

# ornl

ORNL/TM-12906

**OAK RIDGE  
NATIONAL  
LABORATORY**

**MARTIN MARIETTA**

**MANAGED BY  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
FOR THE UNITED STATES  
DEPARTMENT OF ENERGY**

**Baseline Requirements of the  
Proposed Action for the  
Transportation Management Division  
Routing Models**

P. E. Johnson  
D. S. Joy

This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401, FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

NTIS price codes—Printed Copy: A03 Microfiche A01

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

## **DISCLAIMER**

**Portions of this document may be illegible  
in electronic image products. Images are  
produced from the best available original  
document.**

Chemical Technology Division

**Baseline Requirements of the  
Proposed Action for the Transportation Management Division  
Routing Models**

P. E. Johnson\*  
D. S. Joy

\*Computational Physics and Engineering Division

Date Published: February 1995

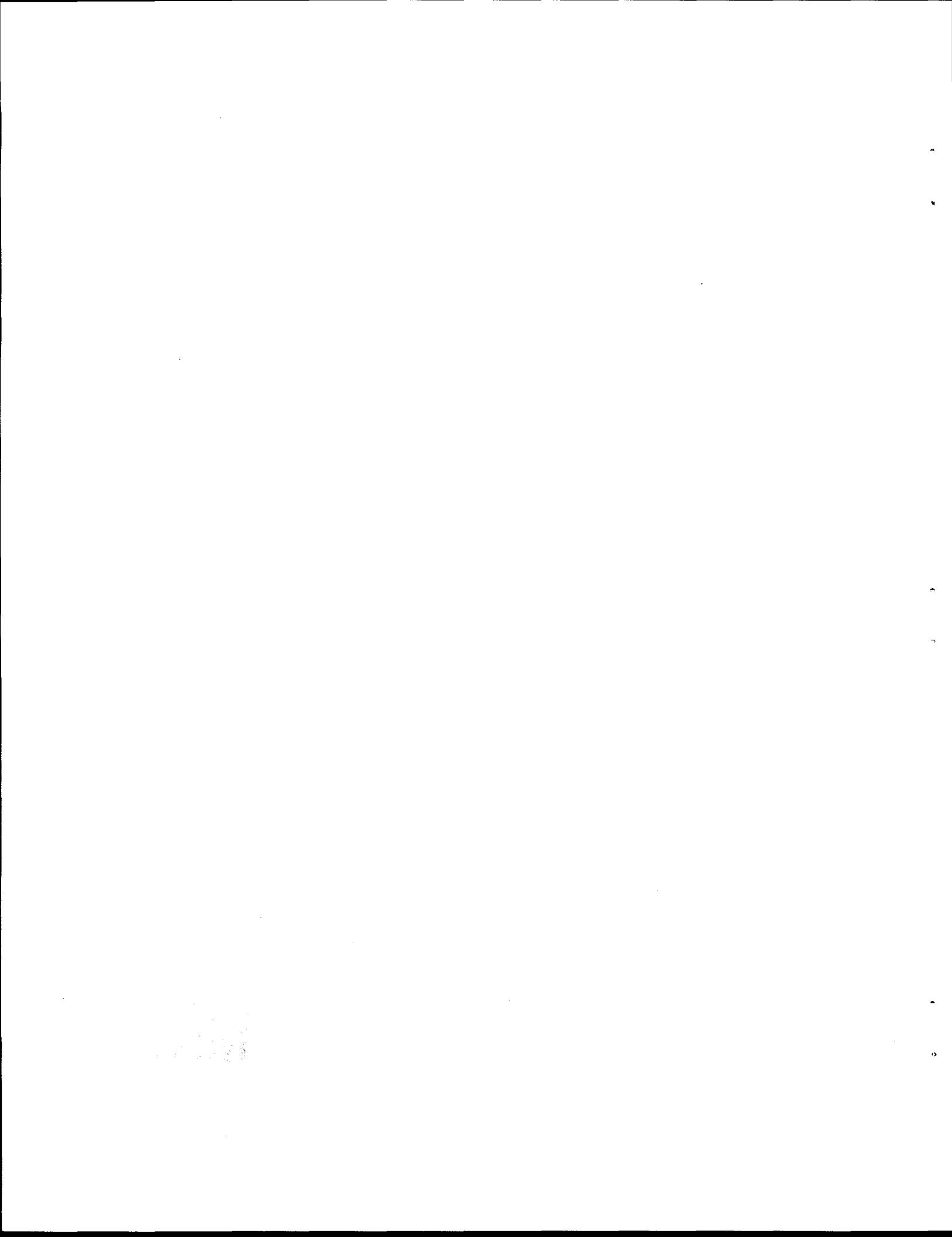
Prepared for  
Transportation Management Division, EM-261  
Office of Environmental Management  
U.S. Department of Energy  
Washington, DC 20585  
TTP No. OR-139002(3)

Prepared by the  
OAK RIDGE NATIONAL LABORATORY  
Oak Ridge, Tennessee 37831-6285  
managed by  
MARTIN MARIETTA ENERGY SYSTEMS, INC.  
for the  
U.S. DEPARTMENT OF ENERGY  
under contract DE-AC05-84OR21400

**MASTER**

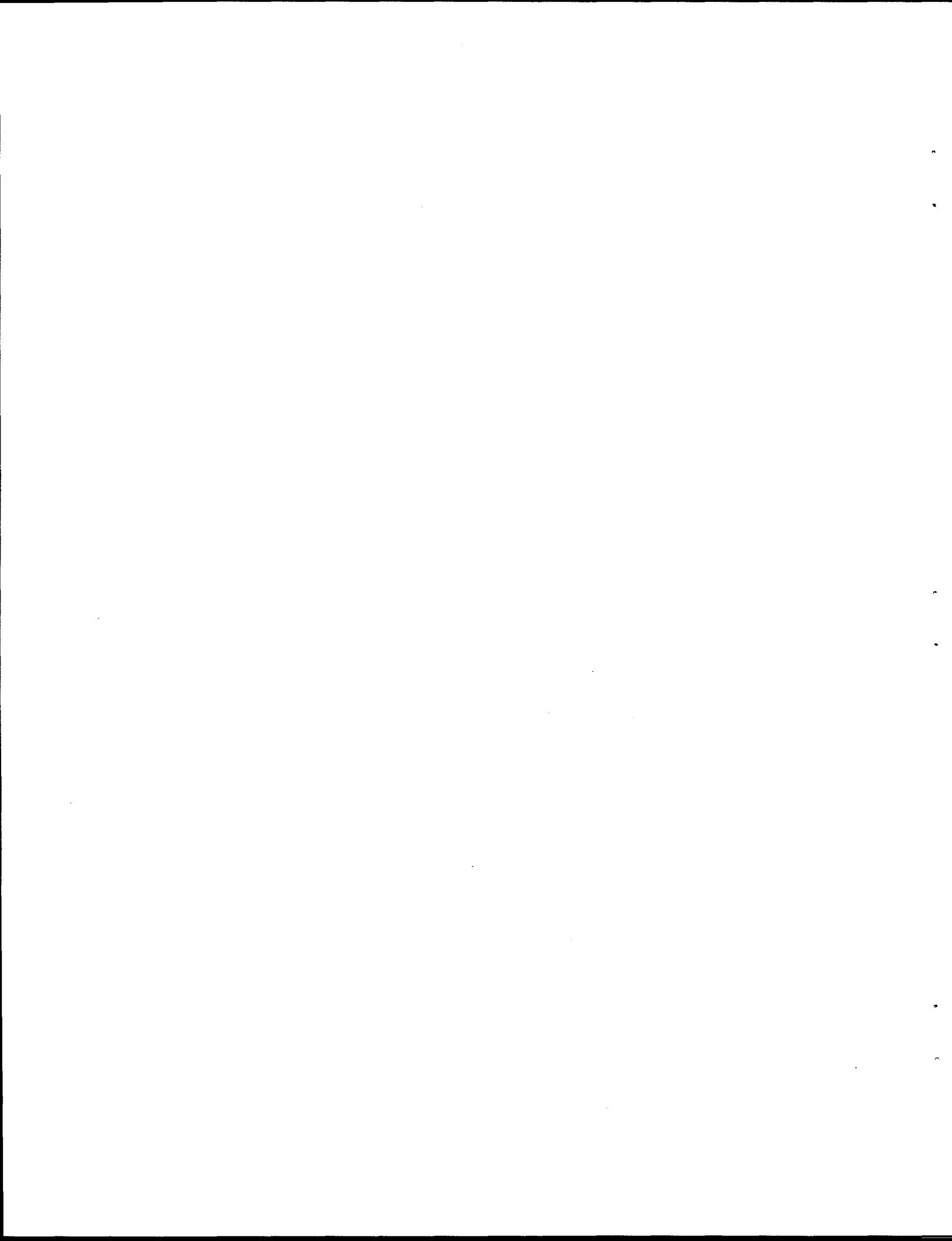
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

*DLC*



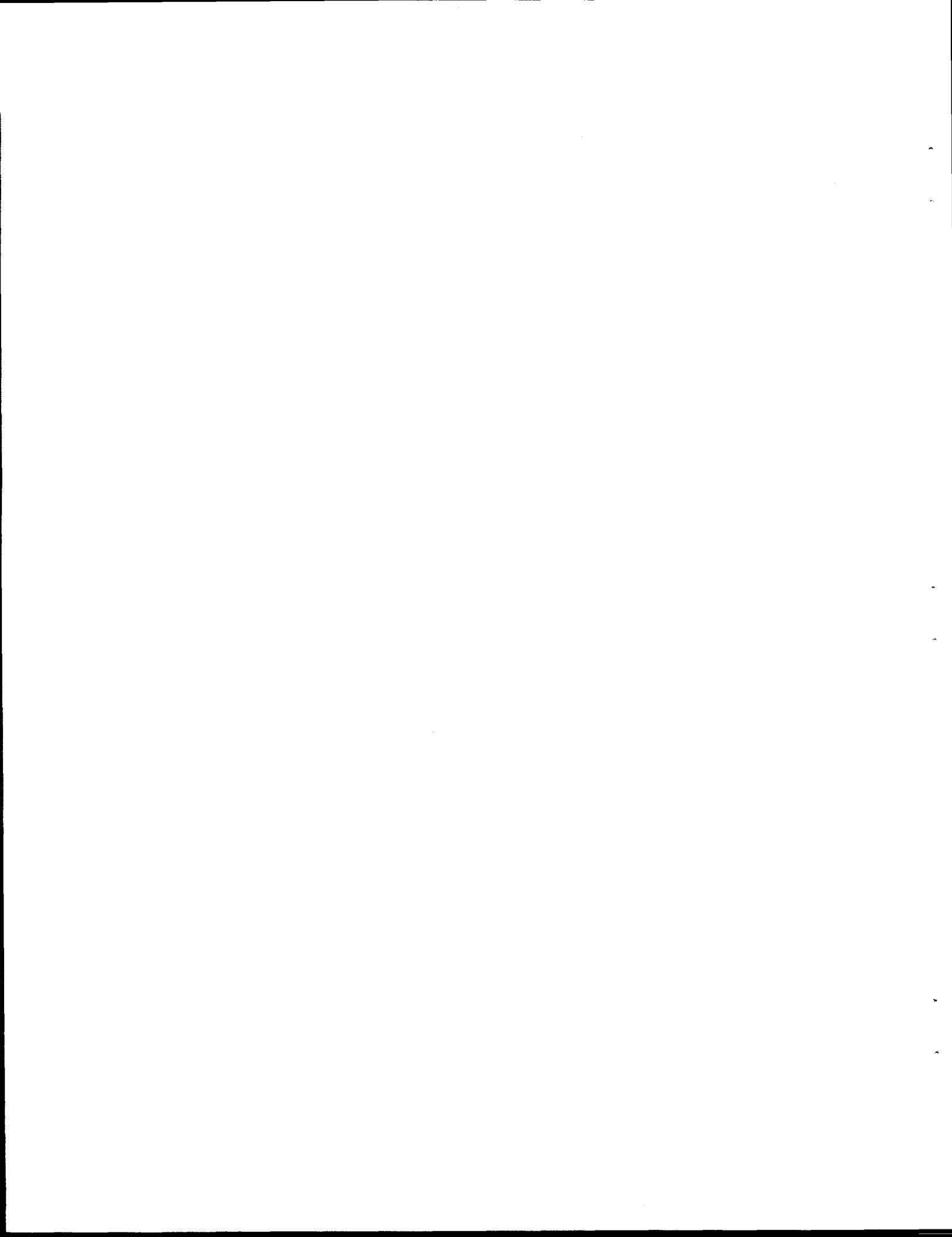
## CONTENTS

CONTENTS .....	iii
LIST OF TABLES .....	v
ACRONYM LIST .....	vii
1. INTRODUCTION .....	1
2. TRUCK ROUTING .....	3
2.1 HISTORY OF THE HIGHWAY MODEL AND DATA BASE .....	3
2.2 DISTRIBUTION OF THE MODEL .....	6
2.3 STATUS AND DOCUMENTATION .....	6
2.4 DATA-BASE STRUCTURE .....	7
2.5 EXISTING FUNCTIONALITY OF THE HIGHWAY MODEL .....	10
2.6 ISSUES RAISED FOR THE TRUCK ROUTING MODEL .....	15
2.6.1 Truck Routing Model Issues .....	15
2.6.2 Truck Routing Data Base Issues .....	20
2.6.3 General Topic Issues .....	24
3. RAIL AND WATERWAY ROUTING .....	29
3.1 HISTORY OF THE INTERLINE MODEL AND DATA BASE .....	29
3.2 DISTRIBUTION OF THE MODEL .....	31
3.3 STATUS AND DOCUMENTATION .....	31
3.4 DATA-BASE STRUCTURE .....	32
3.5 EXISTING FUNCTIONALITY OF THE INTERLINE MODEL .....	37
3.6 ISSUES RAISED FOR THE RAIL AND WATERWAY ROUTING MODEL .....	39
3.6.1 Rail and Waterway Routing Model Issues .....	40
3.6.2 Rail and Barge Modeling Issues .....	43
3.6.3 Rail and Waterway Data Base Issues .....	44
3.6.4 General Topic Issues .....	46
4. LOCATING AIRPORTS .....	51
4.1 HISTORY OF THE AIRPORT PROGRAM .....	51
4.2 STATUS AND DOCUMENTATION .....	52
4.3 DATA-BASE STRUCTURE .....	52
4.4 FUNCTIONALITY OF THE AIRPORT MODEL .....	54
4.5 ISSUES RAISED FOR THE AIRPORT MODEL .....	56
5. RELATED ISSUES RAISED AT THE SESSION .....	59
6. RECOMMENDATIONS .....	61
7. REFERENCES .....	63



## LIST OF TABLES

1. Data elements in the HIGHWAY string file .....	7
2. Data elements in the INTERLINE link file .....	32
3. Data elements in the INTERLINE transfer file .....	34
4. Data elements in the INTERLINE node file .....	35
5. Data elements in the INTERLINE barge chain file .....	35
6. Data elements in the AIRPORT data base .....	53



## ACRONYM LIST

AAR	Association of American Railroads
ANL	Argonne National Laboratory
ASCII	American Standard Code for Information Exchange
CFR	Code of Federal Regulations
COBOL	Common Business-Oriented Language
CRWMS M&O	Civilian Radioactive Waste Management System Management and Operations Contractor
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EM	Office of Environment Management
ESTSC	Energy Science and Technical Software Center
FAA	Federal Aviation Administration
FIPS	Federal Information Processing Standard
FRA	Federal Railroad Administration
FSAC	Freight Station Accounting Code
FY	fiscal year
GIS	geographic information system
HMIX	Hazardous Materials Information Exchange
HRCQ	highway route-controlled quantity
IBM	International Business Machines Co.
MLC	main line classification
MMES	Martin Marietta Energy Systems, Inc.
NRC	U.S. Nuclear Regulatory Commission
NWPA	Nuclear Waste Policy Act
OCRWM	Office of Civilian Radioactive Waste Management
OPSL	Open and Prepaid Station List
ORNL	Oak Ridge National Laboratory
PC	personal computer
RAM	random access memory
RIS	Reporting Identification Symbols
SAIC	Science Applications International Corporation
SECOM	Security Communications
SMAC	Shipment Mobility/Accountability Collection
SNL	Sandia National Laboratories
SPLC	Standard Point Location Code
TIGER	Topologically Integrated Geographic Encoding and Referencing system
TIN	Transportation Information Network
UCCND	Union Carbide Corporation, Nuclear Division
UP	Union Pacific Railroad
USGS	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

## 1. INTRODUCTION

The potential impacts associated with the transportation of hazardous materials are important to shippers, carriers, and the general public. This is particularly true for shipments of radioactive material. The shippers are primarily concerned with safety, security, efficiency, and equipment requirements. The carriers are concerned with the potential impact that radioactive shipments may have on their operations—particularly if such materials are involved in an accident. The general public has also expressed concerns regarding the safety of transporting radioactive and other hazardous materials through their communities. Because transportation routes are a central concern in hazardous material transport, the prediction of likely routes is the first step toward resolution of these issues.

In response to these routing needs, several models have been developed over the past fifteen years at Oak Ridge National Laboratory (ORNL). The HIGHWAY routing model is used to predict routes for truck transportation, the INTERLINE routing model is used to predict both rail and barge routes, and the AIRPORT locator model is used to determine airports with specified criteria near a specific location.

Major progress has been made in the last few years on improving the HIGHWAY and INTERLINE data bases. This progress has included detailed reviews of the highway, rail, and waterway systems. Additional progress in data bases updates and improvement will continue. The new focus for ORNL is the development of an enhanced user interface. This effort will involve developing software that will make the models more user friendly, produce graphical output, and standardize commands and functions between the two models.

As part of the ongoing improvement of the U.S. Department of Energy's (DOE) Environmental Management Transportation Management Division's (EM-261) computer systems and development efforts, a Baseline Requirements Assessment Session on the HIGHWAY, INTERLINE, and AIRPORT models was held at ORNL on April 27, 1994. The purpose of this meeting was to discuss the existing capabilities of the models and data bases and to review enhancements of the models and data bases to expand their usefulness. Twenty-four people attended the session, and another person

who could not attend provided written suggestions for discussion. The following organizations were represented from the government and commercial sectors:

- Government
  - DOE, Transportation Management Division (EM-261)
  - DOE, Office of Civilian Radioactive Waste Management (RW-431)
  - DOE, Transportation Safeguards Division
  - U. S. Nuclear Regulatory Commission (NRC)
- Commercial
  - Argonne National Laboratory (ANL)
  - Association of American Railroads
  - BDM Federal
  - Martin Marietta Energy Systems, Inc. (MMES), ORNL
  - Proteus Corporation
  - Science Applications International Corporation (SAIC)
  - Systematic Management Services
  - S. M. Stoller
  - TRW Environmental Safety Systems
  - The University of Tennessee Transportation Center
  - Westinghouse Bettis Laboratory
  - Westinghouse Hanford Company

The results of the Baseline Requirements Assessment Session will be discussed in this report. The discussions pertaining to the different models are contained in separate sections.

## **2. TRUCK ROUTING**

The HIGHWAY routing model is an extremely useful tool within the DOE transportation community. It is endorsed by DOE as the official truck-routing model. The model can be used to determine routes for a variety of materials including commercial shipments and shipments of highway-route-controlled quantities (HRCQs) of radioactive materials. The HIGHWAY model output has frequently been used to determine population-density information for use in RADTRAN risk assessment modeling.

ORNL is striving to provide the best possible truck-routing model to the DOE community. Part of this process is the continuing review and update of the truck routing data base and model modifications to improve the usefulness of the HIGHWAY model. Future activities include developing a more user friendly geographic information system (GIS) transportation model with a graphical user interface. This model will integrate truck, rail, and waterway networks.

The beginning of this process has been the Baseline Requirements Assessment Session and the subsequent development of this report, which documents the history, data-base information, and activities yet needed to develop a truck routing model.

### **2.1 HISTORY OF THE HIGHWAY MODEL AND DATA BASE**

The HIGHWAY model has evolved from an earlier truck-routing model, COMPU.MAP™, a commercial product marketed by Logistics Systems, Inc. In 1979, a copy of COMPU.MAP and its data base were purchased by Union Carbide Corporation, Nuclear Division (UCCND), the operating contractor of ORNL at that time, and installed on an International Business Machines (IBM) mainframe computer. The cost of the system was \$44,000.

The COMPU.MAP program had a limited number of options. After selecting an origin and a destination, the user could select a route type (commercial, quickest, shortest), a toll bias, number of drivers (one or two), and the date and time of departure. The model would then calculate the route and report summary information and a route listing.

It was determined that other features would be required for DOE transportation programs. For example, the COMPU.MAP program's data base lacked geographic coordinates. (In the original negotiations with Logistics Systems, the company had agreed to assign coordinates to the nodes of the data base, provided that ORNL would provide such data.) A data base of post office place names and coordinates was purchased, and an attempt was made to match the coordinates to the COMPU.MAP data base. The results were unacceptable. As a result, ORNL proceeded to digitize all the nodes of the data base from U.S. Geological Survey (USGS) 1:250,000 maps. Additional nodes and links to include various DOE sites were added to the data base during this process.

The COMPU.MAP model also lacked the flexibility needed for DOE-sponsored research. Some of the COMPU.MAP software, including the original software to process the data base to use with the model, was written in the common business-oriented language (COBOL). ORNL staff who worked on transportation projects lacked sufficient COBOL programming experience to examine and make appropriate modifications to this part of the code. Because of the rigid structure of COMPU.MAP, a new model was written, called HIGHWAY. HIGHWAY included additional capabilities, such as the ability to block individual nodes and links, remove states from consideration, and other routing constraints. Concurrent with the development of HIGHWAY, all of the COBOL data-base-loading programs were abandoned and a new set of loading programs were written in FORTRAN. Logistics Systems was informed of the development of the HIGHWAY model, and the company requested that all of the original COMPU.MAP source code and executable programs be destroyed. The only original material from Logistics Systems which still exists at ORNL is the data base of highway links, which was provided at the time of the original purchase of the COMPU.MAP system in 1979. No further updates have been received since the original purchase, and numerous modifications and data base changes have been made by ORNL staff.

In the late-1980s, Logistics Systems, Inc. was acquired by Rand McNally-TDM, Inc. Rand McNally had been involved in a copyright infringement law suit with Logistics Systems several years before the acquisition. Rand McNally publishes a copyrighted mileage guide tariff which the company claimed Logistics Systems was using to obtain mileages for updating the COMPU.MAP software. One factor in the legal proceeding was that Rand McNally was marketing a software package, MileMaker®, which was in competition with Logistics Systems COMPU.MAP software.

Rand McNally won the lawsuit and then purchased Logistics Systems. Currently, Rand McNally holds the proprietary title to the highway links data base used with the HIGHWAY routing model.

When the COMPU.MAP system was originally purchased, the contract stated that only employees of UCCND could use the system. (In 1984, MMES succeeded UCCND as the managing contractor for ORNL.) Another constraint was that the system could only be installed on one computer at ORNL. A contract modification was made in 1982 at a cost of \$10,000 to grant DOE traffic managers the right to access the data base on the ORNL computer. In 1991, a contract was signed between DOE-Chicago Operations Office and Rand McNally allowing the installation of two additional copies of the data base for a one-time fee of \$75,000. One copy was installed on the TRANSNET computer system at Sandia National Laboratories (SNL), and the second copy was installed on a computer at the DOE Civilian Radioactive Waste Management System Management and Operations Contractor (CRWMS M&O). This contract allows for more open access to these copies of the HIGHWAY model. Rand McNally requested that the following statement appear during the startup of the HIGHWAY model:

"Portions of this System are licensed for use by the United States Government and its contractors under copyrights claimed by Rand McNally—TDM, Inc. Use of this program for day-to-day operational purposes by commercial concerns for other than governmental purposes incidental to the transport of nuclear and other hazardous materials is prohibited."

The 1991 contract also provides a mechanism for the purchase of additional copies of the model at a base cost of \$56,250, plus an adjustment for inflation. In 1992, DOE-Albuquerque Operations Office exercised this option and purchased a copy for \$58,400. This copy was installed at the Transportation Safeguards Division Security Communications (SECOM) facility in Albuquerque.

Over the past decade, the HIGHWAY model has been used for routing analysis in numerous studies. Some of the studies include shipment planning for the Nuclear Waste Policy Act (NWPA), routing and risk assessment for the demilitarization of U. S. Army nerve-gas stockpiles, and other route analysis for environmental assessments for DOE projects. A number of others throughout the DOE community use the HIGHWAY model for similar assessments. The HIGHWAY model is used also to verify that DOE HRCQ route plans conform with U.S. Department of Transportation (DOT) regulations.

## **2.2 DISTRIBUTION OF THE MODEL**

Currently, four copies of the HIGHWAY model are available. The original copy of the model is located on the Transportation Information Network (TIN) VAX™ computer, which is located at ORNL. MMES-approved employees and DOE traffic managers have access to the model on the TIN VAX™. A second copy is available on the TRANSNET system at SNL. Access to HIGHWAY on the TRANSNET system is available to all DOE-approved users. (Note: commercial users are not permitted to use HIGHWAY on the TRANSNET system.) The CRWMS M&O has a third copy, which is used for research on movement of spent nuclear fuel to storage and repository sites. The fourth copy of HIGHWAY is located at DOE offices in Albuquerque, New Mexico, where it is used by the Transportation Safeguards Division to plan routes for classified DOE shipments.

## **2.3 STATUS AND DOCUMENTATION**

The funding for the purchase and development of the HIGHWAY model was provided through the Transportation Technology Center at SNL from the DOE Office of Nuclear Waste Management. The first user's manual for the HIGHWAY model was published in 1982.<sup>1</sup> The DOE Office of Defense Waste and Byproducts Management sponsored a major revision of the HIGHWAY model in fiscal year (FY) 1983, and these changes were incorporated into a new edition of the user's manual in 1983.<sup>2</sup> Further developments of HIGHWAY in the mid-1980s included the additions of the HM-164 routing constraints and the alternative routing feature. In the late 1980s and early 1990s, funding for maintenance of the HIGHWAY model was through the DOE Office of Civilian Radioactive Waste Management (OCRWM). This funding was used to develop the most recent edition of the HIGHWAY user's manual. The DOE Office of Environmental Management (EM) funded the publication of the document in FY 1993.<sup>3</sup> Subsequent to the publication of the most recent user's manual, several changes were made to the HIGHWAY model. A draft version of an appendix describing these new options has been written, but it has not been officially incorporated into the user's manual.

The HIGHWAY data base has undergone extensive update and review over the years. Annually, highway maps are examined to locate newly constructed roads. In the early 1980s, the data base was extensively examined during the process of digitizing all nodes in the data base. A second detailed

data base examination occurred in 1987 which verified highway names, added detail in areas where the data base had generalized nodes, and validated the mileage associated with the individual links. A subsequent examination of the data base was started in FY 1993 and completed in early FY 1994. This review of the data base was more extensive than previous examinations. Additional node and link detail was included in the data base to remove generalized nodes from the data base. All data elements were examined and updated during this review.

#### 2.4 DATA-BASE STRUCTURE

The HIGHWAY data base currently includes two American Standard Code for Information Exchange (ASCII) data files: a string file (which contains the link attribute data), and a node file (which contains the coordinate data). Data base modification to the existing structure of the strings file will occur soon to accommodate the incorporation of the enhanced geographic coordinates for the links. The string file is all that currently remains of the original Logistics Systems COMPU.MAP data, although this has been significantly modified over the years to bring data current with the existing U.S. highway network. The highway names, speed, distance, and node name fields are the only fields that existed in the original COMPU.MAP data; all other fields have been added by ORNL. The file contains the fields described in Table 1.

Table 1. Data elements in the HIGHWAY string file

Columns	Field	Description
1-5	First highway name	These three fields are all similar. The first character represents the sign class of the roads (I—Interstate System, U—U.S. highway, S—state route, T—tollway or turnpike, C—county route, L—local road, and any other character representing an other classification). The following characters may be alpha/numeric and usually represent the route number. The last character in these fields can optionally be either a "\$" which signifies a toll road, or "#", which signifies a toll bridge. Only the first highway name need to contain information; the second and third names are used for joint route designations. It is normal practice not to mix designations on a link (e.g., U47 and S2 as the first and second highway names).
7-11	Second highway name	
13-17	Third highway name	
18	Lane type	The lane-type code is represented by the following values: 1—limited access multilane, 2—limited access single lane, 3—multilane divided, 4—multilane undivided, 5—principal highway, 6—through highway, and 7—other.

**Table 1. Data elements in the HIGHWAY string file (continued)**

Columns	Field	Description
19	Time zone 1	The time zone code is represented by the following values: A—Atlantic, E—Eastern, C—Central, M—Mountain, P—Pacific. Special codes are used for areas that do not observe daylight time; I—Indiana and Z—Arizona. Time zone 1 is required for all link records; time zone 2 is needed only for links which cross state boundaries. Links crossing time zone boundaries within a state are assigned to the predominant time zone.
20	Time zone 2	
21-22	Speed	This value indicates the travel speed (mph) on the link.
28-30	Distance 1	These fields indicate the length of the link. For links lying entirely within one state, distance 2 has a value of zero. For links which cross state boundaries, distance 2 provides the distance within the second state.
32-34	Distance 2	
37-64	Node name	A unique node name is composed of the items which follow. Note that column 60 requires a comma.
37-51	City name	The name of the node
52-53	Direction	Direction the node is from the city (e.g., NE, SW, W). A value which is blank represents the center of a city.
54-55	State abbreviation	Standard postal abbreviation of the state (or province)
56-59	Intersection 1	The values normally represent the highway names of the intersecting roads. With Interstate System highways, in most states, intersection 2 indicates the exit number (e.g., X41).
61-64	Intersection 2	
66-97	Link flags	The flags have values of either "0" or "1". Flags which contain data are listed below.
66	Flag 1	Trucks are not allowed to use this link
67	Flag 2	Link passes through an urbanized area with over 100,000 people
68	Flag 3	Link within an Interstate System beltway around a metropolitan area
69	Flag 4	Link with a low clearance: 13 ft. 6 in. or less
70	Flag 5	Link with a width restriction: less than 96 in.
71	Flag 6	Link is part of the HM-164 or state-preferred network
72	Flag 7	Link represents a ferry crossing
73	Flag 8	Link has restrictions for movements of hazardous materials
74	Flag 9	Link is under study as a proposed state alternative route (ORNL internal use only)
75	Flag 10	Link is part of the New Mexico Waste Isolation Pilot Plant (WIPP) preferred route system
76	Flag 11	Link connects two nonintersecting Interstates
77	Flag 12	Link is an Interstate connector (used for ORNL mapping applications only)

Table 1. Data elements in the HIGHWAY string file (continued)		
Columns	Field	Description
78	Flag 13	Link is an access road from a nuclear plant to an Interstate highway (used for ORNL mapping applications only)
96	Flag 31	Link is a Federal Aid Primary route

The sequence of data in the strings file proceeds as follows;

1. A record containing only the state abbreviation.
2. A record containing information only in node name fields signifying the beginning of a string.
3. Record(s) containing the information for all the data elements listed in Table 1 for the link between the node name identified in the previous record and the node name in this record.
4. When a strings sequence is completed, a node record (item 2) will commence the next string followed by string record(s) (item 3).
5. After all strings within a state are completed, a record with a value of "99" in the state abbreviation field will signify the end of this state. The sequence begins again (with item 1) for all states.

The node data are stored in a file which contains the node name and the geographic coordinates (latitude and longitude) of the node.

The HIGHWAY model does not access the string and node files. These files are processed by a series of programs which create a series of binary direct access files used by the HIGHWAY model. Any network modifications require re-running the loading programs to create a new version of the data base.

Population density information for each link is processed and stored separately from the link information presented in Table 1. Each link is intersected with contoured population density, and the distance of each link within the different density levels is calculated. After these data have been

processed, the data are stored in a file that can be accessed to determine the population density for any link.

## 2.5 EXISTING FUNCTIONALITY OF THE HIGHWAY MODEL

The basic function of the HIGHWAY routing model is the determination of a route between two locations. This determination is accomplished with the use of a shortest-path algorithm, which uses a weighted function of time and distance to calculate the shortest path. A variety of commands and options can modify the way the HIGHWAY model calculates a route. The HIGHWAY user's manual provides a detailed explanation of how to operate the model; a brief overview of the functions of the model will be provided in this section.

**Route** is the most basic command of the model; it generates a route. This command requests the user to identify an origin and a destination and then issues two questions regarding route parameters. These questions can be answered by entering a carriage return to accept the default values. The program will then calculate the route and provide a route summary showing origin, destination, routing parameters and constraints, distance, estimated driving time, mileage in each state, and mileage by road classifications. Upon request, a route listing can also be generated. Parameters that can be changed within the route command are:

1. Route type. Three major route types are available. The default route type is the **commercial** route, which is based on a combination of driving time and distance of the link (see p. 7 of the user's manual for more details). Other route types available include **quickest**, which only considers driving time, and **shortest**, which only considers distance.
2. Toll bias. This factor places an additional penalty on the use of toll roads and bridges. By default, no penalty is placed on toll facilities. The user can place a toll penalty on routes by changing the route parameters in the route command or within the option command.
3. Number of drivers. The number of drivers does not affect the determination of the route, only the driving time of for the route. Two is the default number of drivers. By default, a two-driver team drives 4 h and takes a half-hour break and then repeats this sequence throughout the duration of the trip. The driving time/rest time sequence for a single driver is 5 h, a half-hour break, 5 h, then an 8-h break.

4. Departure date and time. By default, the program will use the current date and time for calculating the route. These values are used by the model to calculate arrival times for locations along the route. HIGHWAY does not use time-of-day information in the decision-making process to calculate routes. The user has the option to change these values in the route command.

**Reroute** is a useful command for generating a series of routes from the same origin. The first route must be calculated by the **route** command; however, subsequent routes can then be generated quickly using the **reroute** command. The destination and departure date and time are the only items that this command requests from the user.

**Retype** is a command that is used to repeat the display of the output from the previously calculated route.

**Option** is the primary command to set up and change all routing parameters and constraints. When options are changed, they are in effect for the duration of the current session of HIGHWAY or until the option is changed later. The options available in the model are itemized in the following, and the discussion of various options are grouped by similar functionality:

1. DOT regulatory routing. One of the primary functions of the HIGHWAY model is its ability to calculate routes that follow DOT regulations of HRCQ of radioactive material. Several options control this feature. The HM-164 routing constraint forces the model to calculate routes that follow 49 CFR Part 397.101. [An additional option has been added for HRCQ shipments to the Waste Isolation Pilot Plant (WIPP) in New Mexico, which has established state-preferred routes to the WIPP facility, which can be used only for shipments to WIPP.] The program uses a weighted factor to penalize the use of roads which are not on preferred HRCQ networks. The user has the option of setting the weighted factor for preferred roads.
2. Shipment parameters. The HIGHWAY data base has several data elements which are accessed with this option. When the model is activated, some of the shipment parameters are automatically activated; these include links which prohibit truck use and links which include ferry crossings. Links with either of these features will not be used unless the user deactivates these parameters. Other parameters that can be activated include avoidance of links within urbanized areas with populations over 100,000 people, links within Interstate beltways of

metropolitan areas, links with height-clearance restrictions, links with width-clearance restrictions, and links with hazardous material restrictions.

3. Population density. The HIGHWAY model can generate summary population density statistics for any calculated route. A summary table is printed which sums the number of miles within 12 different population-density categories, by state, and totals for the route. Additional information on the weighted population and distance traveled in rural, suburban, and urban areas, useful for input to the RADTRAN 4 risk model, is also calculated.
4. Alternative routing. The HIGHWAY model has the ability to automatically calculate alternative routes. During use of this option, the model calculates the base route, which is the normal route that otherwise would have been generated. The user is then prompted if an alternative route should be calculated. If so, the model will calculate an alternative route. After that route is determined, the program prompts the user again. This process is repeated until the program has calculated ten routes or until the user stops the process.
5. Map file. This option directs the program to output a file which contains alternating records with node and link number information. By postprocessing this file with a separate program, a file with coordinates of the nodes and attribute information for the links can be created. This later file can then be used for additional GIS analysis.
6. Detailed route listing. The route listing from the HIGHWAY model lists locations only when there is a change in the highway name. For example, if a calculated route continuously follows the same highway for the entire distance, only the origin and destination would be identified on the route listing. When the detailed route-listing option is activated, every node on the route is listed on the route listing. This can result in a very long route list for cross-country routes.
7. Changing route criteria. Several options are available to change the various route criteria. The default route type (commercial, quickest, shortest) can be changed, and the parameters which make up these types can be modified with the route-options feature. The toll bias and the number of drivers can also be adjusted within the option command. The length of driving time and breaks can be adjusted with the break-time option.
8. Maximum speed. Driving speed is one of the data elements from the HIGHWAY data base which is used in route determination. Travel speed over road segments, along with break times, is the determining factor for calculating arrival times. The maximum speed option allows a user to lower the travel speed for road segments with higher average driving speeds. The use

of this option affects only the calculation of travel time reported on the route summary information.

9. Saving/retrieving option settings. This pair of options allow a user of HIGHWAY to customize his or her own default option settings for the program. Once the user sets the options to meet his or her needs, these settings can be saved to a file. When running the model at a later date, the user can then retrieve the saved option settings and have the model configured as before.
10. Show current option values. This option allows the user to view the current option settings.
11. Link direction for deletions. The HIGHWAY model allows the user to temporarily delete road segments from the data base. An option is available to allow the user to either delete travel in both directions, or just in one direction. The default setting for this function is to delete a link in both directions.
12. Alert for deleted origin or destination. If nodes or links have been temporarily deleted from the data base, this option provides warning to the user that a selected node has been blocked in the data base. This option is activated whenever the HIGHWAY model is started, but it can be deactivated by a user.
13. Route impedance. When calculating a route, the HIGHWAY model uses numerical values to determine the path through the network. For example, if the route type is quickest, each link is evaluated by travel time. When this option is activated, the route impedance value is listed with other route-summary information. This value can be useful when one examines different routes. The user can determine the mathematical difference between several routes. Only an experienced and a knowledgeable user should compare impedance values among routes because other factors (especially alternative routing) can affect the interpretation of these values.
14. Weighted routing. HIGHWAY has an option which allows the user to "weight" road segments based on either road classification (e.g., Interstate, U.S., etc.) or on the lane type (e.g., limited access multilane, multilane undivided, etc.). This option allows a user to maximize the use of these types of roads during the operation of HIGHWAY.
15. Queue output to printer and output width. Several specialized options exist for those installations of HIGHWAY with printer capabilities. The print option automatically sends the route-listing information to a printer. The output-width option is used to control whether the printed output is in 80- or 132-column format.

16. Batch mode. If a user needs to calculate a large number of routes, it is best to set up the program so that it will read the standard input from a file which has all the user responses for the run. If this is done, the batch-mode option needs to be activated. The function of this option is to deactivate features within the program (such as the continue prompts which halt the listing on the screen during interactive use) to increase its efficiency.

Other commands in the HIGHWAY model include remove, delete node, delete link, reset, and links.

The **remove** command allows the user to remove (or restore) entire state(s) from consideration in the model. When a state is removed, no route will pass through the state. For example, if Alabama and Georgia are removed, the model will be able to calculate a route from any location in Florida to another spot in Florida, but the model will give a disconnect network message if a land route is attempted between Florida and any other location outside of Florida.

The **d link** (delete link) command permits the user to block selected links in the data base. Links are not actually deleted from the data base; they are effectively blocked by adding a large value to the link impedance. If a deleted link is the only connection between an origin and a destination in the network, the model will use the link in a route. To remove a link deletion, the user can restore it with the **d link** command, the **reset** command, or by stopping the program.

The **d node** (delete node) command permits the user to block selected nodes in the data base. Nodes are not actually deleted from the data base; they are effectively blocked by adding a large value to the impedance of all links emanating from the blocked node. If a deleted node is the only connection between an origin and a destination in the network, the model will calculate a route which passes through the blocked node. To remove a node deletion, the user can restore it with the **d node** command, the **reset** command, or by stopping the program.

The **reset** command allows the user to reset all deleted nodes and links within the data base.

**Links** is a command that permits the user to examine the connectivity between nodes and links within the data base. The command requests the user to enter a specific node location. Then, information on the links that emanate from that particular node is displayed. The user can then

select a listed link, and the program will then list the links which emanate from the node that was at the opposite end of the selected link. This command offers a method of examining data-base structure and node identification.

**Stop** is the command which terminates the operation of the HIGHWAY model.

## **2.6 ISSUES RAISED FOR THE TRUCK ROUTING MODEL**

The issues developed from the Baseline Requirements Assessment Session for the HIGHWAY model and data base are discussed below. Each issue has been assigned a priority and given a tentative schedule based on the latest DOE guidance and budget information. The actual order of enhancements will be determined by DOE authorization and funding availability.

### **2.6.1 Truck Routing Model Issues**

#### *Issue 1:*

A graphical output for the routing model showing a map with the route(s) was requested by a number of participants.

#### *Suggested action:*

As a result of this and other issues, a new GIS-based truck routing model will be developed that will provide a graphical user interface with maps showing the highway network and routes calculated by the model. This will be one of the primary benefits of the developed of the new truck routing model that will be accomplished during FY 1996.

#### *Issue 2:*

One participant stated that the node-selection method of would be simplified if a map were displayed. This would allow the user to visualize the network in urbanized areas. If a map was displayed, the node could be selected by placing a cursor over the desired node.

#### *Suggested action:*

The ability to select a specific node as an origin, destination, or intermediate point; the ability to add or delete a link or node; and the ability to access information about a link or

node by clicking on that particular feature will be incorporated into the GIS-based truck routing model that will be developed in FY 1996.

*Issue 3:*

The representative of the NRC stated that the HIGHWAY model is used to check applicant's routes for compliance with DOT HM-164 regulation (49 CFR Part 397.101). The current methodology used by the HIGHWAY model for calculating HM-164 routes is to calculate the quickest route and to minimize the use of any route segment which is not part of the HM-164 network. The HM-164 regulation states that the quickest route is to be used for Interstate System highway routing, but that the shortest route should be used from the origin to the nearest Interstate entrance and from the Interstate exit to the destination.

*Suggested action:*

The new truck routing model is being developed that will include routing along the quickest route on the HM-164 preferred route (Interstate and state preferred routes) and the shortest route between the origin and destination and the preferred route. This activity will be accomplished in FY 1996.

*Issue 4:*

The ability to estimate routes to bypass links with low height clearance, narrow width clearance, or hazardous material restrictions was discussed. FY 1994 data-base enhancements include the addition of height clearance, width clearance, and hazardous material routing restrictions for links. A new capability needs to be developed to permit the calculation of routes which bypass these impediments.

*Suggested action:*

The capability to model truck routes that bypass links with low height clearance, narrow width clearance, or hazardous material restrictions will be accomplished in a new truck routing model. This activity will be accomplished in FY 1996.

*Issue 5:*

One participant requested an easier method for loading a previously saved file of option settings. In the current version of the model, the user has to activate an option to reload the saved option values. A simpler method would involve issuing a prompt during startup.

*Suggested action:*

The implementation of this feature will be included in the new truck routing model. This activity will be accomplished in FY 1996.

*Issue 6:*

The ORNL representative suggested a change in the way the toll bias is established. During program initialization, the HIGHWAY program currently prompts the user as to whether or not a standard penalty should be placed on toll facilities as the model starts. The toll penalty can also be activated as part of the route option subcommand. It was suggested that the initial toll penalty question be removed from the model. A new option would need to be added to allow the user to establish a toll penalty. An additional request was made to change the toll penalty from a percentage value to a multiplier, where a value of 1 represents no penalty.

*Suggested action:*

The new truck routing model will use a multiplier value to calculate the toll bias. This activity will be accomplished during the development of the new truck routing model in FY 1996.

*Issue 7:*

The issue of saving routing information was discussed. It was suggested that a file be created which would contain all the information for the routes calculated: complete site information, route listing, mileage information, and a series of latitude-longitude points for the routes. This file must be able to handle multiple routes.

*Suggested action:*

The new GIS-based truck routing model will be able to display all routes and save the route data to a file. The new model will output route information consisting of node-link-node records for the entire route. The node records would consist of the following fields: a key indicating the type of node record, the latitude and longitude of the node, the node number, and the node name. The link records would contain the following fields: the primary and secondary road numbers for the link, state code, distance, speed, and the link number. Geographic shape information, based on the routing data base, will be included in the information. This activity will be accomplished in FY 1996.

*Issue 8:*

The amount of time required to calculate routes with the HIGHWAY model was discussed. The HIGHWAY model was designed in 1980. At that time, the principal computer resources available were mainframe computers, which limited users to a relatively small amount of memory. For that reason, the HIGHWAY model was designed to perform the routing calculations one state at a time. The drawback to this methodology is that the model must continually load new state networks; i.e., it is input-output constrained.

*Suggested action:*

The new GIS-based truck routing model will be written to take advantage of current technology to minimize the run time for route selection. This activity will occur in FY 1996.

*Issue 9:*

The issue of how population density output for use with the RADTRAN model should be reported by the HIGHWAY model was discussed. One participant suggested that the existing summary be expanded to include distance traveled in the rural, suburban, and urban categories for each state along the route.

Subsequent to the Baseline Requirements Assessment Session, a requirements meeting for the RADTRAN model was held on May 12, 1994. The RADTRAN 5 model will no longer be using the aggregate population zone formulation. Population density information on route segments will be provided as input via the "Links" and "Stop Links" features in the RADTRAN 5 model.

*Suggested action:*

Three action items have been identified for this issue:

1. The new truck routing model will provide the required information for the rural, suburban, and urban aggregate zone data by state for use with the RADTRAN 4 model. This activity will be accomplished with the development of the new truck routing model in FY 1996.
2. ORNL will hold a series of discussions with the RADTRAN staff at SNL to define the data that need to be incorporated into the new truck model to assist users in obtaining population density and other information needed in the RADTRAN 5 model. Once

these data are identified, they will be included in the truck routing model. This activity will be accomplished in FY 1996.

*Issue 10:*

Traffic managers who use the HIGHWAY model to verify route plans from trucking companies requested a output to simplify route plan interpretation. Trucking firms provide a list of highways by state. For example, a list would contain the following information for a typical route from northern Arizona to Denver, Colorado: AZ-I-40, NM-I-40, NM-I-25, and CO-I-25.

*Suggested action:*

The new GIS-based truck routing model will graphically depict the route through each state and provide a tabular listing by state and each highway taken. This activity will be included in the development of the route routing model in FY 1996.

*Issue 11:*

A number of users at the meeting stated that Reporting Identification Symbols (RIS) codes are used for identifying DOE facilities. It was recommended that an appendix be developed for the user's manual that would show either the proper node name or the nearest node to a particular RIS code. It was also suggested that this information be a node attribute. The ability to output RIS codes will assist in the coordination with the Shipment Mobility/Accountability Collection (SMAC) project and other activities that use RIS codes for referencing shipping locations.

*Suggested action:*

A two-phased approach is recommended for this issue. Phase I would involve developing a node listing for each RIS code and distribute this list to users during FY 1996. Phase II would entail including RIS codes as a node attribute in the new GIS-based truck routing model. The software would either automatically identify the node closest to the RIS code or the user could specify a RIS code in selecting an origin or destination. Phase II has been assigned a relatively low priority and has been tentatively scheduled for late FY 1998 or FY 1999.

*Issue 12:*

Several participants expressed an interest in having population count as one of the factors to be included in the route selection algorithm. A route with a lower population count that is slightly longer than the standard route might pose a significantly lower risk to the general public.

*Suggested action:*

ORNL will develop a methodology for assigning a population count to individual links. A user survey will be conducted to establish a set of standardized band widths for population counts. Link-specific data will then be calculated for each band width for inclusion in the data base. A future version of the GIS-based truck routing algorithm will include population count as a parameter in route selection. Because of the large number of issues considered high priority identified in this meeting, the use of population-count information as part of the routing criteria has been given an intermediate priority and will probably not be completed until FY 1997.

*Issue 13:*

The capability of multiple segment routing was discussed. This feature would allow users to specify a number of intermediate stops on a trip. The incorporation of this feature would result in the need to include layover times and scheduled departure times from intermediate stops.

*Suggested action:*

The capability of routing between an origin and destination point with a number of specified intermediate points will be incorporated in the new GIS-based truck routing model. This activity will be evaluated during development of the new truck routing model. If it can be implemented with minimal effort it will be included; if more work is needed to implement this feature, it will be delayed until FY 1997.

## **2.6.2 Truck Routing Data Base Issues**

*Issue 1:*

A number of participants expressed a need to expand the HIGHWAY data base to include the sites of receiving or shipping facilities at DOE sites, research reactor locations, port

facilities, and other commonly used facilities. It was also suggested that several additional nuclear sites in Canada be included.

*Suggested action:*

A number of these additional sites have been added to the data base in FY 1994. (These additions included most of the universities with research reactors and several port facilities.) A letter will be sent to the session participants in early FY 1995, requesting a list of sites that need to be added, along with maps showing the locations of shipping and/or receiving facilities. The sites identified in the responses will be incorporated in the new GIS-based truck routing model data base.

*Issue 2:*

The need for standard identification of nodes and links in the HIGHWAY data base was discussed. One participant suggested the use of standard point location code (SPLC) identification as a node attribute.

*Suggested action:*

The usefulness of placing SPLC numbers on the network is rather limited. Currently, it is not recommended that SPLC codes be added to the network.

*Issue 3:*

One participant requested that milepost data be included in the data base. The primary function of this feature would allow users the capability to determine locations along Interstate routes. Exits on Interstates should be labeled with milepost data unless a state sequentially numbers exits. Another participant suggested that a separate GIS file of latitude-longitude coordinates for individual mileposts be created.

*Suggested action:*

Most states identify Interstate exits by milepost number. The truck routing data base will follow this convention of identifying Interstates exits by the milepost number. With a routing data base based on TIGER shapes, milepost locations could be calculated by measuring along Interstate highways from state boundaries. This action is proposed to be undertaken in FY 1997 after completion of the development of the GIS-based truck routing model.

*Issue 4:*

Session participants expressed an interest in including population-count information as a link attribute. If population-count information is to be added to the data base, a standard set of band widths for the population data needs to be determined. One participant suggested band widths of 0.5, 1, 3, and 5 miles from the route. There was a discussion of the problems associated with assigning a population count to each individual link. There is a possibility of double counting. One participant stated that it would be better to double-count some of the population along a link rather than to exclude anyone.

*Suggested action:*

A standard set of band widths need to be determined. The population-count data will then need to be calculated for each link in the new GIS-based truck routing data base. This activity has been assigned an intermediate priority and has been scheduled to commence in FY 1998. Also see discussion for Issue 12 in Sect. 2.6.1.

*Issue 5:*

One participant suggested that the HIGHWAY model should not use posted speed limits to calculate time required to travel a route. In FY 1994, a task was completed that collected and updated speed limit data for all Interstate-quality (multilane limited access) roads in the model. With the exception of these links, the average speeds have been adjusted for congested areas, rugged terrain, occurrence of small towns or rural roads, etc.

*Suggested action:*

DOT will be contacted in FY 1995 to determine if average-speed information is collected for selected points on the Interstate System. If such information is available, an evaluation will be made to determine if this information could be used to estimate the average speed for the links in the truck data base. Also, the new truck routing software will allow the user to enter a factor to proportionally reduce the assigned speed on the links of the network. This activity will be implemented in FY 1996.

*Issue 6:*

The issue of weight limits for bridges was discussed. This issue primarily concerns non-Interstate System routes, where bridges have weight limits less than the standard 80,000 lb. All Interstate System bridges were constructed with a higher weight specification.

*Suggested action:*

Because most of the traffic follows Interstate routes, collecting bridge-weight-limit data for the non-Interstate roads in the data base does not appear to be cost effective. Weight limits are frequently a function of the vehicle configuration; this further complicates the issue. Currently, no further action is recommended.

*Issue 7:*

It was suggested that traffic-count data should be added as a link attribute. Data are available from the DOTs of individual states; however, they may be difficult to interpret and may not be consistent from state to state. Business Location Research, Tucson, Arizona, is believed to possess traffic-count information for Interstate, major U.S., and state highways.

*Suggested action:*

A low priority has been assigned to this issue, and no activities are expected to be initiated in the near future.

*Issue 8:*

Accident rates were discussed a number of times. The participants expressed a desire to include accident data in the data base. However, they also acknowledged that a reliable data base of accident information does not exist, that it is difficult to get exposure data, and that it is difficult to obtain information on the severity of accidents.

*Suggested action:*

During FY 1995, A. Zamboky, of Westinghouse Bettis Laboratory, will be contacted regarding an ANL report on accident statistics. At a later date, this report will be reviewed to determine the best way to incorporate accident rates into the GIS-based truck routing model. This activity will not be considered until FY 1997.

*Issue 9:*

One participant requested that construction zones, bridge outages, and other routing impediments be included as link attributes in the HIGHWAY routing data base.

*Suggested action:*

Data collection would entail regular contact of all state DOTs. The amount of data-base maintenance to keep the data base up to date would be a difficult task and would require frequent (possibly monthly) updates. Under the current system, major changes to the data base are released annually. Minor data-base structural changes, such new HM-164 routes, can be incorporated more frequently (see *Issue 2* in Sect. 2.6.3).

DOE must determine if the truck routing model is to be used as a living, up-to-date route planner or as a route-prediction tool for long-range risk analysis and transportation studies. A significantly increased funding level over that currently available would be required to collect and incorporate data for temporary routing impediments. It is not recommended that detail on construction zones and other temporary routing impediments be included in the GIS-based truck routing data base.

### **2.6.3 General Topic Issues**

*Issue 1:*

The need to include an appendix outlining population-density calculations and a listing of commonly used origins and destinations was suggested by several participants. As the discussion progressed, it was also suggested that information on configuration management and verification and validation should also be included in the user's manual.

*Suggested action:*

Three activities were identified in this issue:

1. Preparation of an appendix describing how the population-density calculations are made is tentatively scheduled for FY 1998.
2. Participants will be surveyed in FY 1995 to identify origins and destinations commonly used in their routing analysis. ORNL will prepare a list of nodes for these locations and distribute the list to all users.
3. The topics of configuration management and verification and validation of the models will be discussed with DOE. At this time, no specific action has been identified.

*Issue 2:*

The NRC representative stressed the importance of maintaining up-to-date information on HM-164 routes. The DOT data base outlining state-preferred routes should be consulted frequently, and the HM-164 network should be updated frequently.

*Suggested action:*

Starting in FY 1995, the Hazardous Material Information Exchange (HMIX) bulletin board will be consulted on a monthly basis to determine if any new or existing preferred routes have been modified. Any changes will be incorporated into the truck routing data base. It is planned that this will be an ongoing activity.

*Issue 3:*

One participant noted that the population-density ranges reported by HIGHWAY are different from those reported in the RADTRAN users manual.

*Resolution:*

This item was resolved on April 29, 1994. There is a misprint in the RADTRAN user's manual and the information reported by the routing models is correct.

*Issue 4:*

One participant noted that when NRC evaluates routes, it has a team drive the route. In some instances, the odometer readings may be as much as 20 miles different from the distances reported by HIGHWAY or other routing models.

*Suggested action:*

The mileage assigned to each link in the HIGHWAY model is calculated to the nearest mile (in INTERLINE this distance is calculated to the nearest tenth of a mile). Because the mileage in the HIGHWAY model is rounded to the nearest mile, the sum of the distances for a long trip could deviate from the actual mileages because of the rounding errors in the summation process. With the development of the GIS-based truck routing model, the link mileages will be recalculated and will be stored in the data base to the nearest tenth of a mile. It was also noted during the discussion that it was not known whether the odometers on vehicles driving the route had been calibrated. Automobile odometer inaccuracies could easily amount to 20 miles over a long trip. No further action is recommended for this issue.

*Issue 5:*

It was suggested that the capability of identifying emergency response locations be included in the HIGHWAY routing model. Some of the discussion centered on developing a model similar to AIRPORT, but one designed to identify emergency response locations near a particular site. This data should include the locations of emergency response capabilities, safe havens, hospitals, law enforcement agencies, Federal Bureau of Investigation offices, location of first responders, cleanup facilities, etc.

*Suggested action:*

Because of time constraints, this topic was not discussed fully. With the development of a GIS-based routing model, the addition of such data would be easier to incorporate. It is recommended that the issue of including emergency response locations will be discussed in a future requirement meeting. Emergency management organizations may have data bases with information that would be useful. At this time, insufficient information exists to develop a plan of action. Further investigation into the availability of data and emergency response facility locations will be investigated in FY 1997.

*Issue 6:*

Intermodal route prediction was discussed during the meeting. Several participants suggested that more emphasis should be placed on combining HIGHWAY and INTERLINE into a single model to predict intermodal shipments.

*Suggested action:*

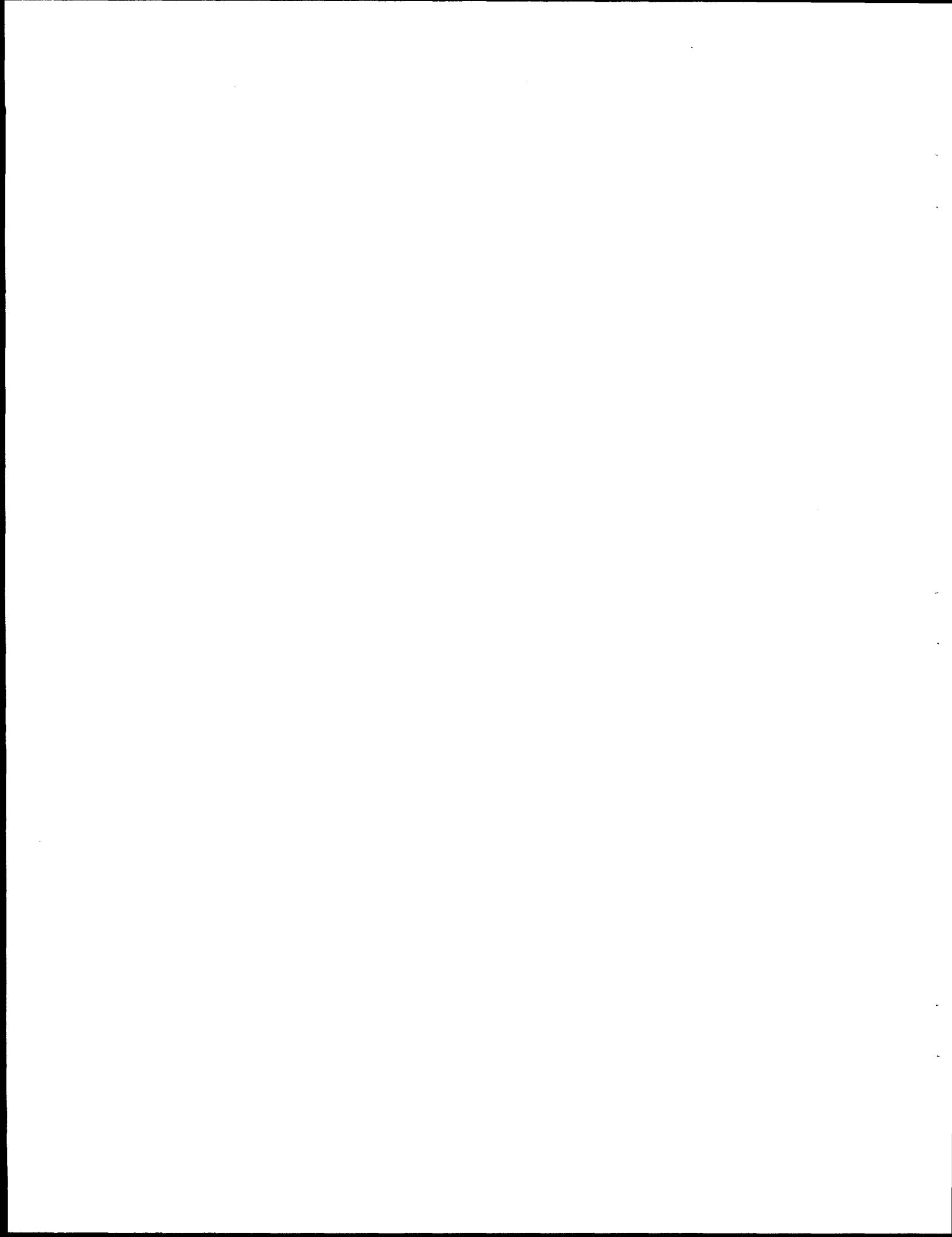
A major data collection effort would be required to identify all intermodal transfer sites and to incorporate the additional detail in the appropriate data bases. A new GIS-based routing model will be developed, starting in FY 1995, that will include the eventual capability for intermodal transfers. The full implementation of intermodal capability will not be completed during the initial stages of the new model.

*Issue 7:*

One participant would like DOE to consider the possibility of modifying the model and data base to perform heavy-haul routing of shipments of ~125 tons. Other participants expressed opinions that this might not be a feasible activity.

*Suggested action:*

This is a very specialized routing requirement. Tri-State Motor Freight uses a routing model to calculate routes for its normal-weight, normal-dimension shipments. Overweight and over-dimensional shipments are routed manually, and the routes are checked before shipment by driving the route to ensure that the route is suitable. Routing of 125-ton shipments from reactors to rail heads or barge facilities should probably be handled on a case-by-case basis. No action is recommended.



### **3. RAIL AND WATERWAY ROUTING**

The INTERLINE routing model is an extremely useful tool in the DOE transportation community and has been endorsed by DOE as the official rail and waterway routing model. The INTERLINE model is also used to determine population density-information for use in RADTRAN risk assessment modeling.

ORNL is striving to provide the best possible rail and waterway routing model to the DOE community. ORNL is developing the next generation of rail and waterway routing models in FY 1995. This new model and data base will be integrated into a GIS to provide an interactive mapping capability to the user. The rail and waterway networks will eventually be integrated with the truck model to form a multimodal network routing model with intermodal transfer capabilities.

The beginning of this process has been the Baseline Requirements Assessment Session and the development of this report which documents the history of the INTERLINE model, data base information, and future activities needed to develop the next generation of routing models.

#### **3.1 HISTORY OF THE INTERLINE MODEL AND DATA BASE**

In the early 1970s, rail transportation in the Northeast was undergoing a number of significant changes as a result of the bankruptcies of many railroads. Congressional action was taken to reorganize the rail system in the Northeast to provide continued rail service within the region. To assist in the analysis of the rail system, the Federal Railroad Administration (FRA) funded, in the mid-1970s, the development of a national rail data base.

ORNL obtained a copy of the FRA rail data base in 1977. In 1979, ORNL initiated a project with funding provided through the Transportation Technology Center at SNL from the DOE Office of Nuclear Waste Management to develop a rail-routing model using the FRA data base. Concurrently, additional work was initiated to update the data base to reflect the numerous abandonments, mergers, and other changes which had occurred after the creation of the original FRA data base. In early

1980, the INTERLINE routing model became operational. Further model enhancements occurred during the early 1980s and the first documentation was prepared in 1984.

The INTERLINE model was originally written by B. E. Peterson of the Energy Division at ORNL. The model was designed to operate on an IBM mainframe. Several of the model subroutines were written in IBM Assembler language, and the rest of the subroutines were written in FORTRAN, thus limiting the operation to only on an IBM mainframe. Throughout the later part of the 1980s, no further development work occurred on the model. In 1989, ORNL, with funding from OCRWM, commenced work to rewrite the entire INTERLINE model in FORTRAN to permit the model to be used on other computer platforms. This effort also expedited the placement of the INTERLINE model on the TRANSNET computer system. In February 1990, the INTERLINE model was successfully converted to FORTRAN and became operational. At that time, a PC version and a VAX version were available. During this process, an alternative routing capability, similar to that incorporated in the HIGHWAY model, was also added to the INTERLINE model.

The data base for the INTERLINE model has undergone numerous modifications. Data-base maintenance and updates are extremely important because of the numerous changes that have occurred and still are occurring with the U.S. rail system. The economics of rail transportation and the competition from other modes of transportation, especially trucking, have resulted in massive abandonments of trackage in rural areas of the country. Rail company mergers have also resulted in route consolidation, resulting in the remaining surplus trackage either being abandoned or sold for short line rail operations. Rail industry deregulation in 1980 has led to a proliferation of new short line railroads. All these actions have resulted in significant changes in most railroad companies. When ORNL first started to modify the rail data base in 1979, the updated data base was referred to as Network 1. Network 11 is the version currently in use.

In the early 1980s, waterway information was added to the data base. Waterway data in the network are represented as two subsystems: shallow draft waterways (inland and intracoastal waterways) and deep draft waterways (connecting the Great Lakes, Atlantic Coast, Gulf Coast, the Panama Canal, and the West Coast). In 1986, the inland waterways were matched to data from the USGS's 1:2,000,000 digital line graphs.

In 1990, ORNL was contacted by M. Abkowitz of Abkowitz and Associates requesting a copy of the rail and waterway data base for his HazTrans™ risk package. This request led to the copyrighting of the rail and waterway data base by the Office of Technology Transfer of MMES, the operating contractor of ORNL. In 1991, a license agreement was signed with Abkowitz and Associates for the commercial use of the rail and waterway data base. The results of the copyright and licensing of the rail and waterway data base are as follows: Commercial distribution of the data base is controlled by a licensing agreement; distribution of the data base for federal government use is unrestricted. The data base and a PC version of the INTERLINE model are available through the Energy Science and Technical Software Center (ESTSC).

During the past decade, the INTERLINE model has been used for routing analysis in numerous studies. Some of the studies include shipment planning for the NWPA, analysis of the Three Mile Island shipments to the Idaho National Engineering Laboratory, routing and risk assessment for the demilitarization of U. S. Army nerve-gas stockpiles, and other route analysis for environmental assessments for DOE projects. A number of users throughout the DOE community use the INTERLINE model for similar assessments.

### **3.2 DISTRIBUTION OF THE MODEL**

Since the INTERLINE model does not have proprietary restrictions associated with the HIGHWAY model, the INTERLINE model is more widely distributed. The primary locations of the model are the TIN VAX computer, the TRANSNET system, and the CRWMS M&O local area network. Additionally, PC versions of the model can be obtained from the ESTSC, for a nominal fee to cover reproduction costs. The PC versions of the model have been distributed to a number of users. As new releases of the model or data base occur, copies are provided to the DOE computer systems identified previously and ESTSC.

### **3.3 STATUS AND DOCUMENTATION**

B. E. Peterson prepared the first INTERLINE user's manual in 1984.<sup>4</sup> In 1990, the model was modified to remove the assembler language subroutines and to operate on a PC. The primary model enhancements included at that time were the alternative routing capability and the inclusion of

population density information. A new user's manual was written and published in 1993, documenting these new features of the model.<sup>5</sup> Funding for the preparation of the latest version of the user's manual was provided by the OCRWM, and the printing and distribution was provided by EM.

The INTERLINE rail and waterway data base has been revised on a fairly regular basis since its inception. The 11th version of the data base is in use. Starting in FY 1991, data-base maintenance was placed on a 3-year cycle, during each one of which one-third of the data base is extensively examined. Thus, at the end of a 3-year cycle, the entire data base will have been reviewed. Data base changes such as abandonments, mergers, and new railroads are incorporated into the data base as they are known and made available when the data base is released.

### 3.4 DATA-BASE STRUCTURE

The INTERLINE model rail and waterway data base is maintained as a series of ASCII files. The following files are used to create the network used by the model: link file, transfer file, node file, barge chain file, network ownership file, and the railroad number translation table. Each of these files will be discussed in this section.

The link file is the primary data file of the rail data base. This file defines the network structure and contains the attribute information for the links. Data elements in the link file are shown in Table 2.

Table 2. Data elements in the INTERLINE link file		
Columns	Field	Description
1-5	A node	Beginning node number of link
6-10	B node	Ending node number of link
11	MLC code	Main line classification (MLC) code of link: 1 = A main line, 2 = B main line, 3 = A branch line, 4 = B branch line, 6 = shallow draft waterway, 7 = deep draft waterway
12-15	Distance	Distance of link in tenths of a mile
16-17	Speed	Speed limit on link, mph.
18-19	State code	State Federal Information Processing Standard (FIPS) code

**Table 2. Data elements in the INTERLINE link file (continued)**

Columns	Field	Description
20-22	Zone number	Zone number of link location
23	Number of tracks	Number of tracks
24	Signal system	Signal system on link: 0 = no signals, 1 = automatic block, 2 = centralized traffic control, 4 = indicator for barge shape available
25	Historic density	Traffic density information for link. Historic density field is from mid-1970s and is not used. Recent density field is updated periodically with new data: 0 = no value available, 1 = less than 1 million ton-miles, 2 = 1-5 million ton-miles, 3 = 5-20 million ton-miles, 4 = over 20 million ton-miles.
26	Recent density	
27	Major market	Major market connector (has not been updated since mid 1970s)
28	STRACNET	Strategic rail line for defense purposes (has not been updated since mid-1970s)
29	Weight	Weight limit on link: 0=unknown, 1=220,000 lbs., 2=263,000 lbs., 3=315,000 lbs. (This data element will become available with the release of Network 12.)
30	Size	Size clearance on link: 0 = unknown, 1 = B plate, 2 = C plate, 3 = E plate, 4 = F plate, 5 = H plate. (This data element will become available with the release of Network 12.)
31-32	Number of railroads on link	Number of railroad companies operating on link. Up to 12 railroads are possible. The Association of American Railroads (AAR) codes are used for identification of operators on links. (997 is used for shallow draft waterway; 998, for deep draft.)
33-35	RR1	AAR code of owner
36-38	RR2	AAR code of first railroad with trackage rights on link
39-41	RR3	AAR code of second railroad with trackage rights on link
42-44	RR4	AAR code of third railroad with trackage rights on link
45-47	RR5	AAR code of fourth railroad with trackage rights on link
48-50	RR6	AAR code of fifth railroad with trackage rights on link
51-53	RR7	AAR code of sixth railroad with trackage rights on link
54-56	RR8	AAR code of seventh railroad with trackage rights on link
57-59	RR9	AAR code of eighth railroad with trackage rights on link
60-62	RR10	AAR code of ninth railroad with trackage rights on link
63-65	RR11	AAR code of tenth railroad with trackage rights on link
66-68	RR12	AAR code of eleventh railroad with trackage rights on link

INTERLINE permits transfers from only one rail system to another (or between rail and water) at designated locations. If two rail subnetworks share a common node, a transfer is not allowed unless it is a recognized transfer location. The transfer file contains the locations where the model allows shipments to move from one subnetwork to another subnetwork. Table 3 provides the data elements in the transfer file.

Table 3. Data elements in the INTERLINE transfer file

Columns	Field	Description
1-19	Name	Name of transfer location
20-32	County	County name of transfer location
33	RR1 to RR2 switch	Special switch controlling use of transfer. Transfer could be used in one direction, but not in the reverse direction. Code values are: 0 = transfer allowed, 8 = transfer used only for local traffic, 9 = track connection, but transfer is not used. (Codes 1 through 7 are not used.)
34	RR2 to RR1 switch	
35-37	Zone	Zone number of transfer location
38-39	State	Postal abbreviation of state at transfer location
40-42	AAR1	AAR number of first railroad at transfer location
43-46	Abbreviation 1	AAR abbreviation of first railroad at transfer location
47-49	AAR2	AAR number of second railroad at transfer location
50-53	Abbreviation 2	AAR abbreviation of second railroad at transfer location
54-58	Node number	Node number of transfer location
59-63	Transfer abbreviation	AAR Rule 260 abbreviation of transfer location. If value is numeric, a dummy link exists between this node and the node in the previous field.

The node file contains the names and coordinates for the nodes. Table 4 contains the data elements for this file.

The barge chain file contains the shape coordinates for the barge links. (Note: Barge links which have shape coordinates have a value of 4 in the signal system field.) Two types of records are found in the barge chain file: header records and coordinate records. Table 5 contains the data elements for these records in the barge chain file.

**Table 4. Data elements in the INTERLINE node file**

Column	Field	Description
1-5	Node number	Node number
6-25	Name	Name of the node
26-27	State	State abbreviation of the node
28-37	Latitude	Latitude of the node
38-47	Longitude	Longitude of the node

**Table 5. Data elements in the INTERLINE barge chain file**

<i>Header record information</i>		
Column	Field	Description
1-5	Sequence number	Sequence number in the chain file
6-10	A node	Beginning node number of link
11-15	B node	Ending node number of link
16-20	Number of coordinate pairs	Number of coordinate pairs that follow

<i>Coordinate record(s) information (for all points in the chain; four coordinate pairs per record)</i>		
Column	Field	Description
1-10	Longitude (1)	Longitude of first coordinate (value is positive)
11-20	Latitude (1)	Latitude of first coordinate
21-30	Longitude (2)	Longitude of the second coordinate
31-40	Latitude (2)	Latitude of the second coordinate
41-50	Longitude (3)	Longitude of the third coordinate
51-60	Latitude (3)	Latitude of the third coordinate
61-70	Longitude (4)	Longitude of the fourth coordinate
71-80	Latitude (4)	Latitude of the fourth coordinate

The railroad network for the INTERLINE model consists of 96 subnetworks. The ownership and translation table files included in the INTERLINE data base control the process of subnetwork

assignment. Each subnetwork consists of either a single railroad company, several railroads which may be commonly owned, or a grouping of small railroads which are represented in the network by only one or two links. Currently, most railroad companies that operate over 100 miles of track are either assigned to a single network by themselves or grouped with other railroads owned by the same company. The remaining railroads are combined into a separate network consisting of other short lines. The waterway systems comprise 2 of the 96 subnetworks.

The ownership file consists of three data fields: the subnetwork number, the subnetwork abbreviation, and the names of the railroads in the subnetwork. This file contains 96 records; the number of subnetworks in the INTERLINE model. Only the first two elements are used during the loading process. The subnetwork number is in columns 3 through 4, and the abbreviation is in columns 7 through 10. From column 13 to the end of the record is text description of the railroad names.

A translation table file is used to convert the AAR code numbers contained in the link and transfer files to the 96 subnetworks used by the INTERLINE model and also described in the ownership file. AAR code numbers range in value from 1 to 999. The translation table file is a vector with 999 elements. All 999 elements are not stored in one continuous record, but in multiple records, with 16 elements per record. The value in the appropriate position translates to the subnetwork number that should be used. For example, the Union Pacific (UP) Railroad's AAR code is 802. In the link file, any link that UP can operate over has that code number 802 in one of the railroad fields (RR1 through RR12). Transfers with the UP and any other railroad in the transfer file have the code number 802 in either the AAR1 or AAR2 fields. Examination of the ownership file for Network 10 would reveal that UP is the 14th of the 96 subnetworks. (With each release of a new subnetwork, the position of a particular railroad company is subject to change. In Network 11, UP is the 13th subnetwork.) The value in the 802th element of the translation table for Network 10 is 14.

A series of FORTRAN programs are used to convert the raw data files into binary data sets which are used by the INTERLINE model. Any network modifications require that the loading programs be run to generate a new version of the data base.

Population density for each link is processed and stored separately from link information previously discussed. Each link is intersected with contoured population-density data, and the distance of each link within the different density levels is calculated. After these data have been processed, the data are stored in a file and can then be accessed to determine the population density for any link.

### **3.5 EXISTING FUNCTIONALITY OF THE INTERLINE MODEL**

The basic function of the INTERLINE routing model is to determine a route between two locations. This is done using a shortest-path algorithm, which, in turn, uses a weighted function of distance and volume of freight traffic to calculate the shortest path. A variety of commands and options can be used to modify the way routes are calculated in the INTERLINE model. The INTERLINE user's manual provides a detailed explanation of operating the model; a brief overview of the functions of the model will be provided in this section.

**Route** is the most basic command of the model; it generates a route. This command requests the user to identify an origin and a destination for the route. The location needs to be entered as city and state, each separated with a comma. The entire name does not need to be entered. If several names are matched, the model will list the possible locations, and the user will be requested to select the correct one. Additionally, if more than one railroad serves the selected city, the model will prompt the user to select one. After the origin and destination have been defined, the model will calculate the route. Upon completion of the calculations, the model will provide a route summary including total route mileage, railroads used, mileage within each main line classification, and mileage within each state. The program then will query the user whether a listing of the route should be provided. If the user answers affirmative, the larger cities on the route and the locations of transfers between railroads will be identified.

**Reroute** is a useful command for generating a series of routes from the same origin. The first route must be calculated by the route command; however, subsequent routes can then be generated quickly using the reroute command.

**Retype** is a command that is used to repeat the display of the output from the previously calculated route.

**Option** is the primary command to set up and change all routing parameters and constraints. When options are changed, they are in effect for the duration of the current session of INTERLINE unless that option is changed at a later time. The options available in the model follow:

1. Alternative routing. The INTERLINE model has the ability to automatically calculate alternative routes. During the use of this option, the model first calculates a base route, which is the normal route between the origin and destination. The user is then prompted if an alternative route should be calculated. If the user answers affirmatively, the model will calculate an alternative route. After that route is determined, the program again prompts the user for another alternative route. This process is repeated until the program has calculated ten routes or the user stops the process.
2. Barge routing. The INTERLINE model has the capability to route by rail and by water. Two waterway subnetworks exist in the data base: shallow-draft inland waterways and deep-draft merchant marine connections. By default, the waterway networks are deactivated. To route by barge or to obtain intermodal route calculations, the barge-routing option needs to be activated.
3. Population density. The INTERLINE model can generate summary population-density statistics for any calculated route. A summary table is printed which identifies the number of miles within 12 different population-density categories for the total route and for each state along the route. Additional information on the weighted population and distance travelled in rural, suburban, and urban areas, useful for input to the RADTRAN 4 risk model, is also calculated.
4. Map file. This option directs the program to output a file which contains alternating records with node and link-number information. After postprocessing this file with a separate program, one can calculate a file with node coordinates and link attribute information. This file can then be used for additional GIS analysis.
5. Expert capabilities. The expert option provides access to additional parameter settings which control the route calculation constraints. The default parameters for calculation of a route include the originating railroad advantage (default value is 0.8), and the main line classification factors (default values are A—main line 1.0, B—main line 1.2, A—branch line 1.9, B—branch line 4.0, inland waterways 0.7, and deep water routes 0.6). When the expert option has been activated, the user is provided with prompts to enter new values for these factors.

Additionally, the user is issued another prompt on railroad sequencing. At this prompt, the user can enter a sequence of railroads that the model will use in determining the route. For example, if the

user wants to calculate a route from Toledo, Ohio, on Conrail to Salt Lake City, Utah, on the UP and wishes the routing to follow Conrail, Chicago and North Western, and UP, the user enters the abbreviation of this sequence of railroads after this prompt. The model will consider only that sequence of railroads in determining the route.

The **link** command permits the user to block selected links in the data base. Links are not actually deleted from the data base, but they are effectively blocked by adding a large value to the link impedance. If a deleted link is the only connection between an origin and a destination, the model will use the link in a route. A deleted link may be restored by the **link** command, or the entire data base may be reset to its original state by exiting and restarting the program.

The **node** command permits the user to block selected nodes in the data base. Nodes are not actually deleted from the data base, but they are effectively blocked by adding a large value to the impedance of all links emanating from the selected node. If a deleted node is the only connection between an origin and a destination, the model will calculate a route which passes through the blocked node. To restore a node deletion, the user may use the **node** command, or the user may exit and restart the program.

The **transfer** command permits the user to modify or list the transfer penalty between subnetworks in the INTERLINE data base. The reader is referred to the latest INTERLINE user's manual for details on the **transfer** command.

The **stop** command allows the user to stop and exit from the INTERLINE model.

### **3.6 ISSUES RAISED FOR THE RAIL AND WATERWAY ROUTING MODEL**

The issues developed from Baseline Requirements Assessment Session for the INTERLINE model and the data base are discussed below. Each issue has been assigned a priority and a tentative schedule based on the latest DOE guidance and budget information. The actual order of enhancements will be determined by DOE authorization and funding availability.

### **3.6.1 Rail and Waterway Routing Model Issues**

#### *Issue 1:*

The issue of graphical output was discussed by a number of participants. Several users stated that the model should be converted to operate as a GIS-based program.

#### *Suggested action:*

As a result of this and other issues, a new GIS-based rail and waterway routing model will be developed that will provide a graphical user interface with maps showing the rail and waterways networks and routes calculated by the model. This will be one of the primary benefits of the developed of the new GIS-based routing model that will be accomplished during FY 1995.

#### *Issue 2:*

One participant stated that the method of selecting nodes would be simplified if a map were displayed. This would permit the user to visualize the network in urbanized areas. If a map was displayed, the node could be selected by placing a cursor over the desired node.

#### *Suggested action:*

The ability to select a specific node as an origin or destination, the ability to add or delete a link or node, and the ability to access information about a link or node by clicking on that particular feature will be incorporated into the GIS-based rail and waterway routing model that will be developed in FY 1995.

#### *Issue 3:*

The participants in the session would like the INTERLINE model to have the "look and feel" of the HIGHWAY model. The INTERLINE model is currently not as user friendly as is the HIGHWAY model. It was noted that consistency in standard terminology, questions, and responses should exist between the HIGHWAY and INTERLINE models.

#### *Suggested action:*

ORNL is developing an integrated rail, truck, and waterway GIS-based routing model. The rail and waterway portion of this model is scheduled to be completed by the end of FY 1995. The "look and feel" of all routing modes will be the same with the completion of this system.

*Issue 4:*

The ability to estimate routes to bypass links with weight limit and size clearance was discussed. An option needs to be added to included in the rail model to permit the calculation of routes which bypass these impediments.

*Suggested action:*

The new rail routing data base will contain weight limit and size clearance restrictions. An option will be included in the new GIS-based rail model that will create routes that bypass links with these restrictions. This option will be implemented in FY 1995.

*Issue 5:*

The issue of reporting population density generated by the INTERLINE model as input to the RADTRAN model was discussed. One participant suggested that the existing summary be expanded to include distance travelled in the rural, suburban, and urban categories for each state and for each rail system along the route.

Subsequent to the Baseline Requirements Assessment Session, a requirements meeting for the RADTRAN model was held on May 12, 1994. The RADTRAN 5 model will no longer be using the aggregate population-zone formulation. Population density information on route segments will be provided as input via the "Links" and "Stop Links" features in the RADTRAN 5 model.

*Suggested action:*

Three action items have been identified for this issue: (Also, see discussion for Issue 9, Sect. 2.6.1.)

1. The new GIS-based rail routing model will be modified to provide additional information for the rural, suburban, and urban aggregate zone data by each state and railroad for use with the RADTRAN 4 model. This activity will be completed in FY 1995.
2. ORNL will hold a series of discussions with the RADTRAN staff at SNL to define the data that need to be incorporated into the new GIS-based routing model to assist users in obtaining population-density information needed in the RADTRAN 5 model. Once the data are identified, they will be included in the new rail routing model will be prepared. This activity will be accomplished in FY 1996.

*Issue 6:*

A number of users at the meeting stated that RIS codes are used for identifying DOE facilities. It was recommended that an appendix be added to the users manual that would show either the proper node name or the nearest node to a particular RIS code. It was also suggested that this information be a node attribute. The ability to output RIS codes will assist in the coordination with SMAC and other activities that use RIS codes for referencing shipping locations.

*Suggested action:*

A two-phased approach is recommended for this issue. (Also, see discussion for *Issue 11*, Sect. 2.6.1.) Phase I would involve developing a list of the appropriate node for each RIS code and distribute the list to users during FY 1996. Phase II would entail including RIS codes as a node attribute in the new GIS-based rail routing model. This software would either automatically identify the node nearest to the RIS code or the user could specify a RIS code in selecting an origin or a destination. Phase II has been assigned a relatively low priority and has been tentatively scheduled for late FY 1998 or FY 1999.

*Issue 7:*

Several participants expressed an interest in including population count as one of the factors used in the route selection algorithm. A route with a lower population count that is slightly longer than the standard route may pose a significantly lower risk to the general public.

*Suggested action:*

Adding population count to the rail routing model is a completely separate project than that described for the truck routing model. (See response in *Issue 12*, Sect. 2.6.1.) The methodology for assigning population count data to the truck routing data base could be used, but all data calculations must be repeated for the rail network. The routing algorithm will include population count as a parameter in route selection. Because of the large number of high-priority issues identified during the requirements meeting, the use of population count as part of the routing criteria has been given an intermediate priority and will probably not be completed until FY 1998.

### 3.6.2 Rail and Barge Modeling Issues

#### *Issue 1:*

One participant requested that the heavy-lift capability intermodal assumption in the INTERLINE model be modified. Currently, the INTERLINE model permits intermodal shipments (rail to barge) only at locations where roll on—roll off capability exist. Intermodal rail-barge transfers in the routing model should have a default of any port (assumes that sufficient lifting capacity is available or could be supplied by a moveable crane). With this additional data, the model should have an option that will allow the user to limit rail-barge intermodal changes to ports that have roll on—roll off capability. The user's manual also needs to address the assumptions involved in waterway shipments.

#### *Suggested action:*

This activity has been assigned a moderately high priority for development in the new GIS-based routing model. First, locations of all rail-barge interface port locations will be identified and included in the rail routing data base. Then, the routing program will include an option which would allow the user to specify all rail-barge interchanges or only those interchanges which have roll on—roll off capability. The primary activity for FY 1995 will be the development of the GIS-based rail and waterway routing model. The implementation of this feature is dependent upon additional modification to the routing data bases which may occur in late FY 1995 or early FY 1996.

#### *Issue 2:*

A participant noted that for intermodal applications, the user should have the option to switch from a waterway to a rail line as soon as possible. An option could be added to change the main line factors for waterway networks to estimate routes that would transfer to the rail system as soon as possible.

#### *Suggested action:*

An option will be included in the new GIS-based routing model to allow the user to switch from a waterway to a rail line as soon as possible. The implementation of this option has been given a high priority and will be included in the development plans for FY 1995.

*Issue 3:*

Several participants recommended that a separate requirements session or caucus on transshipment be held.

*Suggested action:*

Because the level of funding, this action has been assigned a low priority at this time. Discussion will be held with DOE regarding this issue in several years.

### **3.6.3 Rail and Waterway Data Base Issues**

*Issue 1:*

The rail routing data base is a topologically accurate representation of the U.S. rail system, but the geographic accuracy of the node locations could be improved. Also, most data-base links are currently represented as straight-line segments between nodes. Session participants noted that the data base could be vastly improved if it had shapes for the links.

*Suggested action:*

ORNL will investigate sources of data that have shape points for rail and waterway networks. The Bureau of Transportation Statistics is one source of data. A report and recommendation on the findings of this investigation will be completed in FY 1995.

*Issue 2:*

A number of participants expressed a need to expand the rail routing data base to include weight and size restrictions.

*Suggested action:*

A new rail routing data base will be developed for the GIS-based routing model that will include weight limit and size clearance information. Activities in FY 1995 include incorporation of these factors in the data base and the ability to generate routes that avoids these restrictions (see *Issue 4* in Sect. 3.6.1).

*Issue 3:*

A number of participants expressed a need to expand the rail and waterway routing data base to include the sites of receiving or shipping facilities at DOE sites, research reactor locations, port facilities, and other commonly used facilities.

*Suggested action:*

A letter will be sent to the session participants in early FY 1995, requesting a list of sites that needs to be added, along with maps showing the locations of shipping or receiving facilities. This letter will be coordinated with actions outlined in *Issue 1*, Sect. 2.6.2. Assuming that this information is received in a timely manner, these sites will be incorporated into the new routing data base.

*Issue 4:*

Participants expressed an interest in including population-count information as a link attribute. If population count is added to the data base, a standard set of band widths for the population data needs to be determined. One participant suggested band widths of 0.5, 1, 3, and 5 miles from the route. These was a discussion of the problems associated with assigning a population count to each individual link. These is a possibility of double-counting. One participant stated that is would be better to double-count some of the population along a link rather than not make any count.

*Suggested action:*

See discussions in *Issue 7* in Sect. 3.6.1, *Issue 12* in Sect. 2.6.1, and *Issue 4* in Sect. 2.6.2. The population-count data will need to be calculated for each link in the new routing data base. This activity has been assigned an intermediate priority and has been scheduled to commence in FY 1998.

*Issue 5:*

A participant requested that additional node attributes should include SPLC, Freight Station Accounting Code (FSAC), and Open and Prepaid Station List (OPSL) number. The original data files acquired with the original FRA rail network still exist and contain SPLC and FSAC data. However, these data are over 20 years old. The SPLC information is still accurate, but the FSAC information has changed dramatically.

*Suggested action:*

It would take a massive effort to update and correct this information. The benefits of such a project would primarily be limited to activities such as flowing waybill information or determining accident locations. Currently, there is not a proven need for this information, and it is recommended that this issue not be pursued.

*Issue 6:*

Accident rates were discussed a number of times. Session participants would like to have accident data included in the data base; however, they acknowledged that a reliable data base of accident information does not exist, that it is difficult to obtain exposure data, and that it is difficult to get information on the level of accidents.

*Suggested action:*

Also, see discussion on *Issue 8*, Sect. 2.6.2. During FY 1995, A. Zamboky, Westinghouse Bettis Laboratory, will be contacted regarding an ANL report on accident statistics. At a later date, this report will be reviewed to determine the best way to incorporate accident rates into the model. However, the tentative schedule does not include incorporating accident data into the routing data base until FY 1999.

### **3.6.4 General Topic Issues**

*Issue 1:*

The INTERLINE model is designed to predict general freight routes. One participant inquired if dedicated trains would take significantly different routes. Another participant stated that dedicated trains and general freight trains might have different interchange points. ORNL staff did not agree; all valid interchanges are available in the INTERLINE model. If the INTERLINE model weighted transfer points by traffic volume, this argument would be subject to review.

*Suggested action:*

An impedance value is set at junction locations where rail systems interchange freight. The new GIS-based rail model will have an option to set this impedance value to a minimum value, so there will be no disadvantage to switch systems. This option can be used to model dedicated train movements. This activity will be completed in FY 1995.

*Issue 2:*

The need to include an appendix outlining population-density calculations and a listing of commonly used origins and destinations was suggested by several participants. As the discussion progressed, it was also suggested that information on configuration management and verification and validation should be included in the user's manual.

*Suggestion action:*

Three activities were identified in this issue (see *Issue 1*, Sect. 2.6.3):

1. Preparation of an appendix describing how the population-density calculations are made is tentatively scheduled for FY 1998. (Only one appendix on population density needs to be prepared. This appendix can be used in the new GIS-based routing model user's manuals.)
2. Participants will be surveyed in FY 1995 to identify the origins and destinations commonly used in their routing analysis. ORNL will prepare a list of routing nodes for these locations and distribute to all users.
3. The topics of configuration management and verification and validation of the models will be discussed with DOE. At this time, no specific action has been identified.

*Issue 3:*

The need for establishing procedures for validation and verification of the rail model's predicted routes was discussed. (One participant compared INTERLINE route listings with railroads for review and found that INTERLINE routes were viable, although the routes may not have been the most cost-effective.) This activity needs to be documented. The rail model's routes should be compared to those generated by other predictive models (such as ALK and Associates rail model). It should be determined whether a process can be established to validate routes with railroads. The AAR offered to provide information from AAR's 10% hazardous material car-movement data which could be used to validate rail routes.

*Suggested action:*

The AAR will be contacted to obtain the 10% hazardous material car-movement data. Routes generated by the new GIS-based rail routing model will be compared with those provided by the AAR as part of the software development quality assurance process. This activity is scheduled for FY 1996.

*Issue 4:*

One participant inquired as to how the INTERLINE model handled haulage rights.\*

*Suggested action:*

This issue needs further thought. The current rail routing model does not incorporate haulage rights. Haulage rights are a fairly recent development and may involve only certain types of commodities. In the past, haulage rights were given to railroads as a result of merger compensations (Kansas City Southern access to Omaha and Lincoln, Nebraska, and to Topeka, Kansas, as a result of the merger of the Missouri-Kansas-Texas Railroad with UP). Recently, haulage rights have been arranged between railroads to provide access to major markets beyond their normal territory (Atchison, Topeka, and Santa Fe Railway with Burlington Northern Railroad for Birmingham, Alabama). Freight moved per haulage rights normally does not move beyond the second railroad. A specific action has not been developed, but ORNL will continue to review how haulage rights can be best incorporated into the new GIS-based routing model.

*Issue 5:*

One participant expressed the view that commodity mix affects rail routes. Rail routes could be sensitive to other commodities that are being moved over a corridor. The concern was expressed that the route for transporting nonhazardous materials might differ significantly from the routes used for transporting hazardous materials. For example, some coal lines are classified as main lines because of traffic volume. Hence, the rail routing model could route other traffic onto these lines even though in the real world coal is the only commodity shipped along this line.

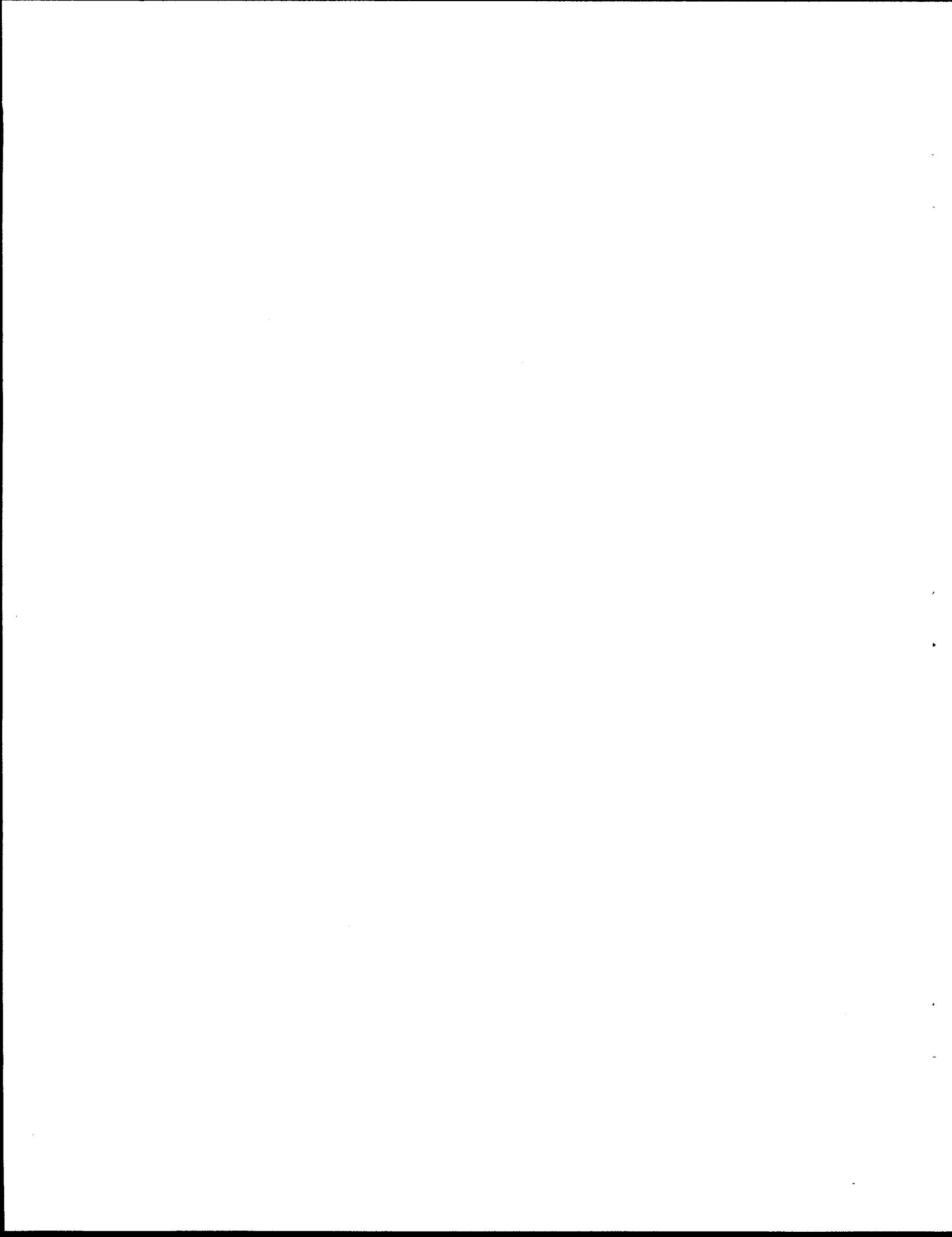
*Suggested action:*

The Appalachian coal fields in the eastern United States are the areas of primary concern for this issue. Most other areas, especially in the western United States, have limited options for commodity-specific route patterns. This is not to say that if a person examined

---

\*The following description explains the concept of haulage rights. Assume railroad *A* does not provide service to city *X*, but railroad *A* has made a haulage rights agreement with railroad *B*, which does provide service to city *X*. Under a haulage rights agreement, shippers in city *X* can arrange with railroad *A* to ship freight. Railroad *B* will pick up the freight and transport it to the interchange location with railroad *A*.

the patterns of various commodities, different patterns would appear. For example, wheat movements flow from agricultural areas to food-processing areas; wood products, from timber areas to major markets; hazardous chemicals, from the Gulf Coast to the Midwest and Northeast; etc. The new GIS-based rail routing model will attempt to move traffic onto routes that carry the most traffic, and the model attempts to minimize use of routes with extremely low traffic.



## 4. LOCATING AIRPORTS

The AIRPORT program is a tool to allow the transportation community to locate nearby airport facilities. Although it has not been extensively used recently, several new features will make it more versatile and useful to the user community. ORNL will continue to update and enhance this model to meet the user's needs per DOE's guidance and direction.

### 4.1 HISTORY OF THE AIRPORT PROGRAM

In 1982, an accident involving the shipment of nuclear material occurred in Idaho. There was concern that a criticality situation might occur. DOE-Oak Ridge Office had a van-operated remote control robot which, if delivered to the accident site, could assist in the separation of the packages involved in the accident. Because of the size of the van, a C5A military air transport aircraft was needed for transport. McGhee Tyson Airport, the nearest major airport to Oak Ridge, could handle a C5A, but locating the nearest airport to the Idaho accident site was a problem. It took several days of frantic phone calls to finally locate an airport near the accident site. However, by this time the situation at the accident site had been significantly downgraded, and the delivery of the equipment from Oak Ridge was not deemed necessary. The difficulty in responding to this accident led DOE to fund the development of the AIRPORT locator program.

The AIRPORT program was closely related to the HIGHWAY model. The data base for the HIGHWAY routing model was modified to include access to major airports. About 900 airports were added to the HIGHWAY data base. The set of airports include all airports that have commercial air service, military airports, major general aviation airports, and airports that have handled DOE shipments. (A list of airports with DOE shipments during the early 1980s was provided from the SMAC data base.) The AIRPORT program used the HIGHWAY data base node identifiers as locations which the user may select for searching for the nearest airports. If the user restricted the search to the airports in the HIGHWAY data base, the program allowed the user to calculate the driving time and distance from the search point to the airports located.

#### **4.2 STATUS AND DOCUMENTATION**

Currently, the AIRPORT program is inactive. Plans are to activate the model on the TIN VAX computer sometime in the future, making it available to users on this system. The model could also be placed on the TRANSNET system. Version 1.0 of the AIRPORT program was developed and documented with a user's manual in late early 1983.<sup>6</sup> About 500 airports with commercial air service in the continental United States were added to the HIGHWAY data base. In 1984, further changes were incorporated into the program and ~400 additional airports were added to the HIGHWAY data base. These airports included most military airports and airfields and other airports that had been used by DOE in the early 1980s for shipments of radioactive material. The AIRPORT program and data base were also modified to include all airports with a paved runway. (If this option is chosen by the user, the model can not calculate the driving time and distance to these airports, all of these airports are not identified in the HIGHWAY data base.) This improvement to the model resulted in Version 2.0 of the AIRPORT program. The changes to Version 2.0 have not been included in any updated edition of the AIRPORT user's manual. No further modifications to the program or data base have occurred since 1984.

The data base for the AIRPORT program was originally extracted from a 1982 version of the Federal Aviation Administration's (FAA) Landing Facility data base. Modifications to Version 2.0 of the data base used the 1984 version of the same data base.

After the multimodal GIS-based routing model is developed, an updated airport listing and location information will be incorporated into the system. A primary source for data will be airport information included on the compact discs distributed by the DOT Bureau of Transportation Statistics. The airport module of the GIS-based routing system will provide a visual location of the runways and characteristics of the airport.

#### **4.3 DATA-BASE STRUCTURE**

The airport data base contains the following data elements identified in Table 6. Most of these data elements were extracted from the FAA Landing Facility data base. A separate data base contained

the information on the weight capacities for the military transport aircraft, and information on passenger service at airports was obtained from airline information.

Table 6. Data elements in the AIRPORT data base

Columns	Field	Description
1-4	Airport identifier	This element is the standard location identifier assigned by the FAA to each airport. For major airports, this is a three character alphabetic code. Minor airports have a four character alphanumeric code.
5-9	Downtown to airport	This field provides information on the distance and direction the airport is from the central business district of the city to the airport. If the airport is 11 miles northwest of the downtown area, this field would contain 11*NW.
11-36	City	The city associated with the airport
37-38	State	The state associated with the airport
39-46	Latitude	Latitude of the airport
47-54	Longitude	Longitude of the airport
55-56	Use	Airport use; public or private
57	Military use	Military use of airport; yes, no, or joint use
58	Passenger service	Type of passenger service at airport
59-61	Beacon light	Type of beacon light at airport
62	Control tower	Control tower at airport; yes or no
63-120	Runway 2 info	Information on the primary runway of airport
63-69	Runway 1 ID	Identification code of first runway at airport; e.g., 04R/22L
70-73	ILS Type	Type of instrument landing system for runway 1
82-86	Length	Length of runway 1, ft
87-89	Width	Width of runway 1, ft
90-99	Lighting schedule	Lighting schedule for runway 1
100-102	G.W.-single	Maximum gross weight for single wheeled aircraft, lbs
103-105	G.W.-dual	Maximum gross weight for dual wheeled aircraft, lbs
106-108	G.W.-dual-tandem	Maximum gross weight for dual-tandem wheeled aircraft, lbs
109-111	G.W.-double dual-tandem	Maximum gross weight for double dual-tandem wheeled aircraft, lbs
112-114	G.W.-C130	Maximum gross weight for C130 aircraft, lbs

Table 6. Data elements in the AIRPORT data base (continued)

Columns	Field	Description
115-117	G.W.-C141	Maximum gross weight for C141 aircraft, lbs
118-120	G.W.-C5A	Maximum gross weight for C5A aircraft, lbs
121-178	Runway 2 info	Similar information for secondary runway, if one exists
179-259	Attendance schedule	Airport attendance schedule
260-301	Name	Name of the airport
302-303	Airport state	State where the airport is located
304-315	Phone	Telephone number of airport
316	Highway	Airport is identified in the HIGHWAY data base

#### 4.4 FUNCTIONALITY OF THE AIRPORT MODEL

The primary function of the AIRPORT model is to locate the nearest airports based upon the user's selected location. Other program functions include a great circle distance function and the ability to trace through the HIGHWAY data base. The AIRPORT user's manual describes the function of the program; a brief overview of the functions, including the new functions for Version 2.0 of the program will be provided in this section.

**Find** is the basic command in the AIRPORT program. This command initially requests the user to select a location upon which to base the airport search. The AIRPORT model uses the nodes in the HIGHWAY data base as the basis for locations in the search for airports. Thus, the prompts for this aspect of the program are identical to the HIGHWAY model. After the location has been selected, the program will issue a series of questions regarding the parameters that will be used in the search.

First, the user is queried as to whether all airports in the data base should be used for the search or if only those airports identified in the HIGHWAY data base should be used. If the user selects all paved runways, the program will examine all airports for the remaining parameters of the search; if the user selects only those airports included in the HIGHWAY data base, only that subset of

airports will be examined, and the user will later have the opportunity to have the model calculate the driving time and distance to the nearest airports.

Next, the user is prompted regarding using both military and nonmilitary airports. If the user selects both, no further subsetting of the number of airports examined occurs, but if the user does not want to examine both types of airports, a subsequent prompt is issued. This prompt lets the user select from the following three types of airports; military use only, military and joint military and civilian use, and civilian use only.

The following questions determine the criteria used to delimit the airports included in the search. First, the user is queried if a minimum runway length is required. If this prompt is answered, yes, the user is requested to enter a runway length in feet. Any airport with a runway shorter than the value entered will be excluded. The next prompt inquires whether qualifying airports should have instrument-landing capability. Then, the program queries whether the user wants to specify the aircraft type and weight. If the user wishes to specify this information, the program then provides the user with a list of military transport aircraft and a list of wheel configurations for the primary landing gear. The selection list includes the following: C130, C141, C5A, single wheel, dual wheel, dual tandem, and double dual tandem. After one of these aircraft or wheel configurations is selected, the user is prompted to enter the weight of the aircraft in thousands of pounds. The final question asks whether the user wishes to change the number of airports listed. (By default, the program will list the 10 nearest airports found.) If the user wants to change the number of airports listed, the program issues a prompt for the user to enter the number to be listed.

At this point, the program will examine the airport data base and identify the airports nearest to the location selected by the user. When the program has determined the airports meeting the user specifications, a list of airports, in ascending order by air distance from the search location, will be generated. If only those airports in the HIGHWAY data base were used in the search, the program will query the user if the actual driving time and distance should be calculated. If the user answers yes, the program will use the HIGHWAY model's routing capability to calculate a commercial route from the nearest airports identified in the search. A table will be generated upon completion of the calculation listing the airport code, distance, and driving time for each airport from the search location.

**Airdist** is another command available in the AIRPORT program. This command allows the user to select two locations (any of the nodes from the HIGHWAY data base), after which the program will calculate the great circle distance between these two locations.

**Search** is a command that permits the user to examine node and link connectivity within the HIGHWAY data base. The command requests the user to enter a location, and then information on the links which emanate from that location is shown. The user can then select one of the listed links. The program will then list the links which emanate from the node that was at the opposite end of the selected link. This command is not used frequently, but it offers a method of examining the structure of the data base.

**Stop** is the command which allows the user to stop the AIRPORT model.

#### **4.5 ISSUES RAISED FOR THE AIRPORT MODEL**

*Issue 1:*

Several participants requested that the AIRPORT model be installed on the TIN VAX.

*Suggested action:*

Because of budgetary constraints and other priorities, current guidance from DOE has moved the activation of the AIRPORT model on the TIN VAX to sometime in FY 1996 or later. The model could be placed on the TIN VAX at an earlier time, if funding is made available. Ideally, it would be best to incorporate the AIRPORT model's functionality as another module in the multimodal GIS-based routing model. This activity is planned to occur in FY 1997.

*Issue 2:*

Participants noted that the AIRPORT data base was last updated in 1984. It was suggested that a current copy of the FAA data base be obtained to revise and update the AIRPORT data base to reflect current conditions.

*Suggested action:*

This is a medium-priority item. If the original AIRPORT model is activated on the TIN VAX in FY 1996, an updated copy of FAA airports data base will be obtained and used for

the model. If a new airport module of the GIS-based routing model is developed, data base work will occur in FY 1997.

*Issue 3:*

A participant working on environmental impact statements stated that a useful function of the AIRPORT program would be the identification of airports that have weather-collecting activities.

*Suggested action:*

Inclusion of an attribute indicating which airports have a flight service station (that collect weather information) will be included during the general update of the airport data base.

*Issue 4:*

Several participants noted that other emergency response information would be useful for the AIRPORT locator model. One participant suggested that R. Spooner, DOE-Carlsbad, would be a source of emergency response locations (first responders, hospitals, etc.) for WIPP corridor states. This information could be used in a program similar to the AIRPORT model to determine nearest emergency response resources.

*Suggested action:*

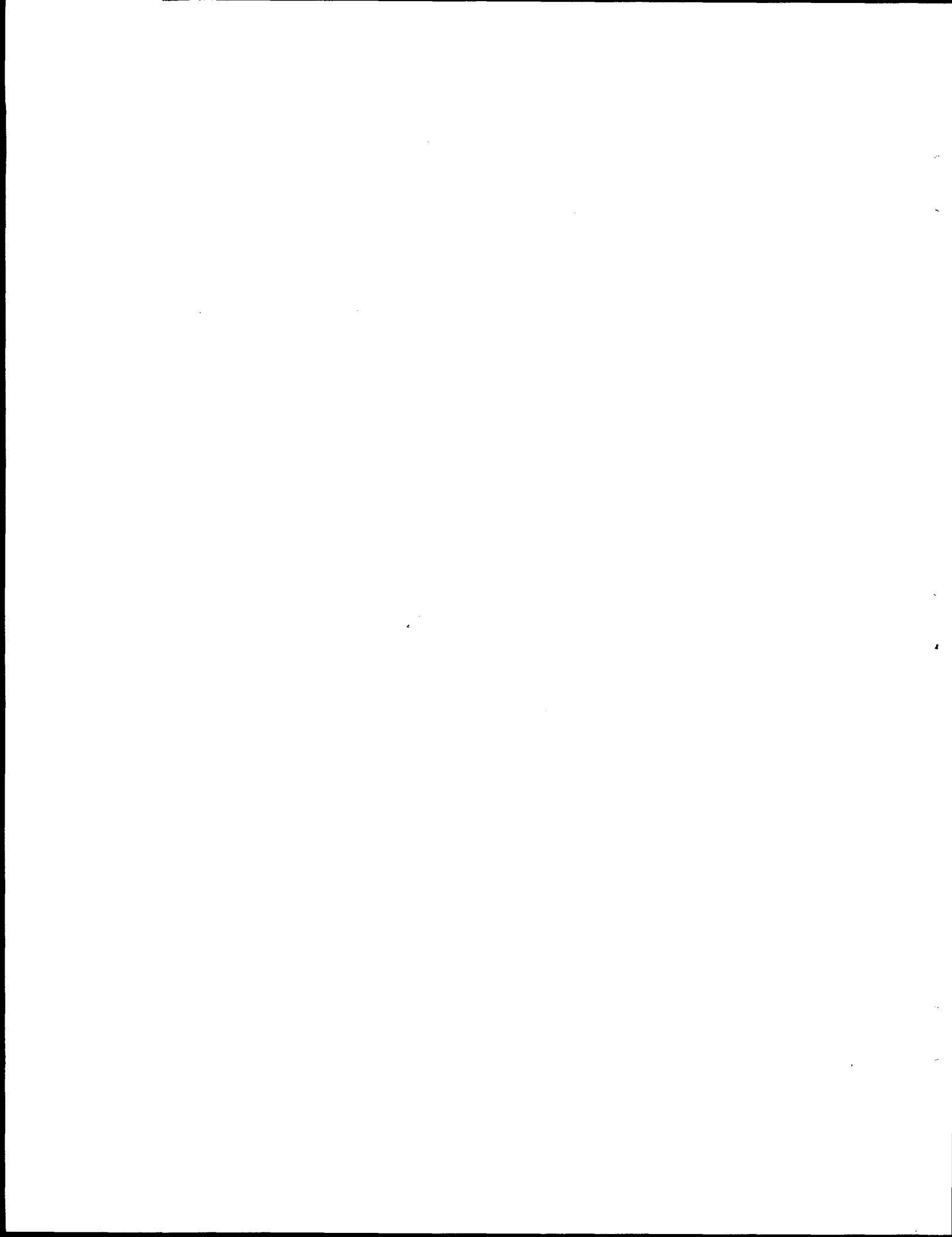
ORNL has contacted R. Spooner. DOE has recently published a report identifying emergency response data used by WIPP. Mr. Spooner will send a copy to ORNL. Currently, the addition of emergency response information to AIRPORT and the other routing models has a low priority. At this time, no specific action has been identified beyond obtaining the previously mentioned report.

*Issue 5:*

One participant requested that information on configuration management and verification and validation of the model should be included in the user's manual.

*Suggested action:*

The topics of configuration management and verification and validation of the models will be discussed with DOE, and an action plan will be formulated based on DOE's decision. At this time, no specific action has been identified.



## 5. RELATED ISSUES RAISED AT THE SESSION

A number of issues were discussed during the meeting that either did not fall into the matters in the previous section or were general enough to fall into several of the previous sections. These issues are discussed in this section.

### *Issue 1:*

Several participants noted that it would be useful to have a bulletin board for routing model users to provide suggestions for changes or identify problems with the routing models. This bulletin board could either be placed on the TIN VAX or TRANSNET. A bulletin board would be a method to share data and to communicate requirements and capabilities without holding an applications development session.

#### *Suggested action:*

This issue has been assigned a high priority and has been included in the FY 1995 plans for the TIN VAX operations. A bulletin board program is available on the TIN VAX, and the activation of this feature will be included as one of the activities for the general automation technical help desk that will be established in early FY 1995 if funding is available. ORNL will also contact TRANSNET to determine whether a bulletin board feature is available for that system.

### *Issue 2:*

Another suggestion was to create PC versions of the routing models, preferably in a Windows™ environment. The official model and data base would be stored on a single machine. Then, individual users could download the latest version for their study.

#### *Suggested action:*

ORNL currently plans to develop a GIS-based multimodal routing model for truck, rail and barge shipments. This model will have a graphical user interface that will allow the interactive display of map and tabular data. Work on the rail and waterway portions of the model will begin in FY 1995 and the truck module development occurring in FY 1996.

*Issue 3:*

The issue of GIS applications for the routing models was discussed. Users expressed the need for overlaying political boundaries, such as state and county outlines, urbanized area boundaries, and locations of major water bodies and rivers. With a GIS-based routing model, users would be able to map a route, overlaying various physical and political boundaries. The University of Tennessee and other sources have data files of these items which could be used for GIS applications.

*Suggested action:*

The ability to display routing data in a GIS type program will be pursued. Feature such as political boundaries, water bodies, and Indian reservations will be included in the new GIS-based routing models.

*Issue 4:*

Participants noted that configuration management is a problem. Currently, there are four copies of the HIGHWAY routing model on different platforms and the INTERLINE model is on three of these platforms; additional copies are on PCs throughout the country. A standardized distribution of revised programs and data base needs to be provided to all users at the same time. One method to accomplish this would be to consolidate the models onto a single machine, and allow users access to that computer. Placing the routing models on a single computer would simplify the installation of new features and data-base upgrades. The Internet system could provide a connection between TIN VAX, TRANSNET and possibly the CRWMS M&O local area network in Washington, D.C. Because the routing analysis performed at SECOM is classified, a separate version of the HIGHWAY program must be installed on the SECOM computer.

*Suggested action:*

Please see related topic in *Issue 2* of this section.

## 6. RECOMMENDATIONS

This report summarizes the results from the Baseline Requirements Session for the HIGHWAY, INTERLINE, and AIRPORT models held at ORNL on April 27, 1994. From the issues discussed in each chapter, several recommendations are proposed to address the future development plans for the HIGHWAY, INTERLINE, and AIRPORT models.

The first recommendation is that further modifications be halted on the HIGHWAY and INTERLINE models and these models be replaced with the development of a GIS-based routing model. This new model will be called the Transportation Analysis Routing Geographic Information System (TRAGIS) and will provide all of the functionality of the existing models with a graphical user interface. Initial development of TRAGIS in FY 1995 will focus on the rail and waterway modes. These modes were selected primarily due to the concerns by users that the INTERLINE model is not as user-friendly as HIGHWAY. In FY 1996, development of the truck module of TRAGIS will occur. Existing functionality of the current models will be incorporated into the TRAGIS model. Many of the other new features suggested by users at the Baseline Requirements Session will also be included during initial development. This action will bring the truck, rail, and waterway routing capabilities for DOE into the current era of graphical user interface.

A second recommendation is that a transition needs to occur from the current restricted data bases to publicly available data bases. The primary reason for this action is to be able to openly provide the TRAGIS models and data bases to all users. With the current restrictions on the data bases, the only method for most users to access the routing models is to obtain an account on either the TIN VAX or the TRANSNET system.

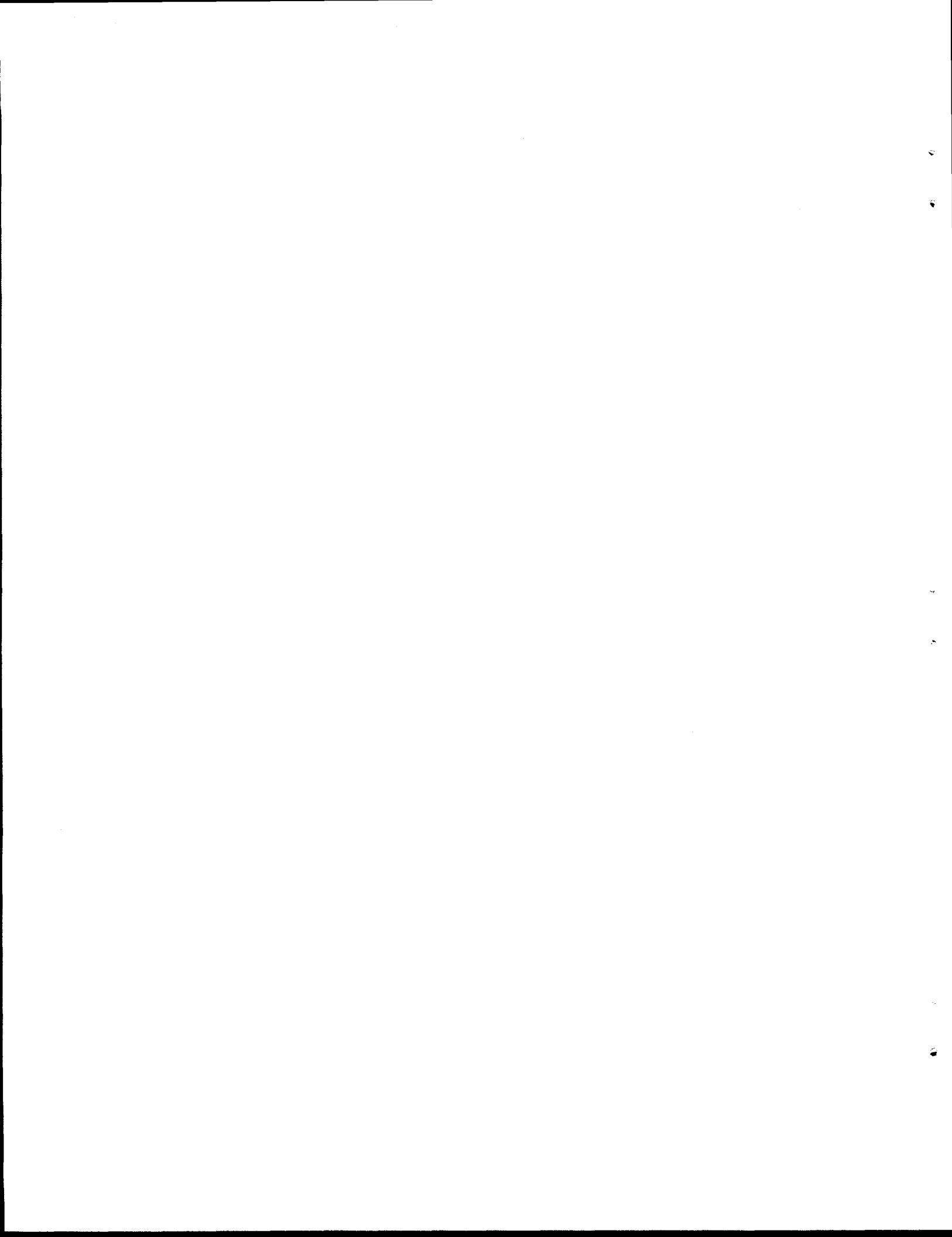
The third recommendation is to incorporate the airport location functionality into the TRAGIS model. This is a lower priority item since the AIRPORT model is not readily available to any users at this time. The development of the airport locating features of TRAGIS will occur during FY 1997 activities. Functionality of the airport locating feature will be more useful to the user community as compared to the AIRPORT model.

The fourth recommendation is to fully incorporate intermodal capabilities into the TRAGIS model modules providing a fully intermodal routing model. Aspects for this functionality will be built into each portion of the model as it is developed, but the data base improvements required to fully implement this feature will need to be built.

Upon completion of these plans, a modern multimodal GIS-based routing model will be available to the DOE community for routing analysis work. TRAGIS will be available to the user community for routing and risk analysis studies.

## 7. REFERENCES

1. D. S. Joy, P. E. Johnson, and S. M. Gibson, *HIGHWAY, A Transportation Routing Model: Program Description and Users' Manual*, ORNL/TM-8419, Union Carbide Corporation-Nuclear Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., December 1982.
2. D. S. Joy and P. E. Johnson, *HIGHWAY, A Transportation Routing Model: Program Description and Revised Users' Manual*, ORNL/TM-8759, Union Carbide Corporation-Nuclear Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., October 1983.
3. 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, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tenn., March 1993.
4. B. E. Peterson, *INTERLINE, A Railroad Routing Model: Program Description and User's Manual*, ORNL/TM-8944, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tenn., November 1985.
5. 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, Martin Marietta Energy Systems, Inc., Oak Ridge National Laboratory, Oak Ridge, Tenn., March 1993.
6. D. S. Joy and P. E. Johnson, *Airport Locator Program: Description and Users' Manual*, ORNL/TM-8610, Union Carbide Corporation-Nuclear Division, Oak Ridge National Laboratory, Oak Ridge, Tenn., April 1983.



**INTERNAL DISTRIBUTION**

1.	S.S. Anderson	19.	D.H. Pike
2.	J.M. Begovich	20-24.	R.B. Pope
3.	K.S. Boes	25.	R.R. Rawl
4.	A.G. Croff	26.	L.B. Shappert
5.	R.C. Durfee	27.	D.E. Vick
6.	R. B. Honea	28.	R.M. Walker
7.	I.G. Harrison	29.	M.W. Wankerl
8.	M.B. Hawk	30.	B.W. Welles
9.	M.E. Hodgson	31.	Central Research Library
10-14.	P.E. Johnson	32.	ORNL Y-12 Technical Library, Document Reference Section
15.	M.A. Kulasha	33.	ORNL Patent Section
16.	A.P. Malinauskas	34-35.	Laboratory Records
17.	L.E. McNeese	36.	Laboratory Records—RC
18.	R.D. Michelhaugh		

**EXTERNAL DISTRIBUTION**

37.	M.E. Bennett, Oak Ridge Operations, U.S. Department of Energy, P.O. Box 2001, Oak Ridge, TN 37831
38.	P.B. Lester, Oak Ridge Operations, U.S. Department of Energy, P.O. Box 2001, Oak Ridge, TN 37831
39.	R.N. Whitehead, Oak Ridge Operations, U.S. Department of Energy, P.O. Box 2001, Oak Ridge, TN 37831
40.	Office of Assistant Manager, Energy Research and Development, DOE-OR, P.O. Box 2001, Oak Ridge, TN 37831
41-42.	Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831