Routing Models for the Transportation of Hazardous Materials–State Level Enhancements and Modifications

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ABSTRACT

Computerized routing models for the movement of radioactive and other hazardous materials by highway exist at the national level. These models use gross estimates of distance and operating speed to select minimum paths for various origin-destination pairs. Although these models are constantly being enhanced, the coarseness of data aggregation that is necessary on a national scale has precluded their use at smaller levels of analysis such as an individual state. The purpose of this paper is to report on efforts to refine the existing models for improved operation on more limited networks. The existing highway network for New Mexico is described and additional data bases are defined and examined to identify supplementary information (such as roadway geometrics and operational parameters) that will improve model performance at the state level. The accuracy and effectiveness of detailed routing projections as well as the asmociated costs, benefits, and sensitivities of the use of various network parameters are also to be evaluated.

Research and development activities in the transportation of radioactive materials have been under way for several years. These efforts have been directed toward a number of areas that include the design and testing of waste-transport hardware, the development and maintenance of a number of computerized data bases that pertain to the transport of radioactive and other hazardous materials, and the development and application of several computerized routing models for the transportation of hazardous materials.

This latter activity has resulted in two nationwide routing models for the movement of radioactive materials by road (HIGHWAY) and rail (INTERLINE). In addition, a data base that contains legislative, regulatory, and operational restrictions (LRIS) on the movement of radioactive and hazardous waste is maintained; efforts are now under way to interface these restrictions with the previously developed routing models. Technical developments in these two areas have been performed primarily by Oak Ridge National Laboratory (ORNL) and have been reported previously in the technical literature (1-5).

Although the nationwide models just described are continually being enhanced, the level of data aggregation that is necessary on a nationwide scale may preclude serious consideration of detailed network geometric and operational factors appropriate at other levels of analysis. Thus, for example, application of the routing models at a more detailed level of analysis, such as a region of the country or a specific state, may require more refined network information than the gross link distances and average driving speeds used in the nationwide code.

The work on which this paper is based is an attempt to "window-in" on only a limited portion of the nationwide network--the state of New Mexico-and investigate the desirability of enhancing network descriptions through the consideration of additional link parameters that may influence the movement of highway vehicles used to transport hazardous materials. Thus, the overall project has four goals:

1. To examine the applicability of currently available nationwide network routing models,

2. To evaluate the appropriateness of such models to regional and state levels of analysis,

3. To assess the availability and applicability of additional statewide network data that are helpful in improving model performance, and

4. To conduct sensitivity analyses to determine the cost-effectiveness of more detailed model applications.

Subsequent sections of the paper contain a description of the existing highway model, its data requirements and its output, a discussion on the state-level network defined by the national model, a list and evaluation of additional data sources that are available at the state level to refine the national model as applied to New Mexico, and an outline of future activities related to improved model performance (including cost-effectiveness) at the state level.

THE HIGHWAY ROUTING MODEL

Network models that involve use of path selection criteria and vehicle trip assignment to previously selected paths have been an integral part of transportation analysis for many years. At the urban-area scale, the emphasis of these models has been on the assignment of passenger vehicles to alternative highway networks based on the selection of minimum paths as a function of distance, travel time, cost, or some general measure of trip impedance (6). More recently, traffic or trip assignment models have been applied to passenger movements at other levels of aggregation, such as regions, states, or even the entire country (7), and analysis methods have been broadened to include the assignment of freight as well as passenger movements (8,9). Conceptually, however, modeling approaches have remained basically unchanged. Thus, for example, groups of paths, or "trees," are first developed on the basis of the minimization of some measure of trip disutility through the network. Then movement volumes, or flows, are assigned to the minimum paths between an origin and all possible destinations. Individual volumes on any one link in the network may then be easily obtained by summing minimum path volumes for all paths that involve use of that link.

Procedures such as those described earlier have been used by ORNL in the development and subsequent modification of HIGHWAY, a routing program for predicting highway paths for the movement of radioactive waste nationwide. The data base used in HIGH-WAY, originally the COMPU.MAP program developed by Logistic Systems, Inc. (10), is basically a computerized road atlas that contains over 240,000 miles of highway on over 15,000 roadway links defined by 10,500 modal intersections. In terms of functional or administrative classification, all Interstate highways and all U.S. numbered highways (with the exception of those that parallel the Interstate system) are included in the HIGHWAY data base. Most principal state routes are also included, and a number of local roads and streets, particularly those that connect nuclear facilities with nearby airports, have recently been added to the network (5).

Information in the data base for each link includes link origin and destination (usually a city, town, or major street intersection), link designation (Interstate, U.S., state, or local road route number), highway functional classification (given in Table 1), estimated driving speed on the link (in

TABLE 1Functional Classificationof the HIGHWAY Data Base

Class No.	Description	
1	Multilane limited access	
2	Two-lane limited access	
3	Four-lane divided	
4	Four-lane undivided	
5	Principal highway	
6	Other through highway	
7	All other roads	

miles per hour), and link length (in miles). Output from the HIGHWAY model consists of the route between an origin-destination pair chosen by minimization of the total impedance (a function of distance and travel time) between the pair.

The model is capable of reacting to several userimposed constraints on the routing. In addition to routes based only on state and local restrictions that govern the movement of normal commerce, the model can also select routes that bypass areas of high population density--the so-called Nuclear Regulatory Commission (NRC) routes--or that maximize the use of Interstate facilities--the U.S. Department of Transportation (DOT) criteria (4,5).

Results obtained by using the different routing criteria are summarized in Table 2, which compares the three routing criteria for a shipment between Barnwell, South Carolina and Richland, Washington. As can be seen in the table, the regular route is the most direct, both in terms of distance and driving time, and uses Interstate facilities for 90 percent of the trip. By using the NRC criteria, in contrast, the route bypasses six metropolitan areas and increases the travel distance by just over 5 percent. The driving time on this route, however, is increased by almost 12 percent because of the greater percentage of use of lower-speed, non-Interstate facilities. The DOT route, which maximizes the use of Interstate facilities, results in the longest distance but, because of the greater use of high speed

 TABLE 2
 Comparison of Routes Between

 Richland, Washington and Barnwell, South

 Carolina (4)

Туре	Distance (km)	Driving Time (hr)	Percent of Interstate
Regular	4312	46.2	90.0
NRC	4542	51.7	56.4
DOT	4562	47.7	96.7

facilities, only a slight increase in overall travel time. The DOT route passes through eight urbanized areas. Differences among the three routes are shown in Figure 1.

The limited amount of data available from the national model, however, may limit its effectiveness



FIGURE 1 Routes between Barnwell, South Carolina and Richland, Washington (4).

when applied to regional or state levels of analysis. As the size of the analysis area decreases, the need to define network parameters in more detail increases. Link lengths of 75 to 150 miles, although appropriate for analyses at the national level, are too coarse for use in state and regional applications. Average driving speeds from road atlas timeand-distance maps, which are the basis for the national network, similarly do not consider variations in driving speed, and, hence, travel time at the state level. Finally, additional data not appropriate at the national level, such as roadway geometrics, operating speeds by time of day, and the identification of critical spot locations (railhighway grade crossings and critical bridges, for example) need to be considered at the lower levels of aggregation. It is the availability and the use of such data that is discussed in the next section.

DATA NEEDS AT THE STATE LEVEL

The New Mexico portion of the nationwide HIGHWAY data base is shown in Figure 2. The New Mexico network shown contains a total of 207 links that range in length from 1 to 153 miles. Estimated driving speeds on the network vary from 60 mph on the state's Interstate facilities to a low of 10 mph on a number of restricted local streets. The only other information available from the national data base for the New Mexico network is functional classification.

One of this project's objectives was the consideration of additional data available at the state



Source: Oak Ridge National Laboratory, Oak Ridge, Tennessee,

FIGURE 2 ORNL HIGHWAY data base.

level to augment the state network represented in HIGHWAY. These additional data were deemed to be necessary because of the coarseness and the limited amount of information available from the national data. The process may be thought of as similar to the process that occurs in the network coding step at the urban transportation planning level where, as the size of the area decreases (or the sophistication of the analysis technique increases), the level of detail and the number of special features to be coded increases. Thus, for instance, broad regionwide planning studies have little need for detailed geometrics whereas small area studies may have to consider such network or operational features as

- Turn penalties at intersections,
- · Roadway capacity,
- · Directional distribution of traffic,
- · Street width,
- The presence or absence of parking,
- Roadway surface type and condition, and
- The predominant land use in the area (6).

Fortunately, a great deal of inventory information on New Mexico roadways exists. This information is maintained in a standard format, for the most part, for a number of state highway offices by the

 TABLE 3 Available Data for Highway Routing-State Level

 File
 Variables of Interest

 Roadway inventory
 Average daily traffic (ADT), average highway speed, critical grade, critical sight distance, functional classification, number of lanes, segment length, left shoulder width, median type, log mile of section start, roadway width, administrative route number, right shoulder width, ROW width, surface width

 Roadway condition
 Adjusted overall rating, capacity rating, percent heavy commercial, design speed, 30th highest hourly volume Roadway gradient, horizontal curvature, average roadway roughness, vertical curvature Highway bridge file

 Highway bridge file
 Future ADT, operating speed, passing sight distance, safe speed, terrain type, percent heavy commercial thin, super-structure condition, vertical clearance

Division of Government Research (DGR) at the University of New Mexico. Not all of the information is appropriate, of course, for the statewide routing issue. Data thought to be most useful have been identified by file source and are summarized in Table 3.

As the data in Table 3 indicate, a large amount of additional network information is available to refine the New Mexico roadway system for the analysis of intrastate routing of hazardous materials. A number of technical issues need to be resolved, however, before the refined network is used in model applications. The issue of the length of sections that define network links, for instance, must be addressed. Link lengths on the existing HIGHWAY network for the state, as previously mentioned, range from 1 to over 150 miles. Segment lengths on the state's Roadway Inventory file for the Interstate system, on the other hand, vary in length from only 200 ft to over 11 miles. Use of the refined state network will require section lengths somewhere between the extremes represented by the HIGHWAY and Roadway Inventory data bases.

Another issue in the use of additional statelevel data to improve network model performance involves the utility of spot, or specific locational data, in conjunction with sections or links of varying lengths. For example, critical geometric factors (sharp curves, steep grades, limited sight distances) may occur at a number of locations along a previously defined network link. In order to use this spot information in the routing code, an index for the section that reflects the number and severity of such critical locations on the link must be developed. The same may be true for accident information contained in the state's computerized accident information system if it is to be used to identify locations (or links) with unusual accident characteristics.

FUTURE DEVELOPMENTS

Considerable work remains to be done to implement improved routing models for the shipment of hazardous materials at the state level of analysis. The existing state network has been defined and data sources available at the state level that will add detailed information on existing links have been identified. Work on extracting the additional variables of interest from a number of diverse data bases is under way and a single source that contains the complete set of desired information is anticipated shortly.

The refined network will then be used to examine the sensitivity of various routing alternatives to the new level of network detail. Alternative routing travel times may be relatively insensitive to roadway geometric features such as vertical alignment, for instance, but may be particularly sensitive to speed and traffic flow volumes by time of day. Regulatory or legislative restrictions that prohibit hazardous materials movement during certain hours or on certain routes may similarly add to the time and costs of scheduling such movements. Geometric and traffic operational parameters may also be related to accident experience on roadway segments, thus identifying possible high hazard locations.

SUMMARY

The research discussed in this paper concerns investigation of the highway routing of radioactive and other hazardous materials in New Mexico through the application and refinement of existing nationwide network analysis models. Truck-related data bases that detail truck movements, as well as detailed geometric and operational inventory data, have been identified at the state level and are being used to refine estimates of hazardous materials movements in the state. Results of this project will enable estimates of the probable routes of such movements to be made within New Mexico and will allow decision makers at various levels to better evaluate the impacts of such movements.

ACKNOWLEDGMENTS

The authors wish to acknowledge Sandia National Laboratories for funding the work reported on in this paper; the Oak Ridge National Laboratory for providing access to the New Mexico highway data base; and R.U. Anderson of the Division of Government Research, University of New Mexico, for supplying information on state-level highway and accident data bases.

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The opinions, findings, and conclusions are those of the authors and do not necessarily reflect the views of the sponsor.

Publication of this paper sponsored by Committee on Transportation of Hazardous Materials.