Trends in DOE Radioactive Material Shipment Costs

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INTRODUCTION

This summary provides the results of an evaluation of radioactive shipment records from the U.S. Department of Energy (DOE) from 1986 to 1994. The analysis examines the impact of differing shipment characteristics for eight definitions of radioactive materials commodity groupings shipped in four modes: air, less-than-truckload (LTL), truckload (TL), and rail. The next section provides an overview of the database used for the study. The third section explains the model specification, which is followed by a discussion of estimation results.

DATA SAMPLE

Records from the DOE's Shipment Mobility/Accountability Collection (SMAC) database are analyzed in this study (for a description of SMAC, see Office of Environmental Restoration and Waste Management, 1994). SMAC is DOE's unclassified, computer-based historical transportation information system. It is a compilation of information on shipments made by and on behalf of DOE since 1983, and it provides centralized collection, analysis, and reporting capabilities to facilitate compliance with all DOE regulatory transportation requirements. SMAC contains records describing shipments by type of commodity shipped, transportation mode used, carrier name, origin and destination of shipment, shipment weight, and cost of shipments (for inbound-collect and outbound-prepaid transactions).

The SMAC system received shipment information from 63 DOE sites in 1993; on average, approximately 50,000 shipments were reported to the system each month. SMAC includes observations for air, truck, rail, and water transportation. However, records showing water shipments of radioactive materials were not included because of the few number of observations. Therefore, this study examines air, truck, and rail transportation. Following industry conventions, truck transportation is divided into LTL and TL groups. LTL is defined to be shipments weighing less than 10,000 pounds; TL are shipments weighing 10,000 pounds or more.

Not all radioactive materials shipment records from SMAC were included in this analysis. The sample selection was not random, but based upon requirements imposed to ensure that complete and reliable observations were used in the estimation of cost functions. First, only those records that reported cost information were used (DOE only knows the cost of shipments that they pay for, which are the inbound/collect and outbound/prepaid shipments). Second, only those records that could be used to estimate distance shipped were included. Distance is not entered into SMAC, but the origin and destination (reported by site-specific code or zip code) are reported. All origins and destinations were converted into zip codes, and the software program *PC*MILER* (from ALK Associates, Inc., 1994) was used to estimate distance shipped. Only shipments within the continental United States were included.

SMAC database records describing radioactive material shipments were reviewed in order to flag "suspect" data items to preclude their consideration. Key to this expert review was the development of a special SMAC summary report that compiled data in such a way to detect suspect data. Vital data items included: the SMAC commodity code, isotopes (listed in order by key number), total activity in curies, transport index, and units used as a multiplier for the activity value. By listing the data fields in this manner, suspect data was detected by examining those items whose listed values clearly fell outside a reasonable range as established by the reviewer. For example, the most common input error was the incorrect assignment of a multiplier for the activity (curie) value. This typically manifested in reported values several (as many as 12) orders of magnitude greater than the majority of shipments reported for that specific commodity for a given year. Another error involved empty-cask shipment records where the transport index was frequently reported much larger than the limit of 0.5. These specific data points were also flagged and eliminated from the group used in this analysis.

In addition to the information from *PC*MILER*, SMAC data were augmented with information on fuel costs provided by the DOE's Energy Information Administration (EIA). Data on the monthly price of jet fuel and diesel fuel by State and Petroleum Administration for Defense Districts (PADD) were obtained on diskette from EIA (as reported in *Petroleum Marketing Annual* and *Petroleum Marketing Monthly*, Office of Oil and Gas, EIA). Estimates for missing state-level data were calculated based upon the average annual change in prices reported for the associated PADD. When available, state-level average fuel prices over each fiscal year were assigned based upon the State of origin. When state-level detail was not available, the average value for the PADD in which that state was assigned was used. When the observation did not have a state allocation (the "other" category), the national average fuel price was used.

Figures 1 though 4 show the trends in real average costs for DOE's radioactive materials shipments for the four modes. The SMAC commodity group categories are summarized with a two-digit code:

- 70 - Radioactive Material Packages, Empty, Containing Residue;
- 71 - Radioactive Material, Fissile;
- 72 - Radioactive Material, Instruments & Articles;
- 73 - Radioactive Material, Limited Quantity or Medical Isotopes;
- 74 - Radioactive Material, LSA;
- 75 - Radioactive Material, NOS;
- 76 - Radioactive Material, Special Form; and
- 77 - Uranium Products, Including Metals, Solids, & Oxides.

MODEL SPECIFICATION

It was assumed that the system cost functions could be expressed using a translog specification. This approach has been used by others estimating freight transportation cost functions, including Grimm et al. (1989), Harmatuck (1991, 1992), Liu (1993), and Westbrook and Buckley (1990). As pointed out by Talley (1988), the translog function is attractive, especially for transportation cost functions, because it assumes no *a priori* restrictions such as separability, unitary elasticity of resource substitution or homotheticity of the underlying production technology employed. The translog cost function is a flexible specification based upon the second-order Taylor's series expansion of the explanatory variables in the cost function.

Figure 1. Trends in DOE RAM Air Shipment Real Average Costs by SMAC RAM Commodity, 1986-94

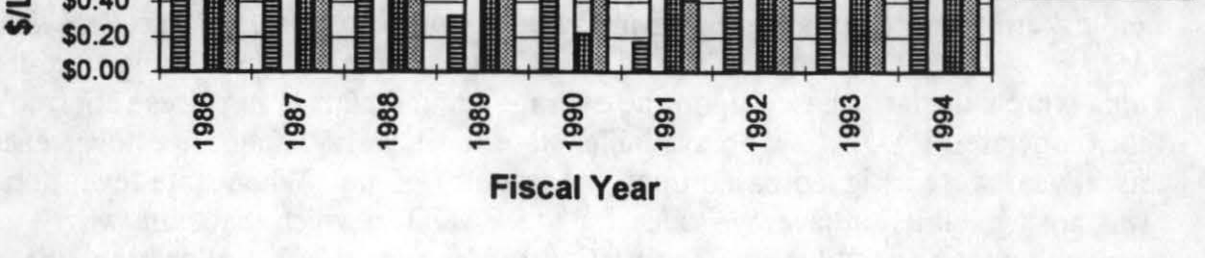


Figure 2. Trends in DOE RAM LTL Shipment Real Average Costs by SMAC RAM Commodity, 1986-94

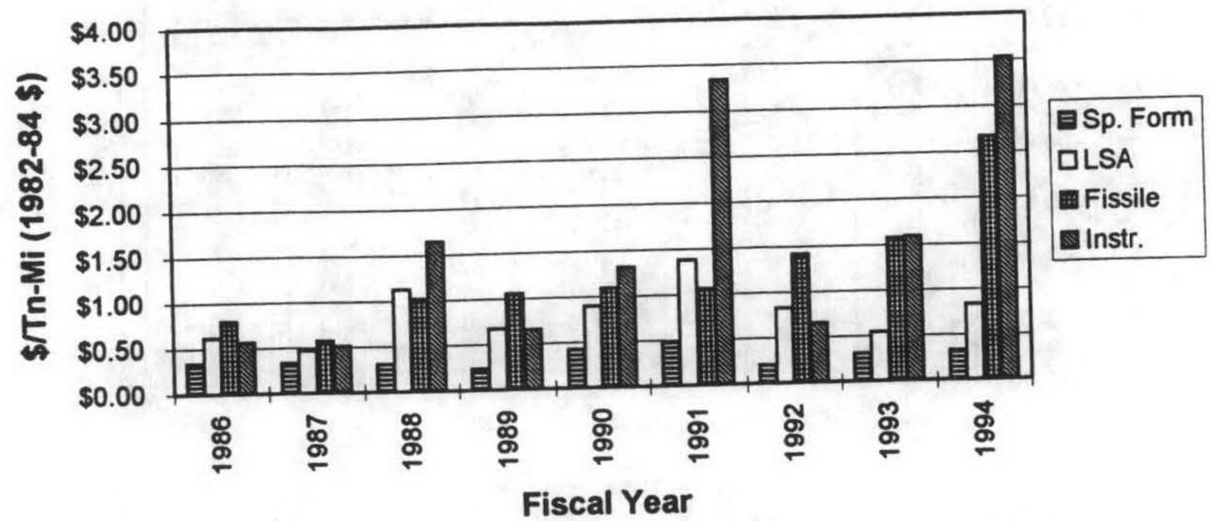


Figure 3. Trends in DOE RAM TL Shipment Real Average Costs by SMAC RAM Commodity, 1986-94

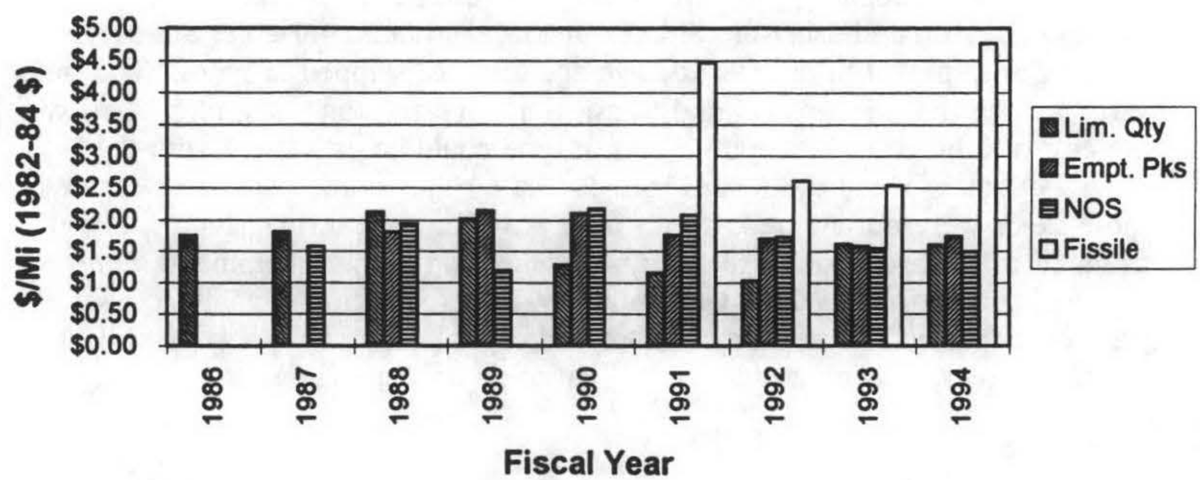
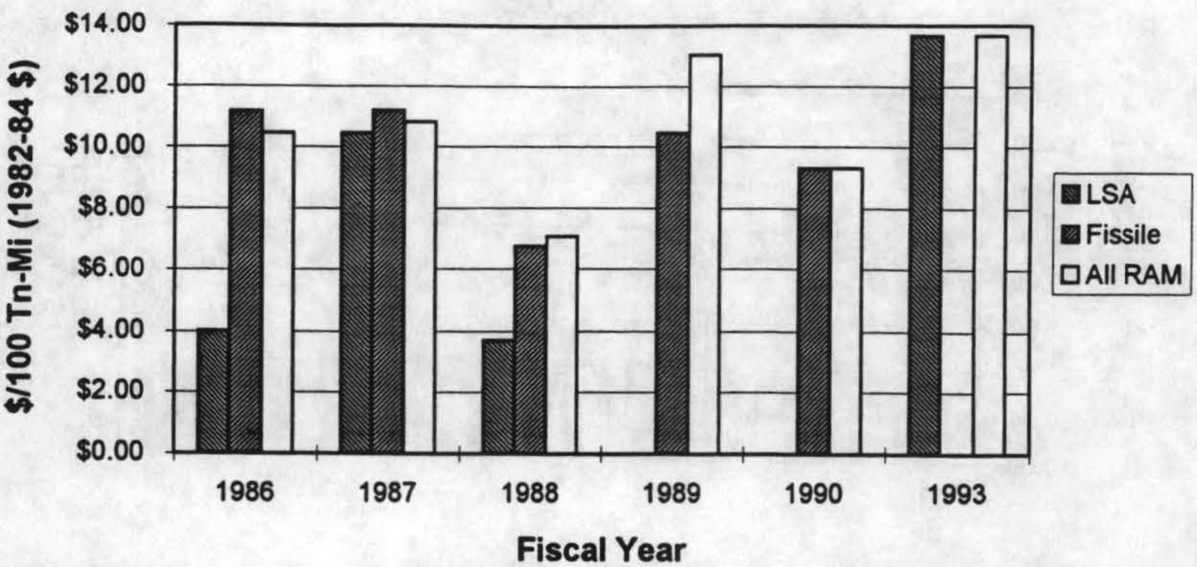


Figure 4. Trends in DOE RAM Rail Shipment Real Average Costs by SMAC RAM Commodity, 1986-93



Assuming that there are two output variables and two input variables, the translog function can be written as:

$$\begin{aligned}\ln C = \; & a_0 + a_1 \ln Q_1 + a_2 \ln Q_2 + a_3 \ln W_1 + a_4 \ln W_2 + a_5[.5(\ln Q_1)^2] + \\ & a_6[.5(\ln Q_2)^2) + a_7[.5(\ln W_1)^2] + a_8[.5(\ln W_2)^2] + a_9 \ln Q_1 \ln Q_2 + \\ & a_{10} \ln Q_1 \ln W_1 + a_{11} \ln Q_1 \ln W_2 + a_{12} \ln Q_2 \ln W_1 + a_{13} \ln Q_2 \ln W_2 + \\ & a_{14} \ln W_1 \ln W_2\end{aligned}$$

where C is the cost of the shipment, the Q_i are output measures, the W_i are input prices, and a_0 through a_{14} are parameters to be estimated. In the model framework estimated using the SMAC sample, the output variables are average weight per shipment in pounds and average distance shipped in miles. The input variables are the price of fuel and transit time. Transit time is used as a proxy for the cost of other variable inputs. Transit time could be estimated from the SMAC database when the record included date shipped and date received. When those fields were not entered, transit time was estimated: truck shipments were assumed to require one day for every 400 miles traveled; air shipments were assumed to require one day. Unfortunately, a more specific variable cost series was not identified for the study. Labor and capital costs could only be collected by month; there was no cross-sectional variation on these series.

RESULTS

The estimated model elasticities by mode and commodity group are shown in Tables 1 and 2. Weight is a significant cost factor for all modes and all

Table 1. Estimated Cost Elasticities for Radioactive Material Air and LTL Shipments by Commodity Groups

Mode/Variable	RAM Packages Empty, Containing Residue Comm. Grp. 70	RAM, Fissile Comm. Grp. 71	RAM, Instruments & Articles Comm. Grp. 72	RAM, Limited Quantity of Medical Isotopes Comm. Grp. 73	RAM, LSA Comm. Grp. 74	RAM, NOS Comm. Grp. 75	RAM, Special Form Comm. Grp. 76	Average All RAM Commodities
AIR SHIPMENTS:								
Weight (Pounds)	0.645*	0.67*	0.677*	0.768*	0.767*	0.666*	0.769*	0.709*
Distance (Miles)	0.184	0.040	0.005		0.145	0.025*		0.080
Days Transit	0.281*	1.943	0.130	-0.002	0.212*	-0.046	0.018	0.362
Price of Jet Fuel (1982-84$)	-0.06*	-0.193*	0.175	0.027	0.368	0.367*		0.114
# Regression Obs.	295	382	195	1,137	228	513	334	
Adj. R-squared	0.792	0.885	0.868	0.896	0.872	0.827	0.857	
Average Values:								
Est. Year Avgs.	1986-94	1993	1994	1994	1994	1993-94	1994	
# Ship. in Year(s)	295	2	19	1,137	16	196	51	245
Cost (1982-84$)	$277.52	$19.54	$30.98	$40.82	$166.75	$37.43	$60.07	$90.44
Weight (Pounds)	505.06	12.50	49.00	78.05	261.31	38.48	101.12	149.36
Distance (Miles)	1,485.17	607.90	1,929.71	1,064.31	1,195.96	1,562.96	1,469.92	1,330.85
Days Transit	1.63	2.00	1.53	1.55	1.63	1.47	2.14	1.71
Price of Jet Fuel (1982-84$)	$0.4766	$0.4228	$0.3817	$0.3760	$0.3582	$0.4665	$0.3984	$0.4115
LTL SHIPMENTS:								
Weight (Pounds)	0.676*	0.565*	0.675*	0.461*	0.586*		0.612*	0.596*
Distance (Miles)	0.311*	0.412*	0.208*	0.162*	0.176		0.062*	0.222
Days Transit	0.049*	0.038	0.066	-0.081	0.063		-0.074*	0.01
Price of Diesel Fuel (1982-84$)	0.033	0.378		0.785			0.022*	0.305
# Regression Obs.	656	394	232	756	520		553	
Adj. R-squared	0.740	0.507	0.750	0.627	0.660		0.641	
Average Values:								
Est. Year Avgs.	1994	1994	1994	1994	1994		1994	
# Ship. in Year	77	39	16	352	43		48	96
Cost (1982-84$)	$407.00	$763.48	$162.58	$465.49	$1,101.47		$174.76	$512.46
Weight (Pounds)	2,346.14	768.13	227.50	3,154.91	2,326.49		733.40	1,592.76
Distance (Miles)	1,474.80	744.53	405.21	653.42	1,146.37		1,510.11	989.07
Days Transit	4.56	2.95	1.81	2.60	3.56		4.77	3.38
Price of Diesel Fuel (1982-84$)	$0.4688	$0.4950	$0.5201	$0.4795	$0.4907		$0.5023	$0.4927

*All constituent coefficients from the translog specification significant at the 5% level or better.

Table 2. Estimated Cost Elasticities for Radioactive Material TL and Rail Shipments by Commodity Groups

Mode/Variable	RAM Packages Empty, Containing Residue Comm. Grp. 70	RAM, Fissile Comm. Grp. 71	RAM, Limited Quantity of Medical Isotopes Comm. Grp. 73	RAM, LSA Comm. Grp. 74	RAM, NOS Comm. Grp. 75	RAM, Special Form Comm. Grp. 76	Uranium Products Including Metals, Solids & Oxides Comm. Grp. 77	Average All RAM Commodities
TL SHIPMENTS:								
Weight (Pounds)	0.444*	17.703*	0.222*	0.201*	0.302*		0.388*	3.210*
Distance (Miles)	0.326	0.598*	0.444*	0.652*	0.797*		0.063*	0.480
Days Transit	0.055	0.131*	0.472*	-0.086*	-0.027		-0.002	0.091
Price of Diesel Fuel (1982-84$)	0.553*	2.535*	0.168	0.281	0.004		0.040*	0.597
# Regression Obs.	617	528	248	800	529		576	
Adj. R-squared	0.770	0.730	0.481	0.595	0.706		0.734	
Average Values:								
Est. Year Avgs.	1994	1993	1994	1994	1994		1988	
# Ship. in Year(s)	25	91	106	800	35		163	203
Cost (1982-84$)	$2,437.42	$1,430.64	$834.17	$1,938.00	$2,097.96		$648.28	$1,564.41
Weight (Pounds)	24,722.28	35,747.80	17,523.55	35,035.09	30,236.97		42,736.39	31,000.35
Distance (Miles)	1,404.28	563.33	517.17	1,757.60	1,403.84		379.67	1,004.32
Days Transit	3.96	3.15	1.68	4.80	4.31		2.17	3.35
Price of Diesel Fuel (1982-84$)	$0.4841	$0.5000	$0.4965	$0.4659	$0.5008		$0.5703	$0.5029
RAIL SHIPMENTS:								
Weight (Pounds)	0.361*	0.362*		0.361*	0.361*	0.362*	0.363*	0.362*
Distance (Miles)	0.429*	0.358*		0.414*	0.424*	0.347*	0.334*	0.384*
Days Transit	0.099*	0.123*		0.131*	0.125*	0.152*	0.107*	0.123*
Price of Diesel Fuel (1982-84$)	0.159	0.068		0.009	0.091	-0.202	0.215	0.057
# Regression Obs.	539	539		539	539	539	539	
Adj. R-squared	0.825	0.825		0.825	0.825	0.825	0.825	
Average Values:								
Est. Year Avgs.	1986-88	1986-90		1986-93	1987	1988	1986-87	
# Ship. in Year	23	392		71	4	3	36	88
Cost (1982-84$)	$8,877.23	$2,463.09		$4,365.67	$10,058.38	$2,383.12	$2,235.67	$5,063.86
Weight (Pounds)	151,244.86	107,377.33		134,130.20	91,458.50	139,811.67	135,998.94	126,670.25
Distance (Miles)	1,758.63	499.33		1,338.06	1,589.23	412.40	330.10	987.96
Days Transit	5.45	8.00		10.24	7.25	25.00	4.30	10.04
Price of Diesel Fuel (1982-84$)	$0.6287	$0.5675		$0.5500	$0.5640	$0.5030	$0.6064	$0.5699

*All constituent coefficients from the translog specification significant at the 5% level or better.

commodity groups. The translog specification was estimated for each of the four modal categories, with separate equations estimated by commodity group for all but rail, which had too few observations to allow for commodity-specific separation of the equation estimation. In addition to the variables identified in the model specification equation above, dummy variables for each year were added to account for additional annual differences. Unfortunately, there was considerable multicollinearity across terms in the translog equations. A modified translog system was estimated by dropping some terms; when the correlation between the single-term elements of the equation and the cross-terms was over 0.9, the cross-term elements were dropped from the equation.

The SMAC database is a tremendous resource for evaluating freight transportation cost trends, and further investigation of the database should provide guidance for DOE traffic managers to plan their shipment needs to help reduce overall shipment costs.

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