A Needs Assessment for DOE's Packaging and Transportation Activities: A Look Into the Twenty-First Century

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INTRODUCTION

The U.S. Department of Energy (DOE) has performed a department-wide scoping of its packaging and transportation needs and has arrived at a projection of these needs for well into the twenty-first century. The assessment, known as the Transportation Needs Assessment (TNA), was initiated during August 1994 and completed in December 1994. The TNA will allow DOE to better prepare for changes in its transportation requirements in the future. The TNA focused on projected, quantified shipping needs based on forecasts of inventories of materials which will ultimately require transport by the DOE for storage, treatment, and/or disposal. In addition, experts provided input on the growing needs throughout DOE resulting from changes in regulations, in DOE's mission, and in the sociopolitical structure of the United States. Through the assessment, DOE's transportation needs have been identified for a time period extending from the present through the first three decades of the twenty-first century.

The needs assessment was accomplished in three phases: (1) defining current packaging, shipping, resource utilization, and methods of managing packaging and transportation activities; (2) establishing the inventory of materials which DOE will need to transport on into the next century and scenarios which project when, from where, and to where these materials will need to be transported; and (3) developing requirements and projected changes for DOE to accomplish the necessary transport safely and economically.

In the TNA, the inventory of materials was defined as materials currently in storage or as materials expected to be produced which will require packaging and transport for processing, storage, or disposal at some date between 1994 and 2030. Once the inventory for each material was established, the scenario was defined for material processing, storage, and/or disposal which requires packaging and transportation of the material. Packaging and vehicle capacities, mode (or modes) of transport, and approximate one-way shipment distances were described as part of the scenario definition. From all of this, the numbers of packagings, numbers of shipments, and travel distances were estimated. The assessment also benefited from the input of 50 experts who participated in a workshop October 25–27, 1994.

This paper outlines some of the findings from the TNA. Included are discussions of the assessment's background, scope, assumptions, and data sources. The projections of quantities of

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commodities to be shipped by DOE over the next few decades are briefly outlined. A brief summary of some of the projected transportation requirements is then provided. Finally, an estimate of costs associated with satisfying these requirements is discussed.

BACKGROUND

DOE has historically shipped various forms of materials into, out of, and between its sites. These shipments began in the 1940s and are projected to continue well into the twenty-first century. To monitor and track the shipments it makes, DOE maintains the Shipment Mobility/Accountability Collection (SMAC) database (DOE 1995a). Data from SMAC for 1993 were used as a basis for comparing current radioactive material packaging and shipping activities with projections for the future.

Overall, DOE's shipments (radioactive and other) in 1993 involved:

• General commodities	590,516 shipments (95% of total)
• Nonradioactive hazardous materials	14,735 shipments (2% of total)
• Radioactive materials	18,434 shipments (3% of total)

Thus, the transport of radioactive materials currently represents a small fraction of the total transportation activity undertaken by DOE. Although these shipments accounted for a gross mass of approximately 495,000 t, coal shipments accounted for over half (270,000 ton) of total tonnage shipped. These figures represent the gross mass of the commodities shipped, including packaging.

By focusing on projected, quantified shipping needs based on forecasts of inventories of materials, the TNA was different from previous efforts which did not have the benefit of the data on inventories. Furthermore, previous studies had focused on short periods of time, whereas the TNA considered longer time periods (well into the twenty-first century). Finally, experts provided input on the growing needs throughout DOE resulting from changes in regulations, in DOE's mission, and in the sociopolitical structure of the United States.

SCOPE OF THE ASSESSMENT

The TNA generally addressed all significant domestic DOE transportation requirements for hazardous (both radioactive and nonradioactive) and nonhazardous materials and for selected international shipments of radioisotopes and spent fuel. Although many aspects of DOE's transportation activities were evaluated in the TNA, the emphasis in this paper is on the TNA findings pertaining to the packaging and transportation of radioactive materials. The scope of the TNA study included addressing (a) all significant domestic DOE transportation requirements for hazardous (both radioactive and nonradioactive) and nonhazardous materials, including selected international shipments of radioisotopes and spent fuel; (b) materials shipped by most of the DOE programs, excluding materials shipped under DOE's safeguards programs and some material shipments related to national defense; and (c) the shipment of commercial spent nuclear fuel within the United States, because the Civilian Radioactive Waste Management Program within the DOE has responsibility for these shipments beginning in 1998.

One of the major areas of change for DOE's packaging and transportation activities will occur as a result of site cleanup and remediation and of processing and disposing of radioactive and other hazardous materials resulting from these activities. Sources of these materials are DOE sites and commercial organizations for which DOE now has some responsibility for accommodating wastes. Waste disposition scenarios were selected using DOE program sources including programmatic environmental impact statements and site experts.

DATA SOURCES AND PROJECTED QUANTITIES TO BE SHIPPED

DOE's current packaging and transportation activities were established using the SMAC database (DOE 1995a). The results of a survey of human resources conducted in November 1994 by DOE were used to define the level of labor resources currently required by the department to accomplish its mission.

The future packaging and transportation activities were defined using the Baseline Inventory Report (BIR). The BIR was under development concurrently with the performance of the needs assessment. Because the BIR was not complete, supplementary data sources were used to make the assessment as complete as possible. This included independently defining potential shipments of plutonium, analytical samples, and depleted uranium. Because the BIR and other sources of data provided only inventory and generation rate data, site treatment processes and disposition paths were developed or assumed based on information derived from other sources.

For miscellaneous radioactive commodities such as instruments, medical isotopes, and limited quantity radioactive materials, the 1993 annual shipping quantities from SMAC were assumed to remain constant over the assessment time horizon. For several special cases, projections and scenarios were developed based on data provided by experts in each field. These special cases included analytical laboratory samples, cesium capsules, highly enriched uranium, low enriched and natural uranium, plutonium, and depleted uranium hexafluoride (UF_6). The projections were developed in terms of the units generally used to define quantities of each commodity [e.g., cubic meters of contaminated soil, low-level waste (LLW), mixed waste (MW), or transuranic (TRU) waste; metric tons of initial heavy metal (MTIHM) of spent nuclear fuel (SNF); number of items such as high-level waste (HLW) canisters, or special form capsules of radionuclides; or metric tons of hazardous materials or general commodities].

The resulting projections included estimates of the time period in which these materials will be shipped and whether the shipments will be inbound, outbound, intersite, or intrasite. The projections were limited not only by the availability and quality of the inventory data, but also by the information used to project scenarios to define when, from where, and to where these materials are projected to be transported. As a result, the data developed and conclusions drawn from this study should be viewed as preliminary; they need to be reassessed and verified using final inventory data and most current plans for remediation. A separate activity which has, *post facto*, been completed by DOE offers the possibility of assessing the accuracy of the data used in the TNA. This activity, *The 1995 Baseline Environmental Management Report* (BEMR) (DOE 1995b), provided official data in March 1995 (3 months after the TNA was completed).

When the TNA was performed, it was estimated that some 1,400 facilities would be transferred to DOE's Office of Environmental Management (EM) for decommissioning, decontamination, or other remediation actions. However, this number has since grown significantly. For example, the BEMR indicates about 3,500 facilities will be transferred to EM for such actions. Thus, there have been and continue to be large uncertainties in the estimates of quantities of material which will ultimately require transport by DOE. Both the BIR and BEMR data make it clear that the remediation activities will lead to significant increases in the numbers and types of radioactive and other hazardous material shipments. The data show that sources of future growth in shipping requirements range from highly radioactive materials requiring shipment in highly shielded, robust casks, to bulk shipments of soil and debris containing relatively low levels of radioactive or other hazardous materials. Although relatively small quantities of radioactive materials are currently being shipped by DOE, substantial quantities of radioactive wastes and other radioactive materials will ultimately require transport, including:

- over 96,000,000 m^3 of contaminated Uranium Mill Tailings Remedial Action (UMTRA) and non-UMTRA soils and 3,500,000 m^3 of debris, some of which will require transport for disposal;
- over 2,800,000 m^3 of buried LLW and 115,000 m^3 of stored LLW at DOE sites, much of which will ultimately require transport for disposal;
- over 174,000 m^3 of MW that will require treatment and disposal;
- over 105,000 m^3 of retrievable TRU waste and an additional 204,000 m^3 of buried TRU waste that must be packaged and transported to the Waste Isolation Pilot Plant (WIPP);
- canisters of vitrified HLW resulting from the processing of almost 400,000 m^3 HLW in tanks at DOE sites;
- at least 63,000 MTIHM of SNF from commercial power reactors and an additional 270 MTIHM of DOE, foreign research, naval, non-DOE, and university reactor SNF; and
- other radioactive materials requiring transportation including several hundred thousand analytical samples, 50 ton of plutonium requiring disposition, 60 ton of highly enriched uranium (HEU), and more than 400,000 metric tons of uranium (MTU) in the form of depleted UF_6 in cylinders.

PROJECTED TRANSPORTATION REQUIREMENTS

With a few exceptions, it was projected that DOE will generally meet new transportation requirements by packaging the materials and shipping them on fully loaded road or rail vehicles (i.e., fully loaded LWTs or fully loaded rail cars). The exceptions are radioactive isotopes and nonradioactive, low radioactivity, or medium radioactivity laboratory samples. These materials generally will be shipped in individual packages either by motor freight (i.e., by road) in less-than-truckload quantities or by air (with road shipments generally occurring both before and following the air shipment).

Estimated Major Increases in Shipping Requirements. The study provided considerable detail on the packaging and shipping requirements by commodity. Examples of these results are summarized herein. These projections are principally for the number of full truck loads and full rail car loads of radioactive materials. In most cases, shipments of individual packages by less-than-truckload motor freight or by air carriers, although currently a significant proportion of DOE's shipments are expected to remain relatively constant over coming years. Therefore, these shipments are not perceived to represent a significant potential for growth in DOE shipping requirements.

The only current DOE operation involving large shipments of full truck and rail car loads of radioactive material entails the shipment of very low radioactive materials resulting from the UMTRA activities. Although these activities currently result in a large number of shipments (~200,000 shipments in 1993), they were mostly intrasite, with a limited number of combined inbound, intersite, and outbound shipments, and they were typically only for a distance of a few miles. It is projected that the UMTRA activities will decline significantly to ~120,000 shipments per year in 2000, to as few as 45,000 shipments per year in 2020, and then to less than 10,000 shipments per year in 2030.

In contrast, major increases in full-truck and rail-car-load shipments of other radioactive materials are projected. Many of these will involve enhanced shipping requirements with transport over long distances as compared with those currently needed for the UMTRA shipments. These increases are summarized in Table 1.

Table 1. Example Summary of Estimated Full-Truck-Load and Full-Rail-Car-Load Shipments of Various Radioactive Wastes and Materials

General radioactive material commodity category	Combined full-truck-load and full-rail-car-load shipments (Shipments per year)				
	1993	2000	2010	2020	2030
Low-level radioactive (other than UMTRA)	>5,000	>45,000	>70,000	>40,000	>5,000
Medium and high-level radioactive	21	>1,500	>1,500	>1,700	>800
Total	>5,021	>46,500	>71,500	>41,700	>5,800
Percentage of current activity	100	926	1,424	831	116

For low-level radioactivity materials, most projected road shipments will result from shipment of contaminated soils and debris other than UMTRA materials. These shipments are projected to generally be over short distances, intrasite or intersite. The quantities of contaminated soils and debris used in this projection are based on an assumption that only about 14% of these materials will require shipment. If the amounts of materials requiring transport were to increase, there would be a commensurate increase in the number of shipments required. Transport of depleted UF_6 outbound from DOE facilities, of low enriched uranium (LEU) and LLW shipped intersite, and of depleted uranium oxide (U_3O_8) inbound to DOE sites accounts for most of the projected rail shipments. The current and projected combined full-truck-load and full-rail-car-load shipments of low-level radioactive commodities, excluding UMTRA shipments, are projected to peak at over 70,000 per year in the early twenty-first century. This is a 14-fold increase over the current level of activity for these materials, and more than 12 times the projected number of truck and rail-car-load shipments of general commodities currently shipped by DOE.

The combined number of road vehicle and rail car loads of medium and high radioactive commodities is projected to grow from 21 in 1993 to over 1,500 per year at the beginning of the next century. In the near term (1995—2000), high radioactivity (i.e., with radiation levels greater than 200 mR/h on contact) laboratory samples, and SNF from naval, DOE, and university reactors are the primary sources of growth. The projected road transport of TRU waste to WIPP in 2000 will require 1,000 truck shipments per year until 2020. From 2010 on, rail transport of HLW canisters and commercial reactor SNF to the monitored retrievable storage system will be an increasing source of transportation demand, especially when compared to the single rail car shipment of HLW waste in 1993. Projected sources of other, smaller shipments are cesium capsules and highly enriched uranium. This projected annual volume of highly radioactive material shipments represents a major change for DOE; it is more than a 70-fold increase in such activities over that currently supported by DOE.

Thus, excluding UMTRA, the number of DOE shipments of radioactive material in full truck or rail car loads is projected to increase from about 5,000 shipments in 1993 to more than 71,000 shipments in 2010.

Estimated Total Shipping Distances. The shipping distances for full truck and rail-car-load shipments (excluding UMTRA-related shipments) of radioactive material is projected to increase from 7 million miles (11.3 million km) per year in 1993 to as high as 34 million miles (54.7 million km) per year in 2010 and then to decrease to about 6 million miles (9.7 million km) per year in 2030.

Projected Packaging and Vehicle Needs. Other needs were projected in the packaging and carrier area. These include (a) more than 1.7 million 210-L steel drums per year for packaging low-level, mixed, and TRU waste for shipping during the early twenty-first century, and (b) more than 150 reusable shipping casks for spent nuclear fuel, canisters of high-level waste, and TRU shipments. Added transportation requirements for various radioactive materials and wastes will require the full-time, steady-state availability of the equivalent of at least 750 rail cars and truck trailers.

Estimated Human Resource Needs. The current DOE transportation system is supported by a large staff of managerial, administrative, and hourly workers. A recent DOE survey determined that 800 managerial and administrative workers currently perform transportation functions at DOE headquarters and its field sites, supporting both radioactive and other material packaging and transportation functions. Furthermore, it was estimated that, for each managerial and administrative worker, three hourly workers perform various shipping, receiving, and local transport functions. This raises the total estimate to 3,200 full-time equivalent (FTE) workers involved in DOE packaging and transportation functions. Future requirements for workers will depend upon factors such as changes in productivity, composition of future shipping needs, and changes in regulations affecting the effort required to prepare and make a shipment. The human resource requirements, assuming no modifications are made in the manner in which functions are performed, were projected to increase from 3,200 FTEs staff per year in 1993 to 6,600 FTEs per year in 2010, and to decrease to 2,900 FTEs per year by 2030.

PROJECTED TRANSPORTATION COSTS

The data which have been summarized in this paper were combined with packaging and infrastructure data to provide a "top-level," rough order-of-magnitude projection of costs for accomplishing DOE's shipping mission. All cost figures were provided in FY 1995 constant U.S. dollars.

Estimated "Base Case" System Costs. From 1993 through 2030, it was estimated that under the current method of performing packaging and transportation activities, DOE will spend on the order of $30 billion to meet its projected shipping needs if it continues to operate in its current fashion. These costs include all identified human resource, packaging, carrier, and vehicle and site maintenance infrastructure costs. Costs estimates shown are those associated with the actual packaging of materials for shipment and the performance of the shipment activities. These costs are borne by the individual DOE sites and programs.

Estimated "Improved" Transportation System Costs. The rough order-of-magnitude cost analysis was used to identify potential areas for cost reductions and to approximately quantify such cost reductions. The cost analysis for this "improved" system often used the best judgment of experienced personnel to establish potential cost savings that would arise in each area associated with an integrated systems approach. An integrated systems approach to transportation resource management was assumed for estimating these cost savings, where primary emphasis was on developing tools and methodologies and implementing them within the DOE complex in a manner such that (a) personnel could become more efficient in performing their tasks (improved productivity), (b) greater efficiencies would result from aggregating shipments and improved utilization of carriers and improved carrier-service procurements, (c) packaging costs would be reduced through consolidating procurements and standardizing package designs throughout the DOE complex, (d) lower tariff rates would result from negotiations and by taking advantage of multiple site shipments, and (e) more efficient use would be made of equipment, facility, and hardware-related resources.

If these steps were taken, an improved system could result which would have the potential for significant cost savings. Such steps should not only reduce costs, but also might enhance effectiveness and safety. However, it must be stressed that an integrated approach to transportation and the assumed development of the tools and methodologies and their implementation in the field, or a similar approach to enhanced efficiency, must be sought early and realized if these cost savings are to be achieved.

Potential Cost Savings. Based upon the rough order-of-magnitude cost estimates performed, DOE's packaging and transportation costs might be reduced by about $7 billion through 2030 by effective application of an integrated systems approach to transportation resource management. The analyses summarized in Table 2 illustrated that human resource costs may be expected to drive overall DOE transportation costs over the next few decades. Human resource costs account for just under $20 billion (65%) of the estimated $30 billion in total transportation costs for the base case. Furthermore, $5 billion of the $7 billion savings in the "improved" system case are projected to result from more efficient utilization of human resources. These savings would result from the elimination of redundant functions and the continuous upgrade of various tools and staff training, making individuals more effective in their jobs.

Table 2. Comparison of Base Case Costs with the "Improved" Case Costs

	Estimated 37-Year Costs [$ millions (U.S.); FY 1995 constant dollars]			
Year	Base case		Improved case	
Cost/percentage of total	Cost	Percentage of total	Cost	Percentage of total
Human resources	19,500	65	14,700	64
Packaging	6,500	22	4,900	21.3
Logistics	3,300	11	2,800	12.2
Vehicle infrastructure	440	1.5	440	1.9
Site infrastructure[a]	130	0.5	130	0.6
Totals	29,870	100	22,970	100

[a]Does not include major infrastructure upgrades such as rail lines into some sites.

CONCLUSION

Based upon the TNA, which has been briefly summarized in this paper, DOE is facing orders-of-magnitude increases in the number of shipments of some radioactive wastes and materials in the early decades of the twenty-first century. For example:

- The projected number of DOE shipments of radioactive material (excluding UMTRA materials) in full truck or rail car loads is projected to increase from about 5,000 shipments in 1993 to more than 71,000 shipments in 2010.

- The projected total shipping distances involving DOE radioactive materials are projected to grow from about 7 million miles (11.3 million km) in 1993 to 34 million miles (54.7 million km) in 2010.

- It is estimated that more than 1.7 million 210-L steel drums per year are to be used for packaging low-level, mixed, and transuranic waste for shipping in the early twenty-first century.

- It is estimated that more than 150 reusable shipping casks are to be used for spent nuclear fuel, canisters of HLW, and some TRU shipments.

- The full-time, steady-state availability of the equivalent of at least 750 rail cars and truck trailers are expected to be needed.

- The human resources involved in DOE radioactive material shipping activities are projected to grow significantly, from about 3,200 FTEs in 1993 to potentially as high as 6,600 FTEs in 2010.

As a result of the projected growth in DOE transportation activities, the total DOE transportation costs (for all commodities) over the period from 1993 to 2030 may reach $30 billion. The TNA, however, demonstrated that a number of measures are available to DOE which offer the potential for significant cost reductions. As much as $7 billion might be saved during the time period extending to 2030. The estimated cost reductions are based upon a rough order-of-magnitude assessment, assuming that an "Integrated Systems Approach to Transportation Resource Management" is implemented. This approach emphasizes developing tools and methodologies and implementing them within the DOE complex to enhance the field's capabilities and efficiencies. It was noted in the TNA study that achieving these savings will require DOE to make near-term (during 1996 to about 2002) investments in developing the integrated approach and providing those tools and methodologies. It is felt that the TNA and the projections resulting from the study establish a starting point for defining future DOE funding needs and for assessing potential areas where efforts could lead to significant cost savings.

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