9. Long Range Transportation Plan for the Central Business District. De Leuw, Cather and Company, Dallas, TX, July 1965.
10. M. V. Bates. Goods Movement by Truck in the Central Area of Selected Canadian Cities. Canadian Trucking Association, 1970.
11. Survey of Usage at the Off-Street Loading Facility, First National Bank Building, Dallas. First National Bank, Dallas, Jan. 1974.
12. Survey of Activity at Republic National Bank Building. Department of Planning and Urban Development, Dallas, 1971.
13. E. M. Whitlock and J. G. Schoon. Planning Criteria for Off-Street Service Areas. HRB, Highway Research Record 399, 1972, pp. 40-50.
14. E. M. Horwood. Center City Goods Movement: An Aspect of Congestion. HRB, Bulletin 203, 1958, pp. 76-98.
15. A Policy on Geometric Design of Rural Highways. American Association of State Highway Officials, Washington, DC, 1965.
16. Shipper-Motor Carrier Dock Planning Manual. American Trucking Associations, Washington, DC, 1973.
17. J. Baerwald, ed. Traffic Engineering Handbook, 3rd ed. Institute of Traffic Engineers, 1965.
18. Thanksgiving Square Feasibility Report for the City of Dallas. Datum Structures Engineering, Inc., 1972.

Publication of this paper sponsored by Committee on Urban Goods Movement.

Abridgment

Determinants of Freight Modal Choice

Mark S. Jelavich,* Peat, Marwick, Mitchell and Company, Inc., Washington, D.C.

In studying the transportation of commodities, the objective of any particular research effort should be kept in mind. A researcher may be interested only in some general notion of the overall demand for freight transportation (e.g., the annual cost of shipping goods), in which case the demand for freight services will be closely tied to the level of national output. However, this procedure starts to collapse when interest centers on the demand for freight services by particular modes (e.g., rail and truck) and becomes rather unworkable. This is true especially from the viewpoint of policy analysis—i.e., when the research effort addresses questions related to the movement of particular goods by certain modes.

Input-output analysis, as well as econometric models, allows an economist or transport planner to forecast disaggregate components of national output (e.g., output by industries). This disaggregation has not been extended to direct modeling of freight demand, because a complete data base on modal characteristics is lacking—especially among unregulated carriers. Individual shipper data are also sparse. Thus, freight forecasting lags behind urban and intercity passenger modal split modeling methodologies. For example, Morton (2) has studied the demand for transport by mode by broad commodity groups, while Nazem (3) has focused on the macro-level approach. In addition, Watson and others (5) and Roberts and others (4) have emphasized individual shipper behavior. Morton found that shipment size and average haul length (AHL) were important determinants of modal choice.

Modes of freight transportation cannot be neatly dichotomized into public and private transport, as is sometimes done in passenger studies. While other researchers have confined their examination of freight haulage to two modes, e.g., Kullman's thesis on rail-truck competition (1), any broad study of freight must deal with more than two modes. If there are n modes for any particular commodity (good f) examined, then

$$\sum_{i=1}^{n} p_{if} = 1 \tag{1}$$

where p_{if} is the probability that a quantity of good f will move by mode i. Dividing both sides of Equation 1 by a nonzero p_{jf}, $i = 1,\ldots,j,\ldots,n$, so that

$$\sum_{i=1}^{n} (p_{if}/p_{jf}) = (1/p_{jf}) \tag{2}$$

Since $p_{jf}/p_{jf} = 1$, then

$$\sum_{i \neq j} (p_{if}/p_{jf}) = (1/p_{jf}) - 1 \tag{3}$$

Assuming strict inequalities, so that $0 < p_{if} < 1$ for all i and f, then the ratios p_{if}/p_{jf} are all positive, $1/p_{jf}$ is greater than one, and p_{jf} is greater than zero.

Because of the first equation, there will be only n-1 modal choices in an n-mode case that can be made freely; therefore, there will be only n-1 equations. While the choice of the base mode, p_{jf}, is arbitrary—and, thus, the results possibly sensitive to the base mode choice—it is desirable that the ranking of modes (in terms of lowest to highest probability of choice) remains invariant to the choice of base mode. If three modes—e.g., rail, truck, and "all else" (including water and air freight)—are being studied, with probabilities p_{rk}, p_{tk}, and p_{ok} of hauling good k, then three ratios could be formed: p_{rk}/p_{ok}, p_{tk}/p_{ok}, and $1/p_{ok}$. Such an approach would waste information, however, in that comparatively good data on a commodity-detail basis are available for rail and truck, whereas poor information is available for the remaining modes. Three alternative ratios could be examined: p_{rk}/p_{ok}, p_{tk}/p_{ok}, and $1/p_{ok}$. Note that as $(p_{rk}/p_{tk})\ (p_{tk}/p_{ok}) = p_{rk}/p_{ok}$, one can still use the "all else" mode as a base. This model can be summarized as follows:

$$\ln(p_{rk}/p_{tk}) = f_{rt}(r_{tk}; r_{rk}; A_k) \tag{4}$$

$$\ln(p_{tk}/p_{ok}) = f_{to}(r_{tk}; r_{rk}; A_k) \tag{5}$$

Mr. Jelavich was with Jack Faucett Associates, Chevy Chase, Maryland, when this research was performed.

$$(p_{rk}/p_{ok})(p_{tk}/p_{ok}) = p_{rk}/p_{ok} \quad (6)$$

$$(p_{rk}/p_{ok}) + (p_{tk}/p_{ok}) + 1 = 1/p_{ok} \quad (7)$$

where r_{tk} and r_{rk} are the truck and rail ton-mile rates respectively (derived below), and A_k is a vector of attributes of commodity k. In Equation 5, since rate data for other modes are not readily available, the "all else" rate term has been suppressed.

Data used to estimate the model's equations appeared in the 1972 Census of Transportation, the 1972 Census of Manufactures, and the 1972 Interstate Commerce Commission's Freight Commodity Statistics reports on rail and regulated trucking. The data in the transport census cover only the 48 contiguous states and shipments to Alaska and Hawaii. The transport census covers only manufactured goods, and pipelines are not included in the modal coverage. Still, the transport census covers a wide number of manufactured goods, and eventually 86 products were selected for the model's data that had either "one-to-one" or easily recognizable Standard Transportation Commodity Code-Standard Industrial Classification (STCC-SIC) concordance, at the three-digit level.

While the manufacturing census does not report physical output in any standardized customary units, the transport census does include an estimate by STCC group of intercity tons and ton-miles shipped over 30 miles. While the distance cutoff excludes local and urban goods movements, it may also exclude local intraurban, interplant shipments that are really related more to the local production process than to the transportation process. Value per ton of a commodity was thus calculated as the ratio of the manufacturing census' value-of-shipments number to the transport census' tonnage number. Rates for truck and rail were based on the 1972 Freight Commodity Statistics reports for rail and common carrier truck; these reports contain estimates, at the three-digit STCC level, of tonnage and gross revenue for the two modes. One major problem concerns the truck rate: since most trucking is done by private carriers, the calculated rate (revenue divided by tonnage) should be considered as an upwardly biased proxy for the private cost of trucking (the bias is due to common-carrier profit margins). The transportation census contains a breakdown of percentage of tonnage hauled by weight blocks, captured in the variables RLBS and MLBS, described below. Finally, three dummy variables were constructed to reflect production differences of commodities, measured by their value-added from the manufacturing census. (Data in the preceding sources appear only in customary units; thus the model constructed here was calibrated only in customary units. However, 1 lb = 0.45 kg, 1 mile = 1.6 km.)

Thus, the equations contain the following independent variables:

RRTA = rail rate per ton-mile of a commodity;
TRTA = truck-rate per ton-mile;
COSTDF = RRTA-TRTA;
AHL = average length of haul over all modes (in miles);
RLBS = percent of shipments weighing over 90 000 pounds;
MLBS = mean of weights of shipments under 90 000 pounds;
DA = dummy variable, equal to unity if the commodity's value added per ton equals or exceeds \$500/ton but is less than \$1500/ton;
DB = dummy variable, equal to unity if the commodity's value added per ton equals or exceeds \$1500;
DC = dummy variable, equal to unity if over one-half of the goods shipments weigh in excess of 30 000 pounds; and
VALSV = value per ton of the shipment.

Table 1. Ordinary least-squares estimates of modal split equations.

Independent Variable	Equation No. 1	2	3	4	5	6
	Dependent Variable					
	$\ln(p_r/p_t)$	$\ln(p_r/p_t)$	$\ln(p_r/p_o)$	$\ln(p_r/p_o)$	$\ln(p_t/p_o)$	$\ln(p_t/p_o)$
RRTA		-0.015 92		0.020 52		0.030 73
		(0.009 04)		(0.027 25)		(0.029 72)
ln(RRTA)	-0.679 34		-0.491 12		-0.206 82(W)	
	(0.349 83)		(0.926 04)		(1.011 40)	
TRTA				0.022 05		0.023 22(W)
				(0.018 85)		(0.020 57)
ln(TRTA)	0.637 75*		-0.136 91(W)		-0.607 86	
	(0.302 98)		(0.802 03)		(0.875 95)	
MLBS		0.000 04*		0.000 10*		0.000 08
		(0.000 02)		(0.000 04)		(0.000 05)
ln(MLBS)	0.174 72		1.221 59*		1.257 17*	
	(0.221 80)		(0.587 13)		(0.641 24)	
RLBS		3.936 54*		5.068 84*		1.748 71
		(0.825 47)		(2.265 59)		(2.472 54)
ln(RLBS)	0.020 02*		-0.135 01		-0.155 80	
	(0.064 77)		(0.171 46)		(0.187 26)	
VALSV		-0.060 92*		-0.117 10		-0.034 78
		(0.029 40)		(0.080 69)		(0.088 06)
ln(VALSV)	-0.715 92*		0.052 24		0.588 43	
	(0.158 72)		(0.420 16)		(0.458 89)	
AHL		0.449 82		1.173 39*		0.550 60
		(0.230 38)		(0.632 31)		(0.690 07)
ln(AHL)	0.780 94*		1.249 98		0.341 96	
	(0.357 15)		(0.945 42)		(1.032 57)	
COSTDF		0.002 49(W)				
		(0.006 87)				
DA	0.704 95	0.130 09	-1.148 33	0.462 87	-1.437 36	0.220 42
	(0.443 04)	(0.307 41)	(1.172 78)	(0.843 71)	(1.280 87)	(0.920 78)
DB	0.993 86*	0.591 23*	0.634 88	1.408 67*	-0.295 79	0.666 71
	(0.305 66)	(0.245 58)	(0.809 13)	(0.674 03)	(0.883 71)	(0.735 60)
DC	0.825 82*	-0.054 10(W)	1.568 44	0.442 55	0.775 90	0.503 91
	(0.317 95)	(0.342 66)	(0.841 63)	(0.940 46)	(0.919 21)	(1.026 37)
Constant	-3.455 99	-2.595 23	-7.425 14	-3.451 93	-5.499 67	-0.998 64
R^2	0.593 92	0.672 59	0.365 66	0.450 16	0.219 97	0.324 91
F	12.350 76	17.346 82	4.867 64	6.913 64	2.381 33	4.064 15

*Coefficient significant at 95 percent confidence (t-statistics appear in parentheses).

The specifications of the equations are

$$\ln(p_r/p_t) = f(RRTA, TRTA, RLBS, MLBS, VALSV, DA, DB, DC) \quad (8)$$

$$\ln(p_t/p_o) = g(TRTA, RRTA, AHL, RLBS, MLBS, VALSV, DA, DB, DC) \quad (9)$$

It is hypothesized that f and g are linear in their independent variables, and that COSTDF replaces one of the rate variables in some cases. Table 1 presents estimates of these equations, along with some logarithmic transformations of the independent variables.

The general form of the equations can also be modified by dropping the variables DA and DB and substituting the following value dummy variables:

DAA = unity if the value of shipments per ton for a commodity is between $1000 and $3000 inclusive, zero otherwise;

Table 2. Alternative estimates of modal split equations under new value format.

Independent Variable	Equation No. 1: Dependent Variable $\ln(p_r/p_t)$	Equation No. 2: Dependent Variable $\ln(p_r/p_o)$	Equation No. 3: Dependent Variable $\ln(p_t/p_o)$
RRTA	-0.016 59*	0.022 35(W)	0.031 20
	(0.009 17)	(0.027 32)	(0.029 68)
TRTA		0.018 20	0.021 22(W)
		(0.018 88)	(0.020 52)
MLBS	0.000 04*	0.000 09*	0.000 07
	(0.000 02)	(0.000 04)	(0.000 05)
RLBS	3.814 42*	4.892 75*	1.563 34
	(0.874 86)	(2.359 51)	(2.563 68)
VALSV	-0.062 50*	-0.112 76	-0.029 52
	(0.031 87)	(0.085 95)	(0.093 39)
AHL	0.461 81	1.140 06	0.510 01
	(0.249 18)	(0.671 82)	(0.730 06)
COSTDF	0.003 99(W)		
	(0.007 00)		
DAA	0.007 27(W)	0.241 87	0.009 61(W)
	(0.354 50)	(0.955 98)	(1.038 70)
	0.368 51(W)	1.212 13	0.505 65(W)
DBB	(0.252 43)	(0.680 74)	(0.739 64)
DC	-0.065 25(W)	0.518 38	0.525 38
	(0.354 44)	(0.955 81)	(1.038 52)
Constant	-2.321 77	-2.897 55	-0.621 07
R^2	0.656 64	0.443 34	0.322 55
F	16.149 31	6.725 47	4.020 58

*Coefficient significant at 95 percent confidence (t-statistics appear in parentheses).

DBB = unity if the value of shipments per ton for a commodity is over $3000, zero otherwise.

Table 2 gives the parameter estimates of the modified equations.

Table 3 gives the results, in summary form, of those equations with multiple correlation coefficients ("R-squares") above 0.4. The determination of the correctness of sign was based on a priori speculation as to the sign of each particular coefficient. What is most apparent is that rate variables do not play much of a role in this model; rather, value of shipment, weight, and, to a lesser extent, average haul length variables are the major determinants of modal choice.

This research implies that, in order to forecast freight commodity flows accurately, it is necessary to take individual commodity characteristics such as shipment size and value into account. The type of mode chosen by a shipper will depend greatly on the commodity to be transported; in turn, this will help determine modal choice. Input-output models provide commodity-group output forecasts that can be used as a starting point to forecast demand for transportation by mode at a commodity level; an appropriate modal split algorithm can—after converting value of output to tons—estimate the tonnage carried by each mode. This methodology is preferable to more macro-related methodologies when research is focusing, for example, on the effects of energy or regulatory policies; it may be that in many cases government actions will not alter shipper choice because of a shipper's perception of transport.

ACKNOWLEDGMENTS

The research on which this paper is based on supported by the Transportation Energy Conservation Division, U.S. Department of Energy. I would like to thank D. J. Kulash, E. J. Mosbaek, J. G. Faucett, and L. A. Fourt of Jack Faucett Associates for their advice and assistance; however, any errors are mine, and the contents of this paper do not necessarily reflect the views of the U.S. Department of Energy.

REFERENCES

1. B. Kullman. A Model of Rail/Truck Competition in the Intercity Freight Market. Massachusetts Institute of Technology, Cambridge, PhD thesis, June 1973.
2. A. Morton. A Statistical Sketch of Intercity Freight Demand. HRB, Highway Research Record 296, 1969, pp. 47-65.

Table 3. Summary of best regression results.

Equation (Table, Number)	Structural Specification	Price Variable	Value Variable	Weight Variable	Haul Length
1, 1	Rail-truck ratio dependent variable; included logarithms of truck and rail rates and production dummies (DA, DB); non-dummies in logarithms	Truck rate significant; rail rate of insignificantly correct sign	Value variable VALSV significant	Weight variables RLBS and DC significant	Average haul length (AHL) significant
1, 2	Rail-truck ratio dependent variable; COSTDF used in place of truck rate; independent variables not transformed into logarithms	COSTDF of insignificantly wrong sign; rail rate insignificant	Value variable VALSV significantly negative	Weight variables RLBS and MLBS significant	Insignificant
1, 4	Rail-all else ratio dependent variable; truck and rail rates used; all independent variables except dummies in logarithms	Both rail and truck rates insignificant	VALSV is insignificant	Both RLBS and MLBS significant	Significant
2, 1	Rail-truck ratio dependent variable; COSTDF and rail rate used; value of shipment dummies used	Rail rate significant; COSTDF of insignificantly wrong sign	RLBS and MLBS have significantly correct signs; DC has insignificant wrong sign	VALSV of significant correct sign; DAA, DBB, of insignificantly wrong sign	Insignificant
2, 2	Rail-all else ratio as dependent variable; rail and truck rates used, along with value dummies	Rail rate insignificantly wrong; truck rate insignificant	MLBS, RLBS significant	VALSV insignificant	Insignificant

3. S. Nazem. Forecasting Rail Freight Transportation Demand. Business Economics, Vol. 11, No. 4, Sept. 1976, pp. 65-69.
4. P. Roberts and others. Development of a Policy Sensitive Model for Forecasting Freight Demand: Phase 1 Report. Office of Transportation Systems Analysis and Information, U.S. Department of Transportation, April 1977.
5. P. Watson and others. Factors Influencing Shipping Mode Choice for Intercity Freight: A Disaggregate Approach. Transportation Research Forum, Proc. 15th Annual Meeting (Richard B. Cross, Oxford, IN), 1974, pp. 138-144.

Publication of this paper sponsored by Committee on Passenger and Freight Transportation Characteristics.

Estimating Effects of Railroad Abandonment

Herbert Weinblatt,* Jack Faucett Associates, Chevy Chase, Maryland
Donald E. Matzzie, CONSAD Research Corporation, Pittsburgh
John E. Harman, U.S. Department of Transportation

Estimates were developed of the potential for rail-service termination and of the probable transport-related effects that such loss of rail service would have on the freight-transport system, transport costs of affected rail users, resulting public- and private-sector investment requirements, and energy consumption. All estimates were developed for lines on which service either had been recently terminated or might be terminated in the future. A survey was conducted of a sample of users of these lines. Estimates of the overall effects of abandonment were developed by a computer program from an analysis of survey responses and from waybill data for shipments originating or terminating on the lines under study. About 80 percent of present rail shipments to or from facilities that lose rail service would continue to be made to or from these facilities by another mode, with most of these made entirely by truck or by a combination of truck and rail. About half of the remaining shipments would continue to be made to or from other locations in the general area. The average increase in transport-related expenditures of affected rail users would be about 17 percent of present railroad charges. It was also estimated that abandonment of the lightest density lines under study would generally result in a small reduction in fuel consumption, while abandonment of uneconomic lines with more moderate traffic densities would result in increased fuel consumption.

The Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act) and other recently enacted legislation contain provisions that can result in increased rates of abandonment of unprofitable branch lines by railroads and that will permit subsidies for continued service on many of these lines. The purpose of this legislation, of course, is to improve the financial health of the currently ailing railroad industry. However, any increase in the rate at which branch-line service is terminated can be expected to have side effects on the rest of the transport industry, on the present users of affected lines, and on the local economies of the predominantly rural areas served by these lines.

This paper presents the methodology used in a recently completed study (1) designed to produce information about the extent of some of these effects. In particular, estimates were developed of the potential effects of railroad abandonment on traffic on the remainder of the freight transport system, transport costs of affected rail users, resulting public- and private-sector investment requirements, and energy consumption. Some of the major results of the study are presented here. Additional data may be found in Weinblatt and others (2) and in the complete report (1).

**Mr. Weinblatt was with CONSAD Research Corporation, Pittsburgh, Pennsylvania, when this research was performed.*

METHOD OF ANALYSIS

For this study, four sets of lines, which had either recently lost rail service or could lose service in the future, were identified:

1. Excluded lines: 8500 km (5282 miles) of line in the Northeast excluded from the Final System Plan (FSP) for Consolidated Rail Corporation (Conrail) (3);
2. Abandoned lines: approximately 4200 km (2600 miles) of line in the Northeast excluded from FSP on which service was discontinued on April 1, 1976;
3. Lines with petitions pending (PP): 9752 km (6060 miles) of non-Conrail lines located throughout the country on which abandonment petitions were pending as of July 23, 1976; and
4. Apparently uneconomic (AU) lines: 48 900 km (30 400 miles) of non-Conrail lines located throughout the country that appeared to be uneconomic on the basis of a computer analysis of traffic data.

For each of the four sets of study lines, estimates of the annual volume of shipments originating or terminating on these lines were obtained for seven regions and 16 commodity groups. For the abandoned and excluded lines, shipment data were acquired from the United States Railway Association waybill files for 1973; for lines with petitions pending and uneconomic lines, data were obtained from the Federal Railroad Administration One-Percent Waybill Sample for 1972, 1973, and 1974. Kilometer and shipment data for the PP and AU lines have been detailed in Weinblatt (4), along with a description of the procedure used in determining the apparently uneconomic lines. Preliminary estimates of the volume of shipments generated by the portions of these two sets of lines in 31 southern and western states were also included in the Transportation Secretary's Report to Congress, mandated under section 904 of the 4R Act (5,6).

Due to space limitations, the results in the latter part of this paper will be presented only for a fifth set of lines, consisting of the apparently uneconomic lines plus those excluded lines that had not already been abandoned. Thus, this fifth set consists of those lines in service in the summer of 1976 that could lose service in the next few years.