A PRELIMINARY COST AND RISK ANALYSIS FOR TRANSPORTING SPENT FUEL AND HIGH-LEVEL WASTE TO CANDIDATE REPOSITORY SITES

K. S. Neuhauser, J. W. Cashwell
P. C. Reardon, G. W. McNair

ABSTRACT

The costs and risks of transporting spent fuel and other nuclear wastes to nine potential candidate repository sites were analyzed. The results are compared with previous analysis in which assumptions about fuel age and the packaging capacity and transport index (TI) were different. The effects of these changes on the costs and the nonradiological and radiological impacts of nuclear-waste transport are discussed.

The Transportation Technology Center (TTC) at Sandia National Laboratories (SNL) analyzed the costs and risks of transporting spent nuclear fuel to each of nine potential candidate repository sites[1]. This analysis was undertaken in support of the Environmental Assessments (EAs) prepared by the U.S. Department of Energy (DOE) under the mandate of the Nuclear Waste Policy Act (NWPA).

In the present analysis (Cost/Risk 84 or CR84), carried out in support of the repository draft EAs, spent fuel is assumed to be sent directly to the repository without either reprocessing, intermediate handling, or consolidation at a monitored retrievable storage facility (MRS); currently certificated packaging designs were used rather than high-capacity design concept (HCDC) casks; and all spent fuel was assumed to be 5 years out of the reactor. In a previous study completed in 1983[2] (CR83), the impacts of transporting 10-year-old fuel in HCDC casks were analyzed for both the once-through and reprocessing fuel cycles. Present-generation casks are designed to transport spent fuel less than 1 year from reactor discharge and, thus, have more shielding than needed for the transport of older spent fuel. This large amount of shielding reduces the payload capacities of the casks. Probable future packagings designed specifically to transport aged fuel will not require as much shielding and, therefore, will have larger capacities.

The total amount of spent fuel to be shipped was assumed to be 70,000 tHM (tonnes of heavy metal). The transport of 300 canisters of high-level wastes from West Valley (WVHLW) and 6720 canisters of defense high-level wastes (DHLW) from Savannah River, which may be sent to the repository, also was evaluated in this study, and the cost and risk estimates given below are totals for all three waste forms.

As in the previous study, two scenarios, in which 100% of all shipments are by truck and 100% of all shipments are by rail, respectively, were analyzed as bounding conditions. The transport scenarios maximize the number of trips for each mode. Since estimates of radiological and nonradiological impacts are proportional to the number of miles traveled and, hence, to the number of shipments, analyses of transport exclusively by truck and exclusively by rail yield estimates that are expected to bound the range of impacts that might actually occur under the assumptions used.

Transportation requirements and shipment numbers were calculated by use of WASTES[3] and the Spent Fuel Logistics Model[4] (SFLM), computer codes developed by Battelle Pacific Northwest Laboratory (PNL) and Oak Ridge National Laboratory (ORNL), respectively, under the sponsorship of SNL/TTC. These codes are used to simulate the movement of spent fuel and nuclear wastes from point of generation to final destination. Input parameters include loading and unloading rates, capacities of the facilities, characteristics of the spent fuel and nuclear wastes, quantities of material requiring shipment, characteristics of the packagings, and operational and equipment costs.

The quantity of spent fuel requiring shipment was derived from the 1984 Spent Fuel Data Base[5], which was compiled for the DOE by PNL from utility responses to a voluntary survey.

Assumed storage capacities at the reactors were the same as in the previous analysis. All spent fuel was assumed to be shipped as unconsolidated assemblies, and all casks were assumed to be fully loaded for each shipment. Because of the large relative differences in the capacities of truck and rail casks, the shipping schedule differs depending on the transport mode. The capacities of the packagings are summarized in Table I, and the total numbers of shipments for each mode of transport are shown in Table II.

TABLE I

Capacities of Packagings

	Truck		Rail	
Waste Form	CR84	CR83	CR84	CR83
PWR Assembly	1	2	7	12
BWR Assembly	2	5	18	32
DHLW Canister	1	1	5	5
WVHLW Canister	1	1	7	7

TABLE II

Number of Shipments Required

	Truck		Rail	
Waste Form	CR84	CR83	CR84	CR83
Spent Fuel	173,229	82,469	22,465	13,415
DHLW	6,720	6,720	1,344	1,344
WVHLW	300	300	43	43

As in the CR83 study, the origin points are (1) the centroids of the reactors in 21 North American Electric Reliability Council subregions and (2) the locations of the West Valley and Savannah River facilities. Six destination points represented the potential candidate repository sites. A single destination was used to estimate shipment distances for each of three pairs of closely grouped sites: (1) Cypress Creek Dome and Richton Dome in Mississippi (also referred to as Gulf Interior Region or GIR sites), (2) Deaf Smith County and Swisher County sites in Texas, and (3) Davis Canyon and Lavender Canyon sites in Utah; the other three destinations were: (4) Vacherie Dome in Louisiana (a third GIR site), (5) the Yucca Mountain site in Nevada, and (6) the Hanford site in Washington State.

Estimated highway and rail distances from the centroids to each of the destination points were developed by the highway and rail routing models HIGHWAY[6] and INTERLINE[7], respectively, which were developed by ORNL. As in the previous analysis, truck and rail routes normally used for general commerce were estimated. For each route, the fractions of travel in urban, suburban, and rural population densities were calculated. Total shipment-kilometers are derived from the numbers of shipments multiplied by the centroid-to-destination distances.

Cost Analysis

For each waste type, the total relative cost of transport (excluding site-specific costs such as construction costs for access roads) is defined to be the sum of capital costs, maintenance costs, and shipping costs. Capital costs include the costs of packagings, trailers, and railcars, but not the cost of maintenance facilities.

In order to derive a total packaging requirement for each waste type the following assumptions were made. Truck shipments travel at an average speed of 56 km/h (35 mph) including stop times. Average rail speeds vary from 5 km/h ($\approx$3 mph) for short hauls to 19 km/h ($\approx$12 mph) for cross-country shipments, including stop times. A total loading-unloading time of 5 days per roundtrip was assumed for rail packages, and 3 days for truck packages. Packages were to be available 300 days per year and to have a lifetime of 15 years. The WASTES model was then used to derive the number of packagings required per year from the spent fuel flow. The total number of packagings identified by the model was further processed to reflect an estimated 300 tHM of repository lag storage and the assumed 15-year lifetime of the casks.

The resulting estimates of packaging requirements were used directly to estimate capital costs, and they were multiplied by maintenance-and-licensing constants to obtain maintenance costs. Shipping costs were derived from published tariffs, where available, applied to loaded and empty packaging weights for the shipment distances previously developed. Total transportation costs by major cost category are given in Table III.

TABLE III

Total Transportation Costs ($Millions)

Mode/Category	GIR	Vach	Perm	Para	Yucca	Hanf
				Repository		
Truck						
Capital	306	312	357	399	452	470
Maintenance	247	254	291	326	370	384
Shipping	1079	1142	1476	1829	2239	2412
TOTAL	1632	1708	2124	2554	3061	3266
Rail						
Capital	856	866	900	1016	1116	1170
Maintenance	247	252	264	297	326	343
Shipping	799	839	1007	1134	1282	1355
TOTAL	1902	1957	2071	2447	2724	2868

Risk Analysis

The two major categories of risk evaluated in this study are (1) risk associated with normal transport (i.e., incident-free transport) and (2) risk associated with accidents. Within each category are radiological and nonradiological components of risk. The computer code RADTRAN II[8] developed by SNL/TTC was used to perform the radiological risk analysis. RADTRAN II permits subcategorization according to population-density zones; in addition, occupational and nonoccupational exposures are calculated separately.

For each transport mode and waste form, RADTRAN II was used to calculate unit risk factors (URFs) for both normal transport and accidents in urban, suburban, and rural population-density zones. The URFs, combined with the number of shipments by the specified mode, the distance travelled per shipment, and the fraction of travel in each population-density zone, give total radiological risk estimates for a particular waste form. The ICRP-26[9] equivalent whole-body dose conversion factor used in this analysis is 2×10^{-4} LCFs per person-rem exposure. Total risk estimates for truck and rail are shown in Table IV.

TABLE IV

Total Transportation Risks (fatalities)

	Repository									
	GIR		Perm		Para		Yucca		Hanf	
Mode/Category	CR84	CR83	CR84	CR83	CR84	CR83	CR84	CR83	CR84	CR83
Truck										
Rad.(LCFs)	1.3	6	2.1	8	2.7	10	3.1	12	3.6	13
Nonrad.	29	15	43	22	59	29	72	36	78	38
Rail										
Rad.(LCFs)	8	13	10	16	13	20	17	25	18	26
Nonrad.	1.7	1.1	2.3	1.4	2.9	1.8	3.6	2.2	3.8	2.3

This comparison of the results reveals a relationship between the number of miles travelled, the capacity of the packaging, and the amount of shielding (The amount of shielding is expressed as a function of the transport index or TI, which is defined as the dose rate in mrem/hr at 1 m from the surface of the package.). In CR83 the effective TI of HCDC casks loaded with 10-year-old fuel was 20 (the regulatory maximum for exclusive-use shipments); the effective TIs of present-generation casks loaded with 5-year-old fuel, which are used in CR84, were calculated by Oak Ridge National Laboratory and found to be 1.47 for a truck cask and 5.4 for a rail cask.

The capacities of present-generation casks are almost half those of HCDC casks. The total number of shipments required to transport a given amount of spent fuel or other waste to a repository depends on the capacities of the packagings used. The smaller the capacity of the packaging, the greater the number of shipments and, consequently, the greater the number of miles travelled.

Nonradiological risk is proportional only to the number of miles travelled. Therefore, the nonradiological component of risk is greater in the present analysis than it was in the 1983 study (Fig. 1). Radiological risk, however, depends on both the number of miles travelled and the dose rate (expressed as TI) of the package. Although the total mileage increased, the TI was considerably lower than that used in the CR83 study, and, as a result, the radiological risk estimates actually decreased in the present analysis (Fig. 1). The increase in nonradiological risk and decrease in radiological risk offset each other sufficiently that the total estimated risks differ from each other by less than a factor of two.

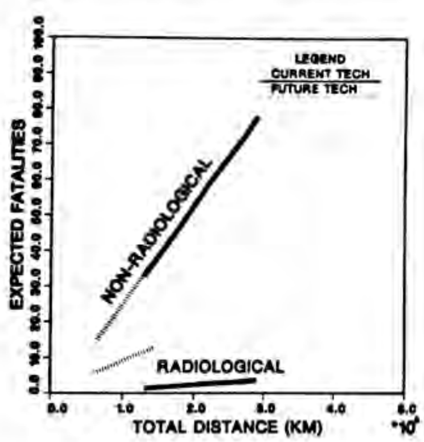

Fig. 1. Transportation risk vs total truck kilometers.

The total risk for truck transport is consistently greater under the present assumptions than in the previous analysis; but the total risk for rail transport is consistently lower under the present assumptions. This is a result of the fact that the radiological risk component makes up a larger fraction (between 0.81 and 0.93) of the total risk for rail transport than it does for truck transport (between 0.04 and 0.29), because the nonradiological impacts (i.e. ordinary accident fatalities) associated with rail transport are lower than those associated with truck transport. Thus, the radiological component of risk makes a proportionately greater contribution to the total risk of rail transport than it does to the total risk of truck transport of spent fuel and high-level wastes.

SUMMARY

This comparison of the two analyses for the "once-through" scenario reveals the impact on transportation-related costs and risks of changes in cask capacity and transport index (TI), where TI is a function of both fuel age and packaging shielding. Recent changes in the base-case scenario options, including (1) insertion of a potential repackaging or MRS facility and (2) consideration of alternative modal options and operational considerations (e.g. barge transport and multiple-car rail shipments), could affect these cost and risk estimates. Analyses of these options will be documented to support the environmental and siting requirements of the NWPA.

REFERENCES

1. Neuhauser, K. S., J. W. Cashwell, P. C. Reardon, and G. W. McNair, A Preliminary Cost and Risk Analysis for Transporting Spent Fuel and High-Level Wastes to Candidate Repository Sites. SAND84-1795. (Sandia National Laboratories, Albuquerque, NM, October, 1984)

2. Wilmot, E. L., M. M. Madsen, J. W. Cashwell, D. S. Joy. A Preliminary Analysis of the Cost and Risk of Transporting Nuclear Waste To Potential Candidate Repository Sites. SAND83-0867. (Sandia National Laboratories, Albuquerque, NM, June, 1983)

3. McNair, G. W., M. R. Shay, J. Fletcher, J. W. Cashwell. "WASTES: A Waste Management Logistics/Economics Model." Paper presented at Waste Management '85, Tucson, Arizona, March, 1985.

4. Joy, D. S., B. D. Holcomb, Logistics Models for the Transportation of Radioactive Waste and Spent Fuel, Oak Ridge National Laboratory, Union Carbide, Oak Ridge, Tennessee, March, 1978.

5. Spent Fuel Storage Requirements, An Update of DOE/RL-83-1, DOE/RL-84-1, May 1984.

6. Joy, D. S., P. E. Johnson, and S. M. Gibson, HIGHWAY, A Transportation Routing Model: Program Description and User's Manual, ORNL/TM-8419, December 1982.

7. Joy, D. S., P. E. Johnson, D. B. Clarke, and S. C. McGuire, "Predicting Transportation Routes for Radioactive Wastes," Waste Management '81, Vol. 1, p. 415.

8. Taylor, J. M. and S. L. Daniel, RADTRAN II: A Revised Computer Code to Analyze Transportation of Radioactive Material, SAND80-1943 (Albuquerque, NM: Sandia National Laboratories, February 1982.)

9. ICRP Publication 26, "Recommendations of the International Commission on Radiation Protection," Annals of the ICRP, Volume 1(3), 1977 (Oxford, England).