written with Environmental Systems Research Institute, Inc. (ESRI) MapObjects software. To keep the program response speed to an acceptable level, the large map data files reside on the user's PC. Data transmitted from the server is limited so the user interface operates quickly and efficiently over the Internet. The software is written to minimize the data transmission, so the speed of operation is virtually the same whether one is connected via a modem or a high-speed Internet connection. The WebTRAGIS mapping software allows users to include additional ESRI formatted shape files in the display, such as Native American reservations or outlines of urbanized areas.

WebTRAGIS is supported with very detailed highway, rail, and waterway routing networks. The geographic quality of the transportation networks is the primary feature where WebTRAGIS differs from the legacy HIGHWAY and INTERLINE models. With the legacy models, the transportation networks were essentially stick figure representations. Node locations, which can be used as origins and destinations for routes, have latitude/longitude coordinates. The link representations between the nodes were represented as straight lines between the nodes. This was sufficient for route calculations, but an accurate representation of transportation networks becomes important when GIS analysis is needed. The highway network developed for TRAGIS is a 1:100,000-scale database. This network was developed from the U.S. Geological Survey (USGS) Digital Line Graphs (DLG) and the U.S. Bureau of Census Topologically Integrated Geographic Encoding and Referencing (TIGER) system. A new 1:100,000-scale rail network is now incorporated into WebTRAGIS. The rail network is also developed from the USGS DLGs. The current inland waterway network is based on the USGS 1:2,000,000-U.S. Geodata. Deep-water routes are depicted in WebTRAGIS as straight-line segments. Future plans are to incorporate a 1:100,000-scale waterway database for the model so that all modes are at a consistent scale.

One of the features of WebTRAGIS is an easy-to-navigate and consistent user interface between the transportation modes. Functions are similar for running highway, rail, or waterway routes. Some variations occur, such as prompts requesting the name of the origin and destination railroad companies to be used. With the graphical layout of the various user screens, the WebTRAGIS model is very easy to

learn to operate by a novice user. This is a major improvement over the legacy routing models that required the user to learn model-specific commands to specify the routing parameters.

The WebTRAGIS home page is located at http://apps.ntp.doe.gov/tragis/tragis.htm. Access to the model is controlled by user identification and password. To obtain access to WebTRAGIS, click on the register link on the home page and then complete the form for prospective users. When the registration form is submitted, the information will be reviewed. An electronic message will be sent to the registrant either confirming or denying access to WebTRAGIS. Since WebTRAGIS is developed and maintained with U.S. government funds, a valid need for access is required before a new account is approved.

GEOGRAPHIC IMPACT OF NEW HIGHWAY AND RAIL NETWORKS

Beyond the change of the graphical interface, the primary difference between WebTRAGIS and the legacy HIGHWAY and INTERLINE models is the incorporation of 1:100,000-scale highway and rail networks. Such databases have been available for about a decade, but they initially were not in a condition for use within a routing model. Additional development work was required to ensure that the topology represents reality for the transportation networks to work properly within a routing model. Work on the 1:100,000-scale highway network started in the mid-1990's and was deployed with the initial development of the TRAGIS model. Development of the 1:100,000-scale rail network did not occur until 2000 and has just recently been deployed in the WebTRAGIS model.

The geographic representation of the shape of the transportation networks provides a significant change between the legacy routing models and WebTRAGIS. The stick figure representations employed in the legacy codes represented the best technology available when these models were developed over twenty years ago. The HIGHWAY model network originally did not have any geographic attributes to the network. A need for displaying maps of routes from the HIGHWAY model quickly led to the addition of geographic coordinates to the network. The nodes in that network were digitized from 1:250,000-scale maps. This scale proved to be more than sufficient for national maps of routes from the HIGHWAY model. The INTERLINE model used a rail network originally developed by the Federal Railroad Administration in the early 1970s. This network had geographic coordinates, but they were digitized from 490 zone maps that varied in scale. Each zone map had only two ground control points used as base points for the digitization of coordinates. Several zone maps even had errors in the coordinate values that created a warping effect for node coordinates for those zones. Over the years, some effort was made to correct such errors, but in most of the network coordinates were not updated. Overall the accuracy of the INTERLINE rail network was not as good as the network used by the HIGHWAY model. But even with these inherent problems, the quality of both of the networks was better than other networks available. Both networks were maintained and updated annually to reflect changes, resulting in the best results from the respective routing model.

With the development of the 1:100,000-scale highways and rail networks provides a major improvement to the WebTRAGIS model. The alignment of roads and rail lines can be shown in great detail as the program allows the user to select and zoom in on a segment of the route for further study. Figure 1 shows the difference between the INTERLINE rail network (straight lines) and the new WebTRAGIS 1:100,000-scale rail network (curving lines). The older HIGHWAY and INTERLINE networks could never accurately represent road and rail curvature, especially when viewing the network representation with large-scale maps. The increased shape detail of the links also provides improved accuracy for overlaying other GIS databases and calculation of population density WebTRAGIS for risk assessment work. Improved geographic representation of the networks has also resulted in additional capabilities, such as providing the mileage of routes through Native American reservations and tribal lands. Other such capabilities can be developed for future needs.

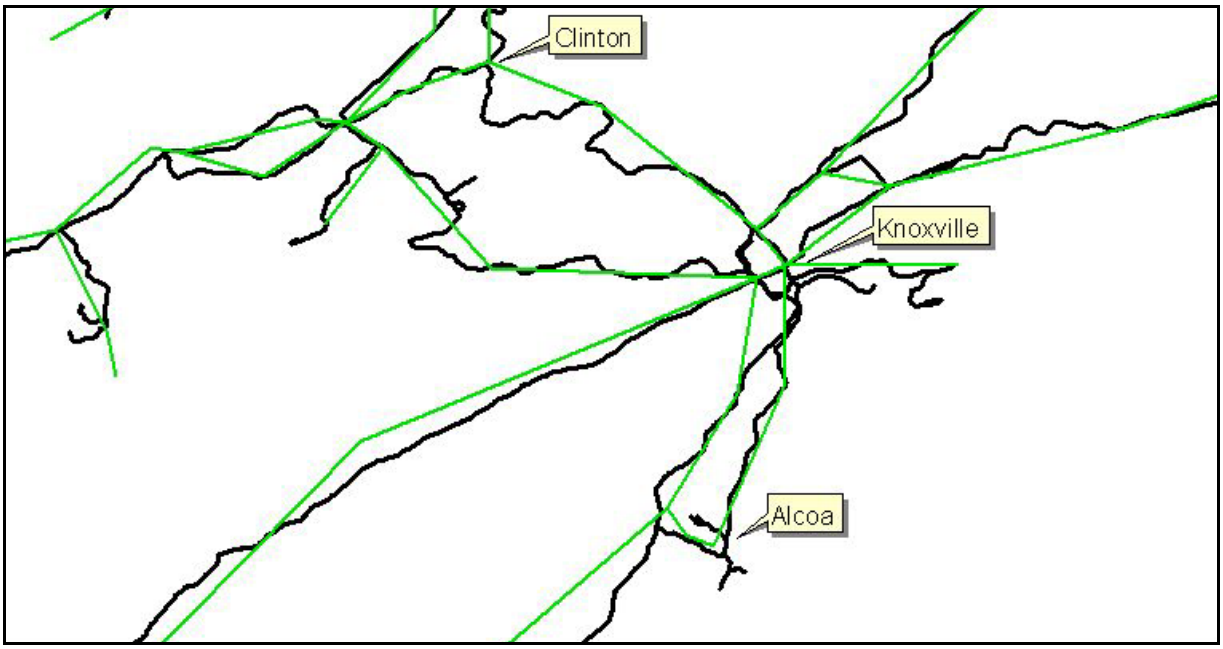

Figure 1. Comparison of Rail Network in the area of Knoxville, Tennessee

MILEAGE IMPACT OF THE NEW HIGHWAY AND RAIL NETWORKS

Mileage in both of the 1:100,000-scale highway and rail networks are calculated from the shape of each network link. This is done for several reasons. First, this removes any possible conflict that distances are obtained from a copyrighted map source. Next, when any new links are added to the network there is no concern about determining a distance for these links because the GIS software can automatically calculate the distance. Finally, the geographic representation of each link is quite accurate, and calculating the distance using an equidistant projection, provides a consistent and uniform method of distance calculation for each link of the network.

The distance for each link in the HIGHWAY and INTERLINE networks was determined from one of several sources. For the HIGHWAY road network, state highway maps and USGS maps were used to determine distances. Distances in the old highway network were only recorded as integers, so the shortest links were either one-mile long or had a distance of zero. Considerable amount of effort was placed on verifying the distance on Interstate highways in the network. For those states with exit numbers based on milepost locations, distances were closely examined to make sure that distances summed to the milepost length from the state boundary. But this method could lead to errors due to alignment changes of Interstate highways over time. The INTERLINE rail network distances were established when the network was created. Over time, some verification of the distances with railroad employee timetables was performed, but no significant changes were ever made to this aspect of the network. One of the reasons is that railroad timetables provide distances between stations and passing sidings. Many of the nodes in the old rail network occur at dummy locations or county lines.

A comparison of routes between the old and new versions of the networks was performed to determine the variation of distances between the databases. HIGHWAY Version 3.6 with Network HW-00.2, the most recent update of this model and network, was used to determine the old truck route distances. TRAGIS Routing Engine Version 1.10 with Highway Network 2.1 was used to determine the new truck route distances. INTERLINE 5.1 with Network 15, the most recent update of this model and network, was used to determine the old rail route distances. TRAGIS Routing Engine Version 1.4.0 with

Rail Network 1.0 was used to determine the new rail route distances. Seventy-six routes were calculated from the commercial nuclear reactor plants to the Yucca Mountain repository in Nevada. This represents a large sample of routes for examination.

Truck routes between the commercial nuclear reactor sites and the Yucca Mountain repository were run on both the HIGHWAY and WebTRAGIS models using the highway route controlled quantity (HRCQ) preferred routing option. The routes are nearly identical to the representative truck routes used in the Yucca Mountain Final Environmental Impact Statement[4]. The average distance for all the truck routes from the HIGHWAY model is 2228.9 miles while the average distance for all the truck routes from the WebTRAGIS model is 2210.4 miles. This represents an average distance variation of 18.5 miles between the two network databases. Variation of individual routes varies from a route 5.0 miles longer to a route 38.8 miles shorter from the WebTRAGIS highway network. The standard deviation of the route variation is 8.0. Upon detailed examination, the variation of the routes is quite small. The route with the largest variation (38.8 miles) crosses 14 states, with two states having slightly longer distances and the other twelve states having shorter distances. The state with the largest difference is less than 9 miles.

Rail routes between the commercial nuclear reactor sites (or the nearest railhead at those sites without direct rail access) and the Yucca Mountain repository, using the proposed rail line from the Valley siding, were run on both the INTERLINE and WebTRAGIS models. These routes are also nearly identical to the representative rail routes used in the Yucca Mountain Final Environmental Impact Statement. The average distance for all the rail routes from the INTERLINE model is 2364.1 miles while the average distance for all the rail routes from the WebTRAGIS model is 2345.6 miles. Coincidently, the average distance variation is also 18.5 miles between the two network databases. Variation of individual routes has a larger variation ranging from a route 36.1 miles longer to a route 67.0 miles shorter in the WebTRAGIS rail network. The standard deviation of the route variation is 17.6. Upon detailed examination, the variation of the routes is somewhat larger compared to the highway routes. The route with the largest variation crosses twelve states, with three states having slightly longer distances and the other nine states having shorter distances. The state with the largest difference is 50 miles.

	Truck	Rail
New 1:100,000-scale network	2210.4	2345.6
Old network	2228.9	2364.1
Average variation	18.5	18.5
Standard deviation	8.0	17.6

Table 1. Comparison of route distances between routing networks.

It is interesting to note that the older straight-line routing networks result in longer routes than the 1:100,000-scale networks. One possible explanation is that the HIGHWAY routing network used integer miles on links. This could result in upward rounding giving longer overall routes. The INTERLINE model routing network represented older technology and as mentioned early was difficult to verify distances. Overall, the results of the older routing networks are rather close to the new 1:100,000-scale networks. The slight over estimation of mileages has provided slightly conservative results for risk assessment studies. A more detailed verification and validation study of the new 1:100,000-scale networks will be performed later this fiscal year to provide further documentation of the more detailed routing databases.

CONCLUSION

The new WebTRAGIS model provides an improved routing capability to the DOE community. With increased availability over the Internet, WebTRAGIS is available to essentially everyone who needs

access to the model. The higher resolution 1:100,000-scale routing networks in WebTRAGIS provide better and more accurate results and provide additional capabilities with other GIS databases.

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[1] P. E. Johnson, D. S. Joy, D. B. Clarke, and J. M. Jacobi, *HIGHWAY 3.1—An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual*, ORNL/TM-12124, March 1993.
[2] P. E. Johnson, D. S. Joy, D. B. Clarke, and J. M. Jacobi, *INTERLINE 5.0—An Expanded Railroad Routing Model: Program Description, Methodology, and Revised User's Manual*, ORNL/TM-12090, March 1993.
[3] P. E. Johnson and R. D. Michelhaugh, *Transportation Routing Analysis Geographic Information System (WebTRAGIS), User's Manual*, ORNL/TM-2000/86, April 2000.
[4] U.S. Department of Energy Office of Civilian Radioactive Waste Management, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada*, DOE/EIS-0250, February 2002.