A COMPARISON OF ACTUAL AND PREDICTED ROUTES USED IN THE SHIPMENT OF RADIOACTIVE MATERIALS*

D. S. Joy
Chemical Technology Division

P. E. Johnson
Computing and Telecommunications Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831

I. G. Harrison
University of Tennessee

ABSTRACT

A number of highway controlled shipments of radioactive materials have been made over the past several years. An excellent example showing the variability of actual routes is the transfer of 45 shipments between the Three Mile Island reactor in Pennsylvania and Scoville, Idaho in 1982 and 1983. Six different routes varying between 2273 and 2483 miles were used. Approximately 75% of these shipments followed a common route which passed through ten Urbanized Areas, defined by the Census Bureau as having a population exceeding 100,000 people. Other routes, while shorter in distance, passed through as many as 14 Urbanized Areas. Routes predicted by the Oak Ridge routing model did not exactly duplicate actual routes used. However, the analysis shows that the routing model does make a good estimate of transportation routes actually chosen by shippers of radioactive materials. In actual practice, a number of factors (weather, road conditions, driver preference, etc.) influence the actual route taken.

INTRODUCTION

The shipment of radioactive materials throughout the United States has, in recent years, become of great interest to state and federal agencies. A number of computer programs have been developed to help the U.S. Department of Energy (DOE) predict the impact of future shipments. The most widely used risk analysis tool is RADTRAN-II.[1] As part of the input to this program, Oak Ridge National Laboratory (ORNL) employs the HIGHWAY routing model[2] and mapping programs to identify the population density distribution along the route.

Because routes chosen for shipments of radioactive materials are influenced by external restraints (e.g., state and local restrictions, weather, and road conditions), future routes suchas those identified by the HIGHWAY program cannot be predicted with 100% accuracy. Under these conditions, it is useful to study how past shipments were routed and compare this experience with routes predicted by the HIGHWAY routing model.

The U.S. Department of Transportation (DOT) routing requirements stipulate that these certain radioactive shipments ("highway route controlled quantities") must be transported on a preferred highway. A preferred highway is defined as any specific road designated as a preferred highway by an authorized state agency as well as any Interstate highway for which a substitute road has not been officially authorized. The carrier is also required to use an Interstate bypass or other preferred bypass route in favor of an Interstate route through a city. In addition, the DOT requires the carrier to report the route used within 90 d after the trip is completed, and these data are compiled in a computerized data base. Route information used in this analysis was extracted from the DOT data base.

The DOE shipments of radioactive materials are coordinated by the Traffic Manager responsible for the shipping facility. The DOE does not specify routes to a carrier for radioactive shipments. Instead, the Traffic Manager requires the carrier to identify two or three alternate routes that meet all federal, state, and local requirements. The Traffic Manager has the authority to approve or disapprove any route. However, once several alternate routes have been established, the carrier then determines which route would be used for a particular shipment.

SURVEY OF ROUTES BETWEEN MIDDLETOWN, PA AND SCOVILLE, ID

Between mid-1982 and mid-1983, DOE made 45 shipments of resins used in the cleanup of the Three Mile Island reactor to the Idaho Falls facility for processing and storage. The amounts of radioactivity contained in the resin are sufficiently large that, by DOT regulations, they are considered "highway route controlled" quantities, and the transportation routes used must comply with rules outlined in HM-164.[3] For the shipments between Three Mile Island (Middletown,

*Research sponsored by the Office of Nuclear and Chemical Waste Management, U.S. Department of Energy, under Contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

PA) and the Idaho Falls Facility (Scoville, ID), two alternate routes were established, a northern route and a southern route. However, as the operation progressed, these routes were further modified for particular shipments due to weather and/or road conditions.

Six different routes were used by three different carriers in transporting the 45 shipments. A map of the routes is shown in Fig. 1, and the numbers in the circles identify the number of shipments that were made along specific highways. For example, 32 shipments traveled along I-70 between Indianapolis, IN and Denver, CO.

A statistical description of each route is contained in Table I. Routes 1 and 6 are nearly identical and follow the northern route. The only differences between these two occur in eastern Pennsylvania and in the area of Scoville, ID. These two routes are 2273 and 2371 miles long, respectively, and each passed through 12 Urbanized Areas. While similar to routes 1 and 6, routes 2 and 3 stayed on I-80 and I-15, passing through two additional Urbanized Areas. Distance along these routes varies from 2344 to 2402 miles.

The most frequently used route (32 shipments) was number 4, the southern path shown in Fig. 1. This route passed through Indianapolis, IN and Denver, CO and then followed the northern route (U.S. 30) in western Wyoming and southeastern Idaho. While this is the longest route (2493 miles), it passes through only ten Urbanized Areas. The fifth route is essentially a combination of the northern and southern routes. The southern portion was followed to Indianapolis, where the route switched to I-74, joining the northern route near Moline, IL. This route also followed I-80, I-84, and I-15 in Wyoming, Utah, and Idaho, passing through a total of 12 Urbanized Areas.

The three population zones, used in the RADTRAN-II[1] code for risk calculations, are defined as follows: rural, less than 170 people/mile^2; suburban, 170-4313 people/mile^2; and urban, greater than 4313 people/mile^2. The percentage of each route that lies within one of these zones is listed in Table I. Route number 4 has the highest proportion of urban travel (1.2% or 30 miles), and the major contributions to this value are the Urbanized Areas located in Missouri and Ohio. While the other routes pass through more Urbanized Areas, the percentage of urban travel is less than observed for route 4. The largest contribution to the urban population zone for routes 1 and 6 is the Chicago, IL-northwestern Indiana area. Routes 2 and 3 also pass through Salt Lake City and Ogden, UT, which almost doubles the urbanized travel when compared to routes 1 and 6.

Predicted Transportation Routes

A number of alternate routes between Middletown, PA and Scoville, ID were estimated using the Oak Ridge HIGHWAY Routing Model.[2] While DOE utilizes routing models in various research and development projects, these models are not used to specify routes for DOE's shipments. As stated above, route selection is the responsibility of the carrier subject to approval from the Traffic Manager.

The routing model does not automatically generate alternate routes. The model is designed to find a route that minimizes a mathematical function (i.e., an "optional route"). However, a number of constraints can be applied to the route selection process, thus producing alternate routes. Constraints which force the route to bypass a specific geographic area are normally used in this process. Alternate routes generated in this way must be checked, since certain combinations of constraints will lead to routes that do not meet HM-164 requirements.

In order to simulate the route between Middletown, PA and Scoville, ID, the preferred routing feature of the HIGHWAY model was used. This option places additional emphasis upon Interstate highways and state designated preferred routes. The term "basic" route will be used to identify the route generated with the preferred routing option without any other constraints and, therefore, may be considered a best estimate.

The basic route, shown in Fig. 2 and Table I, is 2254 miles long and follows I-80 from Pennsylvania to western Wyoming, U.S.-30 to the junction of I-15 in Idaho, and then I-15 and U.S.-26 to Scoville. Comparing this route with the actual routes used shows that route number 6 was essentially the same as the predicted basic route. Although route number 6 is 19 miles longer, it should be noted that the truck drivers used a detour in the Chicago area to avoid construction along I-80, which accounts for the additional distance. Hence, for all practical purposes, the predicted route and route number 6 are identical.

An alternate route (alternate 1) was calculated by bypassing I-80 in the Chicago area. As shown in Fig. 2, the alternate route deviated significantly from the actual routes between Middletown, PA and central Ohio. This alternate route goes south from Harrisbury, PA, through Maryland and West Virginia along U.S. 40 and U.S. 48, and then follows I-79 and I-70 to Columbus, OH. The non-Interstate roads in Maryland and West Virginia have been designated as preferred routes.[4,5] From central Ohio to Scoville, ID, the predicted route duplicates routes actually used to make the shipments. Alternate route 1 is 2348 miles long and is very similar to, but 32 miles shorter than, actual route number 5. The major difference in these routes is the path followed between the source and central Ohio. From a practical point of view, the difference between these two routes is small, but the computer will always select the route which has the lowest objective function value.

A second alternative was predicted by having the route bypass I-80 through Iowa and Nebraska. This route, which is 2417 miles long, follows the first alternate path to central Ohio and then continues along I-70 to Denver.

Applications of the HIGHWAY Routing Model

The DOE sponsors a number of economic and risk studies that deal with the movement of radioactive materials. In order to estimate costs, amount of equipment, and associated risks, transportation distances and transit times are needed. The HIGHWAY routing model has been utilized to produce these basic transportation data. The above analysis shows that the HIGHWAY model does make a good estimate of transportation routes actually used by shippers of radioactive materials. In

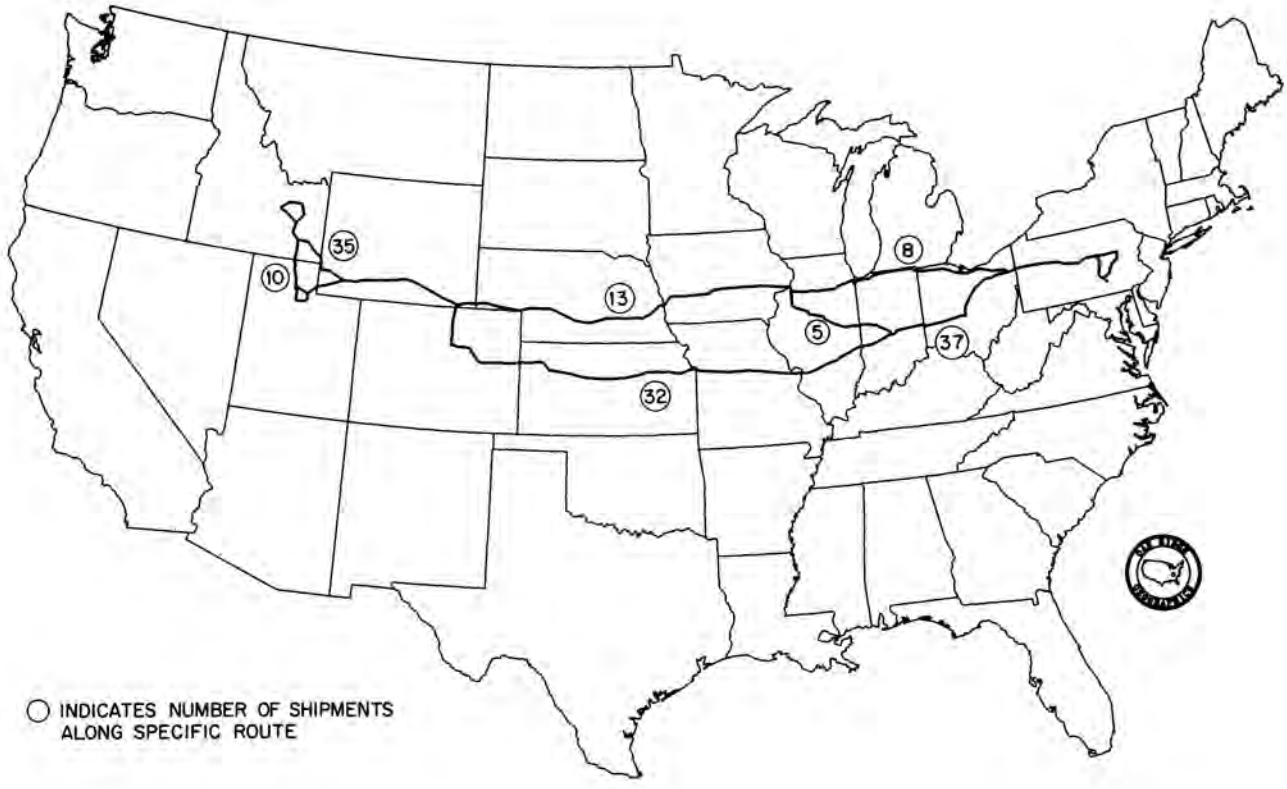

Fig. 1. Actual routes traveled between Middletown, PA and Scoville, ID.

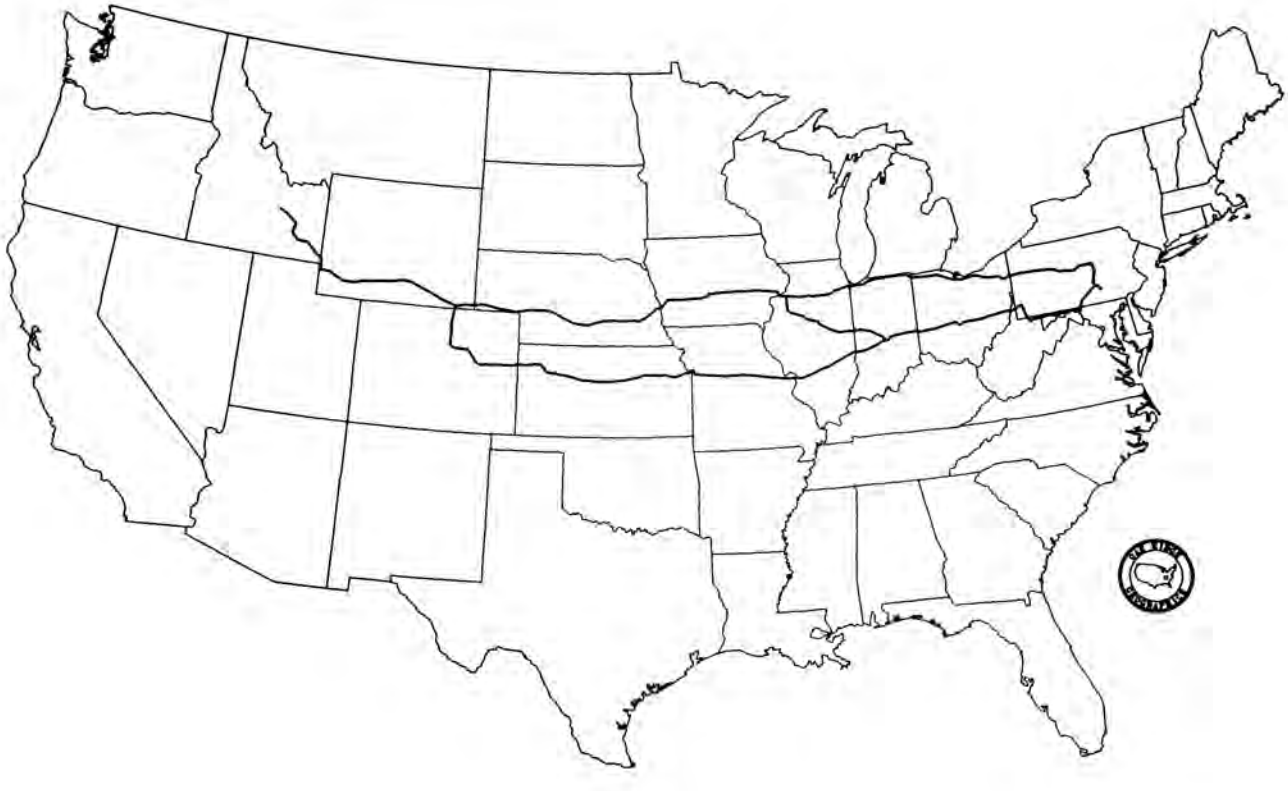

Fig. 2. Predicted routes for transporting radioactive materials between Middletown, PA and Scoville, ID.

TABLE 1

Actual and Predicted Routes Between Middletown, PA and Scoville, ID

Route	No. of shipments	Distance (miles)	Urbanized Areas[a]	Percent travel in population zones		
				Rural	Suburban	Urban
1	1	2371	12	79.8	19.7	0.5
2	1	2344	14	77.9	21.2	0.9
3	4	2402	14	78.1	21.0	0.9
4	32	2493	10	78.3	20.5	1.2
5	5	2480	13	78.8	20.4	0.8
6	2	2273	12	78.9	20.8	0.4
Predicted routes[b]						
Basic		2254	12	79.2	20.3	0.5
Alternate 1		2348	11	78.8	21.1	0.1
Alternate 2		2417	9	77.8	22.0	0.2

[a]Urbanized Areas, as defined by the Census Bureau, are those having a population exceeding 100,000 people.
[b]Predicted routes were identified by the ORNL HIGHWAY model.

actual practice, a number of factors (e.g., weather, road conditions, and driver preference) influence the actual route taken. The range between the longest and shortest routes discussed in this paper is only 11%. Hence, the HIGHWAY routing model does satisfy the requirements for which it was developed, that is, to predict likely routes for the shipment of radioactive materials.

REFERENCES

1. J. M. TAYLOR and S. L. DANIEL, "RADTRAN II: Revised Computer Code to Analyze Transportation of Radioactive Material," SAND80-1943, Sandia Labs (June 1983).

2. D. S. JOY and P. E. JOHNSON, "HIGHWAY, A Transportation Routing Model: Program Description and Revised Users' Manual," ORNL/TM-8759, Oak Ridge National Laboratory (October 1983).

3. FEDERAL REGISTER, 46 (12), 5298-5318, January 19, 1981, Docket HM-164, 46 FR 5298.

4. MARYLAND DEPARTMENT OF TRANSPORTATION, "Highway Routes for Shipment of Radioactive Materials," December 1981.

5. J. D. ROCKEFELLER IV, letter dated January 4, 1984.