TRUCK TRANSPORT OF RAM: RISK EFFECTS OF AVOIDING METROPOLITAN AREAS

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SUMMARY

In the transport of radioactive material (RAM), e.g., spent nuclear fuel (SNF), stakeholders are generally most concerned about risks in high-population-density areas along transportation routes because of the perceived high consequences of potential accidents. The most significant portions of a transcontinental route and an alternative examined previously (Mills and Neuhauser, 1998) were evaluated again using population density data derived from US Census Block data. This method of characterizing population that adjoins route segments offers improved resolution of population-density variations, especially in high-population-density areas along typical transport routes. Calculated incident-free doses and accident dose-risks for these routes, and the rural, suburban and urban segments are presented for comparison of their relative magnitudes. The results indicate that modification of this route to avoid major metropolitan areas through use of non-Interstate highways increases total risk yet does not eliminate a relatively small urban component of the accident dose-risk. This conclusion is not altered by improved resolution of route segments adjoining high-density populations.

INTRODUCTION

Previously, the effect on total risk, and its components, resulting from avoidance of urban areas in the transport of spent nuclear fuel (SNF) was described (Mills and Neuhauser, 1998). In the course of compiling the applicable route-related population densities through the use of the HIGHWAY routing code (ORNL, 1992), a few anomalies were observed in cases requiring geographic precision exceeding what was anticipated at the time HIGHWAY was developed. A particular limitation of the HIGHWAY code is that it cannot locate high-density populations specifically; it was originally designed to calculate distance-weighted average population densities, in three or more bins, for entire transport routes. Transportation of RAM has become a topic of intense scrutiny in recent years as a result of transport activity proposed by the US DOE and the

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actions of involved parties, "stakeholders", who are often concerned about risks in high-population-density areas along transportation routes. The supposed catastrophic consequences associated with potential accidents in these areas are presumed, by some parties, to be determinative for any RAM transport (NRIS, 1997). However, RADTRAN (Neuhauser and Kanipe, 1992) analyses performed over the years have shown that the risks associated with route segments in high-population-density areas (designated as "Urban" in RADTRAN) are a small fraction of the total risk associated with typical transportation routes.

The previous study (Mills and Neuhauser, 1998) of a route from the Crystal River, FL nuclear power plant to the Hanford Site in the State of Washington and alternatives revealed that leaving Interstate highways to avoid metropolitan highways increased total Incident-Free dose because of greater total distance; the Urban portion of that dose also increased because of slower speeds in Urban areas on non-Interstate highways. The Urban component of Accident dose-risk was reduced, but the effect on the total was minimal because the Urban portion is such a small part of the total.

This paper revisits the same route comparison, but population densities within 0.8 km (0.5 mi) of the highway centerline are tabulated by use of a geographic information system (GIS) and US Census Block data. This method affords high resolution of the distribution of population and permits identification of the individual lengths along a route having Urban, Suburban and Rural population densities.

ROUTE DESCRIPTION

Aggregated population-density data were obtained from the HIGHWAY routing code (ORNL, 1992) which also contains routing algorithms. This latter capability of HIGHWAY was used to define the initial route of the present study. The population densities along the route, within 0.8 km (0.5 mi) of the centerline were aggregated into three distance-weighted averages designated as Rural (1 to 66 persons/km^2), Suburban (67 to 1670 persons/km^2), or Urban (>1670 persons/km^2). The HIGHWAY code was also employed to compile population densities along the alternate portions of the route, which were developed to bypass major metropolitan areas such as Atlanta, Georgia, St. Louis, Missouri, Kansas City, Missouri, Kansas City, Kansas and Denver, Colorado. This alternate route departs from Interstate highways onto US highways between Valdosta, Georgia and York, Nebraska. For practical reasons related to manual collection of data with the developmental GIS method, the portions compared in this paper are limited to those between Valdosta and the Missouri-Kansas state line. While the latter endpoints are not identical, the offset is relatively small and large portions of Rural Interstate highways on both routes are ignored (maximizing the contrast of the comparison). The two portions of the route under comparison here are mapped by the bold lines in Figures 1 and 2.

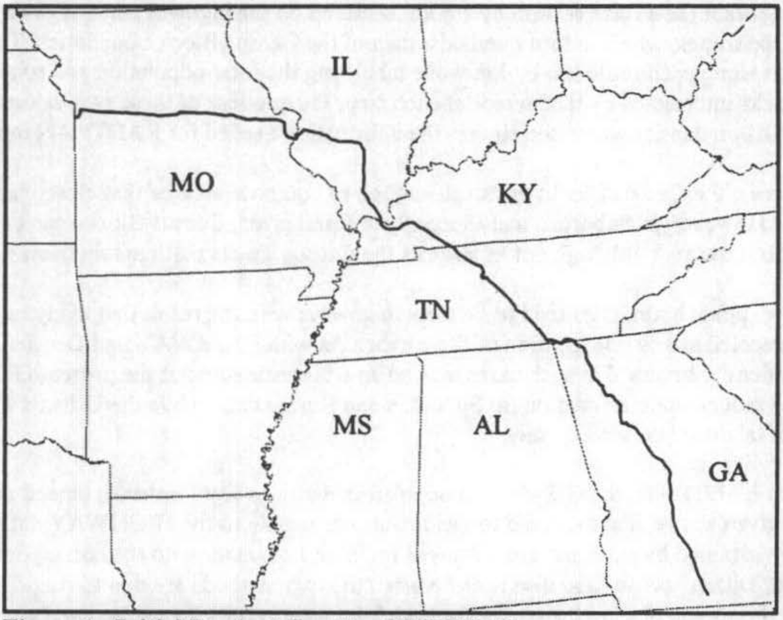

Figure 1. Initial Route defined by HIGHWAY

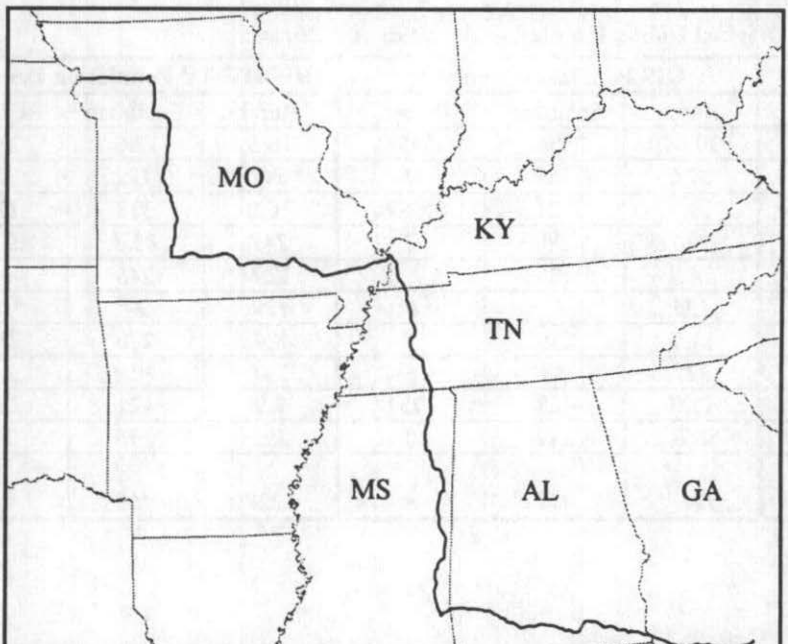

Figure 2. Alternate Route

Disaggregated population-density data were obtained from the GIS by graphically overlaying a rectangular cursor (scale size of 1km by 1.6 km centered on the highway) on a highway map displaying the routes, which in turn overlaid a map of the Census Block boundaries. This cursor was stepped along each route km-by-km while tabulating the total population and total area in the Census Blocks intersected by that cursor at each step; the quotient of these two values was taken as the population density within the cursor, the information needed for RADTRAN input.

In Urban areas, the Census Blocks are small enough to compose an area that closely approximates the cursor. However, in Suburban and especially in Rural areas, Census Blocks can be large compared to the cursor although not as large as the Census Tracts that contain them.

Furthermore, block boundaries tend to lie along highways with the result that many large blocks can be intersected at any one location of the cursor. As with HIGHWAY and Census Tracts, the population density obtained in such cases may be an underestimate, but the present GIS method is expected to reduce underestimation (in Suburban and Rural areas) while the Urban areas of public concern are tabulated very accurately.

For input to RADTRAN, the GIS-derived population densities were ordered, binned according to the ranges given above, and averaged to yield data comparable to the HIGHWAY data. The results were grouped by state and are displayed in Table 1 together with the corresponding route length data. Differences in total distances between the two methods are due to rounding and accumulated errors in placing the cursor for each kilometer in the GIS method and are not considered significant as a fraction (~ 1%) of the total distance.

Table 1a. Original Route, Population Densities and *Distances*

	GIS Population Densities			HIGHWAY Population Densities		
State	Rural	Suburban	Urban	Rural	Suburban	Urban
Georgia	20.64	356	1951	16.5	286	2329
km	*371*	*189*	*4*	*342*	*192*	*12.1*
Tennessee	19.3	521	1982	16.2	338	2202
km	*216*	*90*	*2*	*217*	*81.1*	*9.10*
Kentucky	14.5	185		12.4	245	
km	*135*	*15*	*0*	*129*	*24*	*0*
Illinois	11.7	259		8.4	270	2190
km	*227*	*56*	*0*	*244*	*40.4*	*2.30*
Missouri	12.0	468	1757	7.9	421	2257
km	*268*	*149*	*2*	*295*	*130*	*20.8*
Total Dist's.	*1217*	*499*	*8*	*1227*	*468*	*44.8*

Table 1b. Alternate Route, Population Densities and Distances

	GIS Population Densities			HIGHWAY Population Densities		
State	Rural	Suburban	Urban	Rural	Suburban	Urban
Georgia	13.9	258		12.2	280	
km	*147*	*32*	*0*	*146*	*40.1*	*0*
Alabama	14.1	224		9.70	294	1765
km	*314*	*61*	*0*	*337*	*53.7*	*0.6*
Mississippi	15.3	173		12.2	228	
km	*370*	*71*	*0*	*388*	*42.8*	*0*
Tennessee	23.5	259		13.5	322	2012
km	*144*	*48*	*0*	*136*	*50.3*	*1.5*
Kentucky	11.1	140		12.9	109	
km	*64*	*5*	*0*	*80.9*	*9.2*	*0*
Missouri	11.0	356		8.40	329	2111
km	*799*	*60*	*0*	*754*	*86.9*	*5.80*
Total Dist's.	*1838*	*277*	*0*	*1842*	*283*	*7.90*

RISK CALCULATIONS

The two different sets of distances and population densities describing each of the two routes were incorporated into RADTRAN input files for calculation of Incident-Free doses and Accident dose-risks. The results of the Incident-Free calculations are shown in Table 2a and the Accident results appear in Table 2b.

Table 2a. Incident-Free Doses (Person-rem)

	Initial Route (All Interstate Highways)				Alternate Route (All US Highways)			
Pop. Den. Source	Rural	Sub.	Urban	Total	Rural	Sub.	Urban	Total
HIGHWAY	201	81.3	8.53	291	320	92.7	13.1	426
GIS	200	87.6	1.54	289	320	90.1	0	410

Table 2b. Accident Dose-Risks (Person-rem X 100)

	Initial Route (All Interstate Highways)				Alternate Route (All US Highways)			
Pop. Den. Source	Rural	Sub.	Urban	Total	Rural	Sub.	Urban	Total
HIGHWAY	0.452	4.59	0.205	5.25	1.11	4.99	0.0541	6.15
GIS	0.556	6.05	0.0309	6.64	1.39	4.18	0	5.57

For more convenient comparison of risks for the two routes and the differences resulting from the two population-density determinations, the ratios of values for the Alternate route to the Initial route are presented in Table 3.

Table 3. Risk Ratios, Alternate Route to Initial Route

	Incident-Free Risk				Accident Risk			
Pop. Den. Source	**Rural**	**Sub.**	**Urban**	**Total**	**Rural**	**Sub.**	**Urban**	**Total**
HIGHWAY	1.59	1.14	1.54	1.46	2.46	1.09	0.26	1.17
GIS	1.60	1.03	0.0	1.42	2.50	0.69	0.0	0.84

In addition to dose values, RADTRAN also calculates potentially exposed populations under incident-free conditions for each link, i.e., the population density for that link is multiplied by the link length and the width of interest (1.6 km). Subtotals for the Rural, Suburban and Urban portions of each route are listed in Table 4, together with the route totals, for both routes and both sets of population data.

Table 4. Comparison of Potentially Exposed Populations (Incident-Free)

	GIS Population Densities		HIGHWAY Pop. Densities	
Population Category	Initial Route	Alternative Route	Initial Route	Alternative Route
Rural	31,400	40,100	24,200	30,400
Suburban	323,000	110,000	246,000	132,00
Urban	24,200	0	160,000	26,100
Total	378,600	150,000	430,200	188,500

Discussion and Conclusions

As noted earlier, the less than 1% differences in total distance between the two methods of determining population density are not considered significant. However, the differences in fractions of the total distance apportioned to Rural, Suburban and Urban are significant in that the Urban distances determined by the GIS method are substantially less than the HIGHWAY-derived distances. Population densities were variably increased or decreased by the GIS method relative to HIGHWAY values, with a general increase for the Original route and a less discernible trend for the Alternate route. Both techniques are expected to yield low estimates of population density outside Urban areas since the population density is assumed to be uniform (or approximately so) over areas which can be large compared to 1.6 km^2 and population naturally concentrates near roads. This concentration tends to be more prevalent with respect to non-Interstate highways than for Interstate highways as may be expected from the undesirable aspects of living next to high-traffic roadways.

Both methods for determining population density lead to an increase for the Alternate route relative to the Initial route in Rural and Suburban Incident-Free doses (Table 2a). For Urban doses HIGHWAY yielded an increase while the GIS method yielded a decrease to zero. Because the Urban dose is a very small fraction of the total dose, the total dose is nevertheless larger for the Alternate route with either set of population data.

The Urban Accident dose-risk is reduced substantially or eliminated (Table 2b) but the effect on Total Accident dose-risk is mixed for the two methods. The GIS-derived population densities suggest that a small benefit in Total Accident dose-risk is possible through use of the Alternate route. However, it must be remembered that the Total Incident-Free dose for this route increases substantially, with either set of population data. The Incident-Free doses are also much greater than the Accident dose-risks.

Inspection of the potentially exposed populations presented in Table 4 indicates that the Alternative route exposes fewer people to Incident-Free doses according to either set of population data. However, the number of people potentially exposed along Rural portions of the Alternative route increases for both sets of population data.

We conclude, as in the earlier study, that modification of routes to avoid major metropolitan areas through use of non-Interstate highways will typically lead to increased total risk of RAM transport (especially the dominating incident-free dose) while reducing a relatively small Urban component of the accident dose-risk. This conclusion is expected to be generally true in view of the fact that the route analyzed here covers many states and a range of population densities which is representative of typical SNF transportation routes. The use of population data having finer geographic resolution does not alter this conclusion although differences within Urban areas can be identified more specifically using the GIS-based method of tabulating route population densities.

References

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References

SESSION 11.2

Criticality and Shielding