UNIVERSITY OF
ILLINOIS LIBRARY
AT URBANA-CHAMPAIGN
BOOKSTACKS

Digitized by the Internet Archive
in 2012 with funding from
University of Illinois Urbana-Champaign

http://www.archive.org/details/costfunctionsfor262sidh

Faculty Working Papers

COST FUNCTIONS FOR CLASS II RAILROADS--1968 AND 1973

Nancy D. Sidhu, Alberta Charney, and John F. Due

#262

Transportation Research Paper #9

College of Commerce and Business Administration
University of Illinois at Urbana-Champaign

FACULTY WORKING PAPERS

College of Commerce and Business Administration

University of Illinois at Urbana-Champaign

July 30, 1975

COST FUNCTIONS FOR CLASS II RAILROADS--1968 AND 1973

Nancy D. Sidhu, Alberta Charney, and John F. Due

#262

Transportation Research Paper #9

COST FUNCTIONS FOR CLASS II RAILROADS--1968 AND 1973*

A major policy issue in the transportation field at the present time is the extent to which the inadequate earnings of the railroad industry are a product of excessive light-traffic-density mileage, and therefore whether or not extensive abandonment is desirable in order to improve earnings and avoid economic waste. Various approaches to this question have been used by the Department of Transportation, the United States Railway Administration, and various state transportation agencies in the last two years. A question of major importance in resolving this issue is the nature of the cost functions of light traffic lines. To what extent are firms able, over time, to adjust total costs to the volume of traffic? The primary purpose of this paper is to develop cost functions for such lines, utilizing cost data of Class II railroads, those with gross revenue less than $5 million a year. These roads typically, but not universally, have light traffic density. Such an analysis of branch lines of Class I railroads would be much less satisfactory because many costs are incurred in common for branch and main line operation, and accounting systems are not such as to permit the ascertainment of the amounts for which the branch lines are actually responsible. If we assume that the cost functions for branch lines of Class I roads and the independent Class II roads analyzed in this study are similar, although the actual figures will differ, the conclusions derived from studying the latter group will also apply to the former.

---

*The authors are indebted to the Rail Services Planning Office, Interstate Commerce Commission, for providing data, and to the University of Illinois Graduate Research Board for financial assistance.

Portions of this paper appeared in Working Paper #203 but are reproduced here for purposes of completeness.

More specifically, the paper seeks to establish:

1. The nature of the cost functions for Class II railroads.

2. The significance of the average length of haul for average cost.

3. The significance that these cost functions have for the viability of light traffic lines. There are, of course, other influences in the decision about whether a rail line should be retained in addition to cost-revenue relationships, but the latter is obviously a key consideration.[1]

Substantial analysis has been made of the cost functions of Class I roads by John Meyer, et al.,[2] George Borts,[3] Ann Friedlaender,[4] Zvi Griliches,[5] and Theodore Keeler,[6]. The general findings are that there are few if any economies of scale for the larger railroads,[7] although Keeler and Friedlaender

---

[1] Other factors which should also be included in any abandonment decision are considered explicitly in John F. Due and Nancy D. Sidhu, "Private versus Social Decision-Making for Railway Abandonment," The Quarterly Review of Economics and Business, XIV:4 (Winter, 1974), pp. 23-42.

[2] John R. Meyer, et al., The Economics of Competition in the Transportation Industries (Cambridge: Harvard University Press, 1959).

[3] George H. Borts, "The Estimation of Rail Cost Functions," Econometrica, XXVIII (January, 1960), pp. 108-31.

[4] Ann F. Friedlaender, "The Social Costs of Regulating the Railroads," American Economic Review, LXI (May, 1971), pp. 226-34.

[5] Zvi Griliches, "Cost Allocation in Railroad Regulation," Bell Journal of Economics and Management Science, III (Spring, 1972), pp. 26-41.

[6] Theodore E. Keeler, "Railroad Costs, Returns to Scale, and Excess Capacity," Review of Economics and Statistics, LVI (May, 1974), pp. 201-08.

[7] The overall results are summarized by T. G. Moore in the appendix to "Deregulating Surface Freight Transportation," in A. Phillips, ed., Promoting Competition in Regulated Markets (Washington: Brookings, 1975), pp. 93-98.

conclude that there is substantial "excess capacity" in the Class I rail network. Little work has been done with the Class II road data.

Of primary concern for this purpose is the long run cost function, derived by cross section analysis, under the assumption that for the particular year selected the firms have made all feasible long run adjustments. This approach encounters the danger of the "regression fallacy"--but the danger does not appear serious in this instance. These roads are single track operations; they cannot vary trackage, so long as they serve the same points, but can and do adjust annual maintenance expenditures, and they can easily adjust the amount of equipment (they own only diesels as a rule) to changes in traffic conditions. Time series data will be used in subsequent work in order to explore short run adjustments to changes in volume.

The Cost Functions: Data and Methodology

The study utilized two sets of cross section data. The first included data on costs for 209 Class II roads for the year 1968 from ICC published statistics for that year--the last year for which such data were published.[1] The second was a sample of 44 railroads using 1973 data much more disaggregated than in the 1968 study.[2] With this data we estimated several

---

[1] Interstate Commerce Commission, Transport Statistics in the United States: 1968, Section A-11 was the source of all the 1968 data used in this study.

[2] Data for the 1973 sample were obtained from the individual railroad annual reports for 1973 filed with the Interstate Commerce Commission, copies of which were provided by the Rail Services Planning Office. The roads selected were primarily those exhibiting, so far as could be ascertained, typical characteristics of smaller independent roads. Eliminated were roads with passenger traffic; roads operated as integral parts of Class I systems; ones much of whose revenue came from switching on one segment of the line; roads whose expenditures were merged to some degree with those of other railroads or other companies; those with substantial net income from rental of cars; those under five miles in length. An initial sample of 50 roads was reduced to 44 as data proved to be unavailable or unsuitable for some of the lines. One group in the sample consisted of roads from 8 to 20 miles in length, the second, ones over 20, and the third, purely random. The roads actually used in the study are shown in Table 3.

long run average cost functions for light traffic railroads. The dependent variables were various elements in cost per net ton mile. Two variables of output were used, distance and volume (net ton miles per mile of line), the latter being of primary concern. In the 1968 study, distance was measured by mileage of the road, under the assumption that all traffic was handled over the entire length of the road. For these smaller railroads, this assumption is frequently, but not universally, valid. Better data in the 1973 sample permitted the calculation of average length of haul. Length of line or haul has not been a significant variable in studies of Class I roads, but Class II railways are much shorter, and therefore terminal (switching, train assembly, etc.) costs are likely to be a much larger component of total cost than they are for Class I roads.

Two different models were set up, both with the same general form

(1) $C = C(V,D)$,

where C = cost per thousand net ton miles,

V = volume, and

D = distance, or average length of haul.

Model I is linear in the logarithms of V and D:

(2) $C = a + b_1 \ln V + b_2 \ln D.$

Model II is linear in the reciprocals of V and D:

(3) $C = a + b_1(1/V) + b_2(1/D).$

These models were utilized in order to introduce nonlinear possibilities into the linear regression procedure.[1] They differ chiefly in that Model II

---

[1] Keeler, op. cit., selected his functional form by deriving short run cost functions from a Cobb-Douglas production function and then finding the long run cost function as the envelope of the short run functions. This is a very elegant approach, but is limited by the choice of production function. In addition, we are interested in the relative variability of many different types of costs. Keeler's model was inherently nonlinear, imposing computational costs that exceeded those permitted in the study.

approaches an asymptote as V or D increase while Model I falls continuously as V or D increase. Scatter diagrams of the data indicated that the signs of b_1 and b_2 should be negative for Model I and positive for Model II, implying that average cost per ton mile declines as volume or length of haul increases.

Eleven cost items were used as dependent variables for each model for the 1968 sample; 22 items were studied with the 1973 sample. A test developed by Goldfeld and Quandt[1] was used to check for heteroscedasticity. It proved to be severe in the 1973 sample but absent in the 1968 data. The 1973 problem was corrected using a transformation developed by Glejser.[2] A regression was run for each model and cost item. Then the absolute values of the ordinary least squares residuals, $|e|$, were regressed on linear functions of the volume variable (i.e., $|e| = \alpha_0 + \alpha_1(\ln V)^j$ for Model I and $|e| = \alpha_0^* + \alpha_1^* (1/V)^j$ for Model II). The exponent j was allowed to take on values of 1, -1, and ½ to determine the correct form of the relationship. The fit was clearly superior for both models when $j = 1$. The estimates of α_1 were always negative while those of α_1^* were positive, implying that the conditional variances of the errors decrease as volume

---

[1] Stephen M. Goldfeld and Richard E. Quandt, "Some Tests for Homoscedasticity," Journal of the American Statistical Association, LX: 310 (June, 1965), pp. 539-47; also cited in John Johnston, Econometric Methods, 2nd edition (New York: McGraw-Hill, 1972), pp. 218-19.

[2] H. Glejser, "A New Test for Heteroscedasticity," Journal of the American Statistical Association, LXIV:325 (March, 1969), pp. 316-23; also cited in Johnston, op. cit., pp. 220-21.

increases. The data were transformed, therefore, by dividing through by $[a_0 + a_1 \ln V]$ and $[a_0^* + a_1^* (1/V)]$ for Model I and Model II respectively, where the a's are estimates of the α's. The transformed data were then used to estimate the cost functions which follow.

The Cost Functions--Results

The results of the two regression analyses on each of 11 cost items for 1968 and 22 items for 1973 are presented in Tables 1 and 2 respectively. The coefficients are presented with their t-statistics given in parentheses. Virtually all of the coefficients of the volume variables have the correct sign. Six of the 1973 average length of haul variables have the incorrect sign, but they are insignificantly different from zero. While the R^2s are not particularly high, the multiple F-statistics are almost all significant at the one percent level. Besides the fact that there is much variation in the costs of small railroads, there are two other factors contributing to the relative smallness of the 1973 R^2s, namely the disaggregation of the cost components[1] and the transformation process which was used to correct the heteroscedasticity.[2] Mild intercorrelation was present between various pairs of independent variables in the two samples ranging from 0.364 to 0.648.

The first estimated relationship includes all operating costs (per thousand ton miles) as the dependent variable (C_1).[3] Results for the two

---

[1] See Henri Theil, Principles of Econometrics (New York: John Wiley and Sons, Inc., 1971), pp. 180-87.

[2] Jan Kmenta, Elements of Econometrics (New York: The Macmillan Company, 1971), pp. 256-64, notes that correction for heteroscedasticity often produces equations with lower R^2s than those yielded by using ordinary least squares regressions on the original variables.

[3] Operating costs do not include taxes, equipment rentals, or interest but do include depreciation (the track itself is not depreciated).

Notation of Types of Cost

C_1	total operating cost
C_{1a}	total maintenance of way cost
C_{1a_1}	roadway maintenance
C_{1a_2}	all other maintenance of way cost
C_{1b}	maintenance of equipment
C_{1b_1}	locomotive repair
C_{1b_2}	equipment depreciation
C_{1b_3}	equipment maintenance costs
C_{1c}	transportation-rail line expenses
C_{1c_1}	employee compensation, train crews
C_{1c_2}	train fuel costs
C_{1c_3}	loss, damage, casualties, personal injury
C_{1c_4}	other transportation costs (superintendence, etc.)
C_{1d}	traffic, administrative, miscellaneous
E_r	equipment rental
E_c	necessary return on equipment and salvage value of line
E_t	taxes (except income taxes)
E_{t_1}	railroad retirement system and unemployment compensation payroll taxes
E_{t_2}	property taxes

TABLE 1

ESTIMATED COST FUNCTIONS - 1968 SAMPLE

Parameter Estimates⁺

	Type of Cost	Model	a	b_1	b_2	R^2	F (2,206)
1	C_1	I	565.87 (18.29)**	-61.418 (-9.87)**	-42.657 (-4.99)**	0.513	108.28**
2		II	37.584 (4.25)**	1956.1 (11.94)**	668.05 (8.80)**	.637	180.84**
3	C_{1a}	I	181.79 (13.57)**	-22.598 (-8.38)**	-9.580 (-2.59)*	.378	62.59**
4		II	16.743 (4.16)**	885.31 (11.85)**	71.082 (2.06)*	.487	97.63**
5	C_{1b}	I	59.503 (12.85)**	-5.854 (-6.28)**	-4.518 (-3.53)**	.312	46.80**
6		II	8.468 (5.23)**	71.266 (2.37)*	82.576 (5.93)**	.231	30.99**
7	C_{1c}	I	225.03 (13.94)**	-23.265 (-7.16)**	-19.609 (-4.40)**	.385	64.45**
8		II	1.759 (0.46)	752.53 (10.58)**	410.7 (12.47)**	.683	221.77**
9	C_{1d}	I	106.02 (14.21)**	-11.042 (-7.36)**	-8.371 (-4.06)**	.381	63.40**
.0		II	12.444 (4.64)**	268.67 (5.39)**	94.494 (4.10)**	.269	37.83**
.1	E_r	I	49.372 (6.01)**	-4.750 (-2.87)**	-3.949 (-1.74)	.091	10.26**
.2		II	10.195 (3.61)**	70.421 (1.35)	24.065 (0.99)	.023	2.30
.3	E_t	I	76.324 (10.24)**	-4.361 (-4.88)**	-10.052 (-2.91)**	.222	29.33**
.4		II	14.736 (5.71)**	148.07 (3.45)**	76.41 (3.09)**	.148	17.83**
.5	E_{rt}	I	125.7 (9.18)**	-9.11 (-3.31)**	-14.00 (-3.70)**	.184	23.25**
.6		II	24.93 (5.21)**	218.49 (2.46)*	100.47 (2.44)*	.089	10.01**

(Continued next page)

TABLE 1 CONTINUED

	Type of Cost	Model	a	b_1	b_2	R^2	F (2,206)
17	E_{rc}	I	131.67 (11.18)**	-15.175 (-6.40)**	-9.838 (-3.02)**	.299	43.93**
18		II	-0.586 (-0.20)	685.94 (12.81)**	165.53 (6.67)**	.615	164.70**
19	E_{rtc}	I	207.99 (12.77)**	-19.537 (-5.96)**	-19.889 (-4.42)**	.333	51.35**
20		II	14.15 (3.06)**	834.01 (9.72)**	241.94 (6.09)**	.508	106.37**
21	C_1+E_{rtc}	I	773.86 (17.78)**	-80.953 (-9.24)**	-62.546 (-5.20)**	.496	101.34**
22		II	51.733 (4.33)**	2790.1 (12.60)**	909.99 (8.87)**	.654	194.40**

+ Values of Student's t statistics are given in parentheses beneath each parameter estimate.

* Significantly different from zero at the 5% level.

** Significantly different from zero at the 1% level.

Source: Calculated from data found in Interstate Commerce Commission, *Transport Statistics in the United States: 1968*, Section A-11.

TABLE 2

ESTIMATED COST FUNCTIONS - 1973 SAMPLE

	Type of Cost	Model	Parameter Estimates†				
			a	b_1	b_2	R^2	$F_{(2,41)}$
1	C_1	I	439.34 (7.67)**	-52.499 (-4.04)**	-11.782 (-0.58)	0.1626	3.98*
2		II	24.266 (0.87)	4378.9 (3.37)**	629.66 (2.08)*	.2631	7.32**
3	C_{1a}	I	127.02 (7.70)**	-17.93 (-4.78)**	2.0695 (0.36)	.1576	8.32**
4		II	18.658 (2.07)*	1329.6 (4.04)**	48.131 (0.51)	.2743	23.44**
5	C_{1a_1}	I	64.905 (6.94)**	-7.5805 (-4.15)**	-0.5584 (-0.21)	.9929	2367.4**
6		II	12.259 (2.19)*	859.62 (3.74)**	43.213 (0.72)	.2120	5.514**
7	C_{1a_2}	I	36.982 (4.62)**	-5.0023 (-3.31)**	+0.4181 (0.20)	.1118	2.581
8		II	4.2799 (1.00)	647.93 (2.57)*	16.199 (0.34)	.0700	1.543
9	C_{1b}	I	41.400 (5.77)**	-5.195 (-3.14)**	+0.4597 (0.10)	.6823	44.03**
10		II	4.7148 (1.08)	241.49 (1.35)	113.34 (2.42)*	.1745	4.33*
11	C_{1b_1}	I	17.197 (6.38)**	-1.722 (-2.65)*	-0.741 (-0.83)	.0693	[illegible]
12		II	1.0185 (0.65)	84.012 (1.26)	52.239 (3.11)**	.2375	6.384**
13	C_{1b_2}	I	11.998 (4.66)**	-1.207 (-3.00)**	-0.8223 (-1.88)	.2120	5.515**
14		II	-0.27128 (-0.27)	104.93 (1.53)	35.263 (3.04)**	.2084	5.396**
15	C_{1b_3}	I	15.52 (3.93)**	-1.6366 (-2.72)**	-0.7979 (-1.26)	.2570	7.092**
16		II	1.1149 (0.61)	109.56 (1.23)	35.769 (1.78)	.0990	2.252
17	C_{1c}	I	163.32 (6.32)**	-19.396 (-3.31)**	-4.6621 (-0.51)	.1195	2.78
18		II	7.088 (0.61)	1980.5 (3.47)**	192.11 (1.50)	.2319	6.19**
19	C_{1c_1}	I	75.498 (5.35)**	-9.181 (-2.92)**	-2.7744 (-0.55)	.1619	3.959*
20		II	5.3249 (0.79)	635.39 (2.32)*	75.443 (1.05)	.1397	3.33*
21	C_{1c_2}	I	6.5879 (8.15)**	-0.8676 (-5.68)**	+0.0307 (0.14)	.3029	8.908**
22		II	0.9204 (1.96)	83.314 (3.65)**	4.876 (0.95)	.1716	4.246*

(continued on next page)

TABLE 2 CONTINUED

	Type of Cost	Model	a	b_1	b_2	R^2	$F_{(2,41)}$
23	C_{1c_3}	I	11.041	-1.2476	-0.5151	.8809	151.7**
			(3.16)**	(-2.06)*	(-1.46)		
24		II	0.7482	186.23	7.8928	.0375	0.798
			(0.61)	(2.03)*	(0.55)		
25	C_{1c_4}	I	122.11	-3.694	-26.29	.1395	3.324*
			(3.399)**	(-0.438)	(-1.848)		
26		II	-0.6997	271.5	315.93	.1695	4.183**
			(-0.047)	(0.639)	(2.142)*		
27	C_{1d}	I	81.658	-9.869	-2.627	.0297	0.626
			(5.43)**	(-3.80)**	(0.82)		
28		II	-3.1975	760.16	255.35	.2806	7.998**
			(-0.46)	(2.02)*	(3.28)**		
29	E_r	I	32.682	-3.0729	-2.2922	.8048	84.5**
			(4.48)**	(-3.00)**	(-2.46)*		
30		II	2.2062	124.42	85.628	.3080	9.115**
			(1.26)	(1.09)	(4.27)**		
31	E_c	I	21.866	-3.7906	+1.032	.2797	7.959**
			(5.69)**	(-4.42)**	(0.74)		
32		II	2.0809	291.75	-11.793	.7263	54.387**
			(1.32)	(8.39)**	(-0.80)		
33	E_t	I	71.667	-9.6091	-1.464	.3331	10.238**
			(7.32)**	(-4.35)**	(-0.40)		
34		II	3.4247	743.5	48.448	.2438	6.609**
			(0.93)	(4.02)**	(1.20)		
35	E_{t_1}	I	50.649	-6.6389	-1.408	.3104	9.229**
			(6.89)**	(-4.01)**	(-0.52)		
36		II	2.7375	437.00	42.029	.2585	7.146**
			(0.85)	(3.43)**	(1.22)		
37	E_{t_2}	I	14.869	-1.940	+0.0324	.4342	15.73**
			(5.37)**	(-3.61)**	(0.04)		
38		II	1.0838	243.04	+11.451	.1307	3.083
			(1.04)	(3.53)**	(0.95)		
39	E_{rc}	I	46.489	-4.8368	-1.0266	.5905	29.55**
			(6.56)**	(-2.83)**	(-0.44)		
40		II	4.8498	626.84	72.74	.2589	7.164**
			(1.43)	(3.79)**	(1.95)		
41	E_{rtc}	I	119.61	-14.199	-3.1555	.1427	3.411*
			(7.23)**	(-3.82)**	(-0.54)		
42		II	9.3116	1332.2	114.84	.2952	8.585**
			(1.32)	(4.20)**	(1.50)		
43	C_1+E_{rtc}	I	631.36	-75.123	-24.385	.2848	8.161**
			(8.04)**	(-4.29)**	(-0.87)		
44		II	32.329	5782.2	748.48	.2694	7.559**
			(0.95)	(3.59)**	(2.02)*		

†Values of Student's t statistic are given in parentheses beneath each parameter estimate.

*Significantly different from zero at the 5% level.

**Significantly different from zero at the 1% level.

Source: Calculated from data found in individual railroad reports covering the year 1973 submitted to the Interstate Commerce Commission.

models are presented in the first two lines of Tables 1 and 2. Both models have significant F-statistics, but Model II provides the better specification in both years. In this model, both the volume and the length of haul variables are of the expected sign and significant. When the components of operating costs are analyzed separately below, some are shown to depend heavily on volume alone while others are also related to distance.

The next set of estimated cost functions involved various components of operating costs. The first is maintenance of way costs (C_{1a}). For 1973, this category is subdivided into two parts: roadway maintenance, which is the largest single component of way maintenance costs (C_{1a_1}), and all other maintenance of way costs (C_{1a_2}).

The results of this set of regressions are shown in lines 3 and 4 of Table 1 and lines 3 through 8 of Table 2. Only in the two 1968 equations is the length of haul coefficient significantly different from zero. This result is not unexpected. The volume coefficient was signigicant in all cases, however. For total maintenance of way costs, Model II again appears to be the better specification. For both components of maintenance of way in Table 2, Model I is clearly superior even though it has a b_2 coefficient with an incorrect (though insignificant) sign.

The second major component of operating costs is maintenance of equipment (C_{1b}), whose cost function estimates are shown in lines 5 and 6 of Table 1 and lines 9 and 10 of Table 2. Equipment maintenance for 1973,

in turn, was broken down into locomotive repair (C_{1b_1}), equipment depreciation (C_{1b_2}), and other equipment maintenance costs (C_{1b_3}). Results of these regressions are presented in lines 11 through 16 of Table 2. Although average maintenance of way costs do not change significantly with different lengths of haul, some maintenance of equipment costs do. For locomotive repairs, C_{1b_1}, Model II is clearly the best specification. The coefficient of the length of haul variable is significant at the one percent level, indicating that this cost component is dependent upon the average length of haul. It is difficult to choose between the models for depreciation, C_{1b_2}, but again Model II has a significant distance variable. Therefore, longer hauls appear to result in better utilization of equipment and lower average costs. The third maintenance of equipment cost includes such expenses as superintendence of equipment maintenance, repairs to shop and power-plant machinery, other equipment repairs, and equipment retirements. These cost items do not appear to depend upon the average length of haul, but they do change significantly with changes in volume. The fact that the total maintenance of equipment cost (per ton mile), C_{1b}, does not vary systematically with the average length of the haul while two major components do illustrates the importance of disaggregating the cost items as finely as possible.

The third major cost component of operating costs (C_{1c}) is transportation-rail line expenses, or the costs of actually running the trains. The total for 1973 is disaggregated into four parts: employee compensation of train crews (C_{1c_1}), train fuel costs (C_{1c_2}), costs of loss, damage, casualties and personal injuries (C_{1c_3}), and all other

transportation costs (C_{1c_4}). Other transportation costs include superintendence and dispatching, station service, yard employees, yard switching fuel, and other train expenses.

Employee compensation of train crews is the largest single component of transportation-rail line costs. Lines 19 and 20 of Table 2 illustrate that this cost is invariant with respect to distance. Similarly, average train fuel costs, C_{1c_2}, and loss, damage, casualties and injuries to persons, C_{1c_3}, do not change significantly with a change in the average length of the haul. Also, for the first three cost items, Model I appears to be the better specification. Model II, however, is the better specification for the "other transportation" costs, C_{1c_4}, and the significance of the coefficient of the average length of haul indicates that longer hauls cause average other-transportation costs to fall. When all transportation costs are aggregated, the effect of distance on the other transportation variable is lost. Model II is also the better model for C_{1c}, but the distance variable is no longer significant.

The fourth and last component of operating costs consists of traffic, administrative, and miscellaneous expenses (C_{1d}). Results of regressions with this dependent variable are shown in lines 9 and 10 of Table 1 and lines 27 and 28 of Table 2. It is hard to predict *a priori* which variable, distance or volume, is likely to be most important in explaining these expenses. Model I looks better for 1968, but Model II is the better specification in 1973. Both indicate that these cost components decline very rapidly as the length of the haul increases.

Next, we ran a series of regressions on cost items other than those classified as operating costs. These are: equipment rentals (E_r),[1] the rate of return calculated on railroad investment (E_c),[2] and tax payments made to various levels of government (E_t) (other than income taxes). From this last group, we have broken out 1973 retirement system contributions and unemployment insurance payments (E_{t_1}) and property taxes (E_{t_2}) as separate items. The results for these costs are presented in lines 11 through 20 in Table 1 and 29 through 42 of Table 2. Note that the last several pairs of regressions are combinations of the individual items in the previous ones. E_{rc} is our estimate of a railroad's total return on capital, E_r plus E_c, while E_{rtc} combines rents plus taxes plus return on equipment, etc.

Model I appears to be the better description of rental expenses; average rent paid per ton mile decreases as volume or length of haul (in 1973) increase, the latter reflecting better utilization of cars when hauls are longer.[3] On the other hand, both models identify volume as the

---

[1] Since most small roads do not own their own freight cars, these are mostly per diem payments for cars owned by other rail lines.

[2] E_c was calculated as the sum of \$300 per mile of track (six percent interest on a salvage value of \$5,000 per mile, a figure estimated from recent ICC decisions relating to abandonments) plus a six percent return on investment in other equipment. The percentage was applied to estimated necessary equipment rather than actual equipment. Necessary equipment, in turn, was estimated by a formula relating equipment investment to total ton mileage. For example, for less than 200,000 ton miles, investment was estimated to be \$25,000; 200,000 to 500,000, \$37,500; etc. These figures were built on the basis of motive power requirements for various volumes of traffic.

[3] The per diem rate is a function of time the car is kept, the mileage, and the type of car.

more important factor in influencing 1973 necessary return on investment and taxes paid per ton mile, as would be expected. This is also true of both of the tax categories broken out in lines 35 through 38 of Table 2. Retirement system contributions (E_{t_1}) of course follow the pattern of employee compensation (C_{1c_1}). Property taxes follow the same type of pattern, which is not so surprising since in many states railroads are assessed for property taxes on the basis of capitalized earnings rather than fixed amounts per mile. The sum of these three variables, E_{rtc}, appears to follow the pattern set by the individual units.

The last pairs of cost functions, shown in lines 21 and 22 of Table 1 and 43 and 44 of Table 2, are most important from an overall standpoint, since these estimate the average cost per ton mile including all accounting costs plus the necessary rate of return on salvage value. The equations leave no doubt about the significance of volume in explaining variations in average costs. The importance of length of haul depends on the model and year selected. Because some of the disaggregated cost components are related to distance, we prefer Model II, where the length of haul is significant, though less so than volume, for both years. This result differs from the earlier findings of Meyer that length of track was not significant for average costs for Class I roads. This is not surprising: differences in distance are much more likely to be significant for short roads than for longer ones since terminal costs make up a higher percentage of total cost.

In summary, the two largest components of operating costs are maintenance of way (C_{1a}) and transportation-rail line expenses (C_{1c}).

These vary much more with volume than with distance; in other words, they cannot be adjusted closely to changes in the volume of traffic. This is also true for all of their subcategories in 1973 except other transportation costs (C_{1c_4}), which depend more on distance. The other two components of operating costs, maintenance of equipment (C_{1b}) and traffic,[1] administration, and miscellaneous costs (C_{1d}), are related to both volume and distance. Rate of return (E_c) and tax payments (E_t) depend on volume alone, but equipment rentals (E_r) depend on volume and distance. The fact that equipment rentals, maintenance of equipment, traffic and some of the transportation costs are related to distance implies a better utilization of manpower and equipment for longer hauls. It is clear, however, that volume is the most important determinant of average cost.

Diagrammatical Presentation

Figure 1 shows the estimated average cost functions for 1973 with various average lengths of haul, using Model I (line 43 of Table 2), and Figure 2 provides the same type of information using Model II (from line 44). Both, of course, show a steady decline up to 140,000 ton miles per mile, but with Model II the curves flatten out beyond this figure. The Model II chart also shows a much greater significance of the distance variable for roads with lengths of haul under 25 miles than over 25 miles.

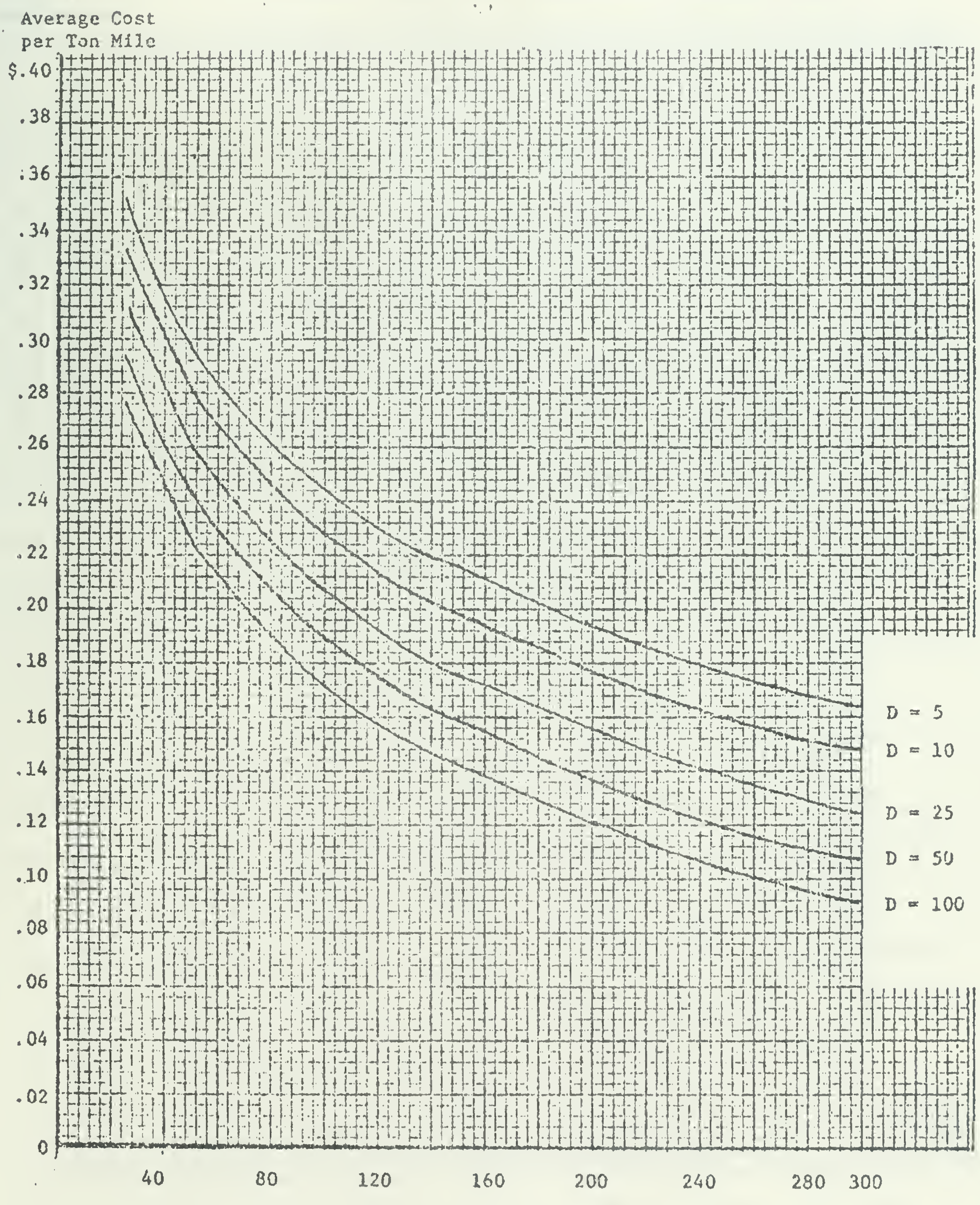
Table 3 shows the operating costs per ton mile and total costs per ton mile for the roads in the 1973 sample. The roads are in the order of net miles per mile of line. The data suggest the following conclusions:

---

[1] Costs related to issuance of tariffs and solicitation of traffic.

FIGURE 1

ESTIMATED AVERAGE COST FUNCTIONS BY DISTANCE--MODEL I



000 Net Ton Miles per Mile

D = Average length of haul

FIGURE 2

ESTIMATED AVERAGE COST FUNCTIONS BY DISTANCE--MODEL II

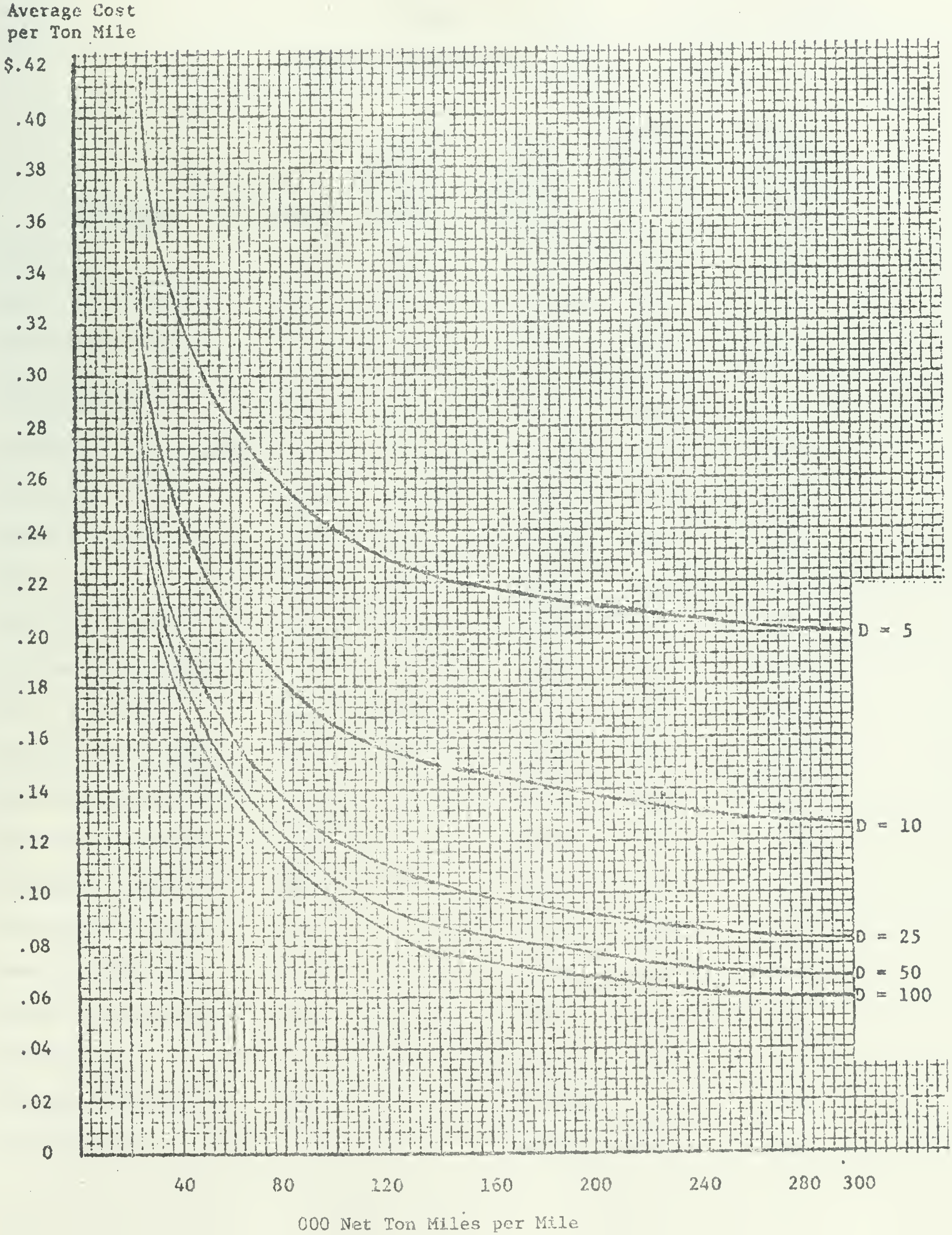


TABLE 3

COST DATA, SAMPLE ROADS, 1973

Railroad	Miles	Average Length of Haul, Miles	Net Ton Miles per Mile of Line	Average Operating Cost per Ton Mile ¢	Average Overall Cost per Ton Mile ¢
Yancey	13	7	8,046	34.5	51.3
Warren & Saline River	19	3	9,764	44.7	54.6
Cotton Plant-Fargo	6	6	10,974	33.6	46.0
Fonda, Johnstown & Gloversville	20	11	16,024	55.0	75.4
Hillsboro & Northeastern	5	5	17,131	20.2	28.6
Montpelier & Barre	14	5	25,147	49.6	57.5
Arcade & Attica	15	11	27,358	36.9	42.1
Cadiz	10	10	35,270	22.7	26.8
Bellefonte Central	18	5	37,818	27.2	33.8
Bath and Hammondsport	9	7	43,533	32.5	41.3
Hollis & Eastern	34	19	43,773	8.2	10.7
Virginia Blue Ridge	10	8	45,897	20.1	26.0
Greenville & Northern	11	5	54,757	24.7	30.9
Pecos Valley Southern	34	16	66,438	7.9	9.9
Winchester & Western	20	20	68,758	6.7	8.8
Garden City Western	14	7	72,133	10.9	15.0
Texas & Southeastern	21	5	93,197	24.8	28.4
Prescott & Northwestern	31	13	97,104	13.0	14.9
Mississippian	24	17	119,195	7.0	9.3
Hartford & Slocomb	22	22	120,990	7.6	9.1
Yreka Western	8	7	132,134	20.5	23.5

TABLE 3 (continued)

Railroad	Miles	Average Length of Haul, Miles	Net Ton Miles per Mile of Line	Average Operating Cost per Ton Mile ¢	Average Overall Cost per Ton Mile ¢
Belfast & Moosehead Lake	33	19	132,229	9.7	12.6
Amador Central	12	12	140,055	14.1	17.4
Angelina & Neches River	12	4	167,218	17.2	21.5
McCloud River	108	40	211,963	5.9	7.2
Tucson, Cornelia & Gila Bend	44	44	212,202	2.9	4.2
Oregon & Northwestern	51	25	212,852	4.1	5.2
Dardanelle & Russelivill e	5	5	224,995	15.4	20.9
Graysonia, Nashville & Ashdown	32	16	228,274	3.8	5.3
Vermont	129	67	235,218	4.0	5.2
East Tennessee & Western North Carolina	12	8	253,054	11.0	14.6
Aberdeen & Rockfish	46	21	296,747	4.4	5.6
Louisiana & Northwest	63	38	313,628	4.2	5.4
Sabine & Northern	29	15	391,270	4.2	5.4
City of Prineville	18	18	432,456	5.4	6.8
Arkansas & Louisiana Missouri	54	28	546,656	4.1	5.8
North Louisiana & Gulf	39	23	567,331	4.4	5.9
San Manuel Arizona	29	26	572,404	3.4	4.9
Valdosta Southern	10	10	702,344	4.7	7.0
Bevier & Southern	10	10	719,420	3.6	4.2
Apache	72	72	819,255	1.4	1.9
Corinth & Counce	16	16	1,006,767	3.3	4.6
Mississippi Export	42	40	1,747,042	2.0	3.0
Atlanta & St. Andrews Bay	81	71	2,413,119	1.6	2.2

1. There are substantial economies of scale, but these are ultimately exhausted.

2. All roads with traffic under 55,000 ton miles per mile have costs in excess of 25 cents a ton mile except the grain-hauling Hollis and Eastern.

3. No roads with volume over 55,000 ton miles per mile and average hauls over 7 miles had costs per ton mile in excess of 18 cents per ton mile.

4. No roads with volume over 200,000 ton miles per mile and hauls over 8 miles had costs in excess of 7 cents per ton mile.

5. The heaviest traffic roads in the sample had costs under 5 cents a ton mile.

The cost per ton mile data without adjustment for distance are plotted against volume on Figures 3 and 4 for 1968 and 1973 respectively.

Economic Justification of Light Traffic Lines

These data provide us with substantial information for establishing some criteria as to the economic viability of light traffic lines. Their viability, without regard to externalities, is a function of:

1. The cost per ton mile on the main line (C_1);
2. The cost per ton mile on the light traffic line (C_2);
3. The length of haul on the main line (M_1);
4. The length of haul on the light traffic line (M_2);
5. Cost of competitive motor transport (C_c);
6. Cost of transfer between motor transport and rail at the junction (T).

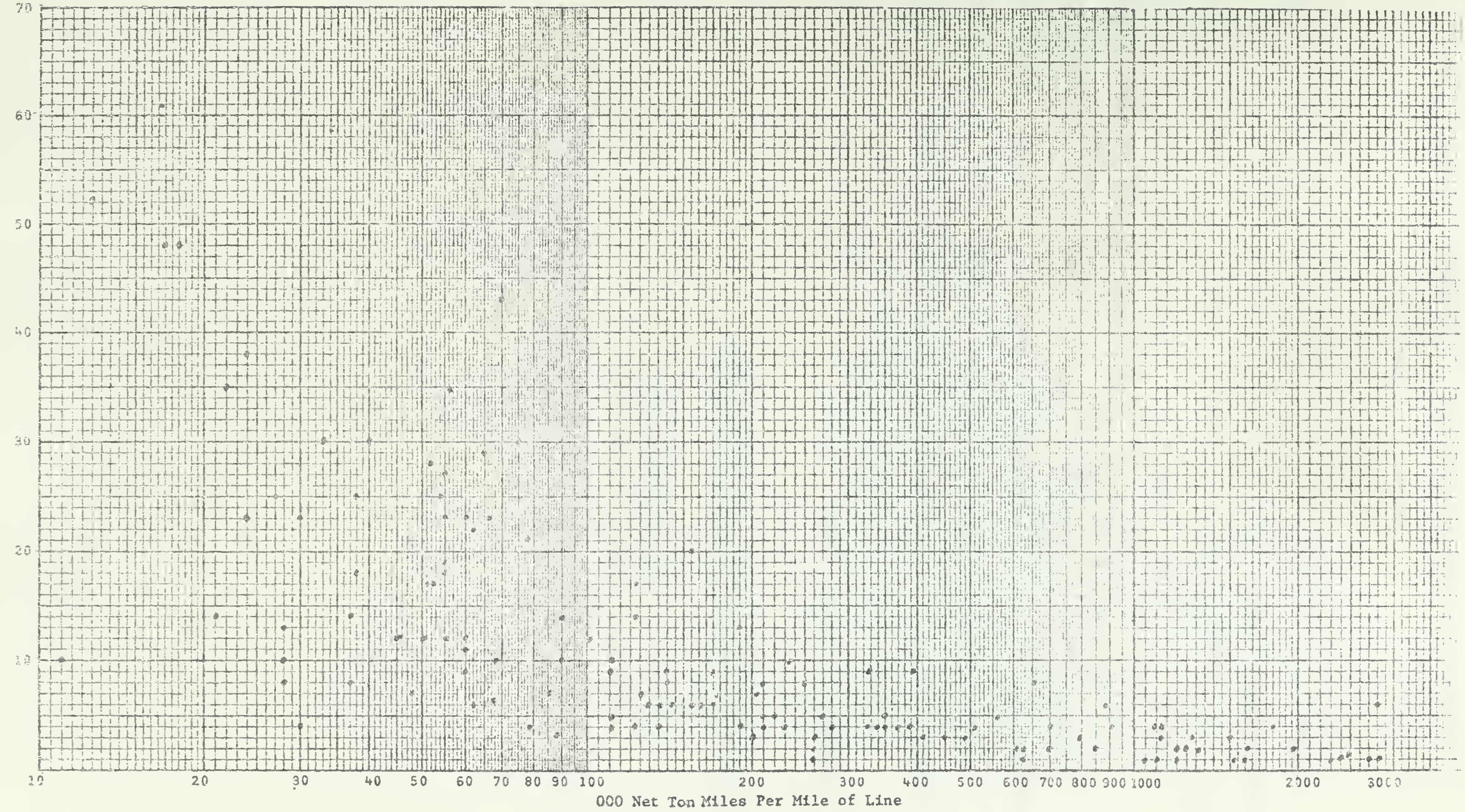
Initially, 6, the cost of transfer, will be excluded from consideration. For simplification, water transport will be omitted from the analysis.

The length of main line haul necessary for the line to be viable can be determined on the basis of the following formula:

$$M_1C_1 + M_2C_2 = C_c(M_1 + M_2). \tag{4}$$

FIGURE 3

RELATIONSHIP OF COST PER TON MILE AND NET TON MILES PER MILE OF LINE (UNADJUSTED FOR DISTANCE)
SAMPLE OF CLASS II RAILROADS, 1968



revenues (we assume that the economic distortions caused by the revenue source for the subsidy are less than those that would result from excessively high rates or loss of the road). In the past, this subsidy has often been provided by the connecting main line road through liberal rate division, in excess of the Class II line's contribution to the main line's net revenue, contrary to the basic economic objection to any form of cross-subsidization. There is, therefore, strong justification for subsidization of those lighter traffic Class II roads economically justifiable on the criteria noted above in addition to subsidization justified by externalities. With the heavier density lines (over one million ton miles per mile), marginal cost approaches average cost and the subsidy should be unnecessary.

Nancy D. Sidhu, Associate Professor of Economics
Northeastern Illinois University

Alberta Charney, University Fellow &
Research Assistant
University of Illinois, Urbana

John F. Due, Professor of Economics
University of Illinois, Urbana

FIGURE 4

RELATIONSHIP OF COST PER TON MILE AND NET TON MILES PER MILE OF LINE (UNADJUSTED FOR DISTANCE)
SAMPLE OF CLASS II RAILROADS, 1973

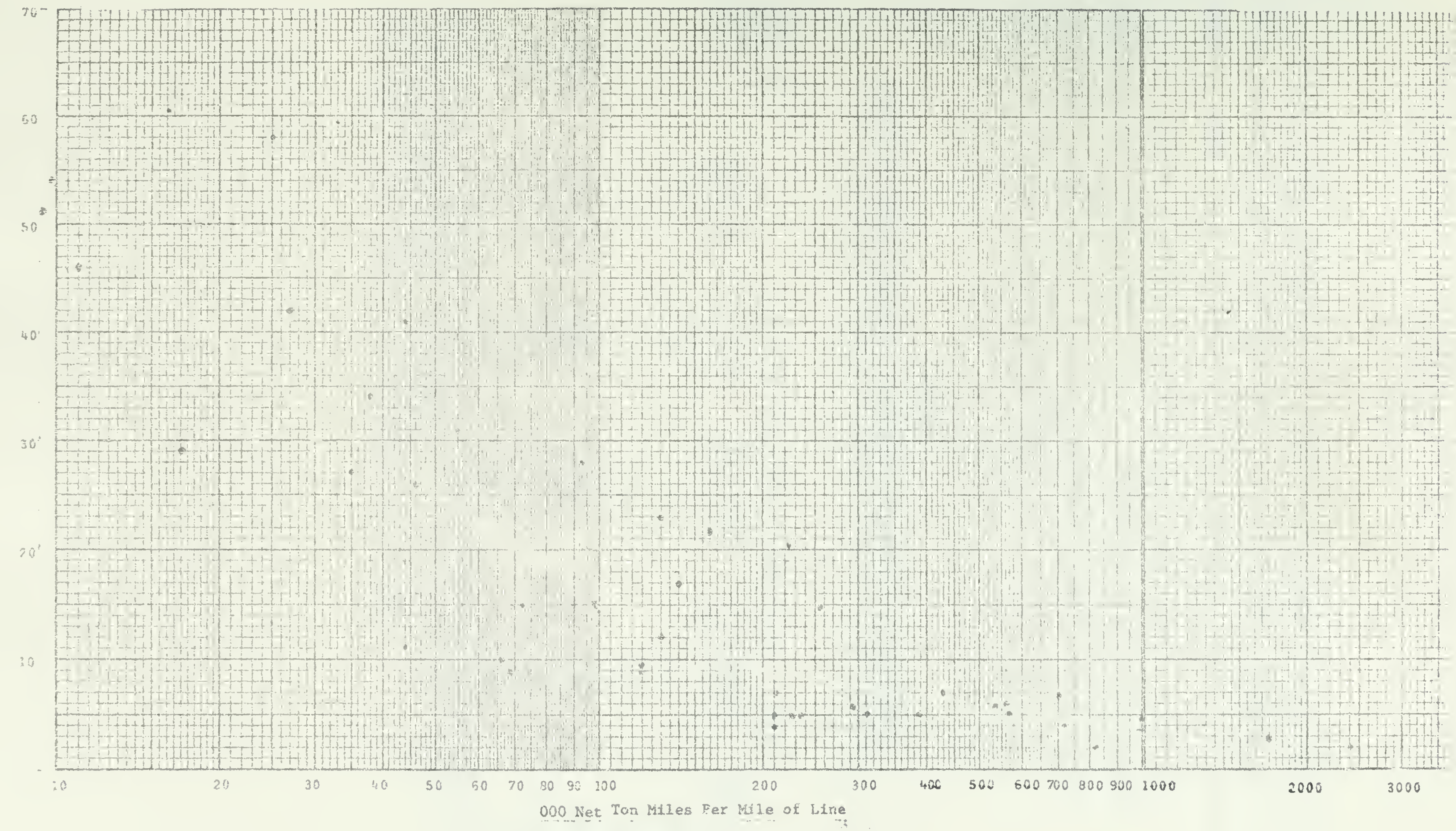


Table 4 shows the figures for length of main line haul necessary for branch line viability, without regard to externalities, assuming competitive trucking costs of two cents per ton mile, main line costs of 1.5 cents per ton mile, varying costs per ton mile on the Class II road, and varying lengths of haul of the Class II road. The higher is cost per ton mile on the light traffic line, the longer must the (lower cost) main line haul be to justify existence of the branch.

TABLE 4

LENGTH OF MAIN LINE HAUL NECESSARY FOR CLASS II RAILROADS TO BE ECONOMICALLY VIABLE, TRUCKING COSTS OF 2¢ PER TON MILE

Length of Haul on Class II Road	Cost per Ton Mile on the Class II Road				
	C_2 = 2¢	C_2 = 4¢	C_2 = 6.5¢	C_2 = 13¢**	C_2 = 26¢
5	0	20	45	110	240
10	0	40	90	220	480*
25	0	100	225	550*	1,200*
50	0	200	450	1,100*	2,400*
100	0	400	900*	2,200*	4,800*

* Indicates that transfer from truck to rail at the junction is cheaper, with some transfer cost. See below.

**The Model II cost figure for the median road in 1973.

While the cost assumptions for Class I and Class II roads are reasonable for 1973, the competitive cost figure may be regarded as on the low side; only under the most favorable circumstances--full loading and full backhaul, owner-operated trucks--can trucking costs be as low as two cents per ton mile. More typical costs of four cents would reduce the necessary main line haul in half, as shown in Table 5.

TABLE 5

LENGTH OF MAIN LINE HAUL NECESSARY FOR CLASS II RAILROADS TO BE ECONOMICALLY VIABLE, TRUCKING COSTS OF 4¢ PER TON MILE

Length of Haul on Class II Road	C_2 = 2¢	C_2 = 4¢	C_2 = 6.5¢	C_2 = 13¢**	C_2 = 26¢
5	0	10	22.5	55	120
10	0	20	45	110	240*
25	0	50	112.5	275	600*
50	0	100	225	550*	1,200*
100	0	200	450*	1,100*	2,400*

* Indicates that transfer from truck to rail at the junction is cheaper, with some transfer cost. See below.
**The Model II cost figure for the median road in 1973.

The conclusions based on Tables 4 and 5 about economic justification are subject to the constraint of item 6 above: if the cost of transfer of the commodity from road to rail at the nearest rail junction (using road

instead of rail for the branch route) allows a lower cost than an all-rail haul, then the branch is not viable. In this case, the important relation is:

$$(5) \qquad M_2C_2 = M_2C_c + T.$$

If we assume four cents per ton mile truck costs,[1] 13 cents branch line costs, and $1.50 transfer costs per ton, transfer to truck would be advantageous rather than retention of the branch line whenever the branch line haul exceeds 17 miles in length. Alternatively, with a branch line cost of 26 cents per ton mile (or a median road with empty backhauls), a branch haul of more than seven miles in length would be unjustified; with a cost of 6½ cents, 60 miles. Similar calculations can be made for other levels of transfer costs. The influence of distance on branch line cost per ton mile, shown in Figures 1 and 2 but not reflected in Table 3, increases the breakeven distance for the branch only slightly. These figures do not take externalities into consideration; externalities may justify retention of lines not economically viable on the basis of revenues and costs alone.

Roads with volume in excess of 800,000 ton miles per mile of line, which have costs close to two cents per ton mile, are clearly economically justifiable even if there is no main line haul, since truck costs can reach this figure only under the most favorable circumstances. While there were only two roads in the 1973 sample with costs this low, the 1968 data with a larger sample show similar results.

Elasticity of Cost Items with a Median Road

Another aid to interpretation of our results is given in Table 6, showing data for a hypothetical railroad which carries the median volume

---

[1] This type of truck operation normally involves an empty backhaul.

of our 1973 sample, 136,142 ton miles per mile of line with an average length of haul of 14.12 miles, the 1973 sample median length of haul. Table 6 shows the costs per ton mile and elasticities of the various cost items with respect to changes in ton miles for both Models I and II.[1]

This table suggests the following conclusions for a light traffic road near the median:

1. The elasticity of all items is less than one, indicating that all factor inputs cannot be adjusted perfectly to changes in volume without loss of efficiency.

2. The highest Model I elasticity is found with C_{1b}, maintenance of equipment (0.72); the lowest is with C_{1c_4}, other transportation costs (0.13).

3. The highest Model II elasticity is found with C_{1a}, maintenance of way (0.59); the lowest elasticity of the correct sign is with C_{1b_1}, locomotive repairs (0.19).

4. The elasticity of all operating expenses is approximately 0.57 under Model I (0.24 under Model II); the elasticity for all costs is very similar (0.50 under Model I and 0.25 under Model II). These figures contrast sharply with Griliches' figure of over 0.95 for large Class I roads.

<u>Regional Cost Functions</u>

The last stage of this project consists of estimations of regional cost functions. Previous work by Borts[2] on Class I railroads indicates

---

[1] The lower elasticities for Model II are due to the particular volume level of the median road used in the calculation of the elasticities. Model II has a relatively steep descent and then flattens out after 140,000 ton miles per mile. The elasticities would be higher for larger volume levels.

[2] Borts, op. cit.

TABLE 6

ESTIMATED COSTS PER TON MILE AND COST ELASTICITY FOR A MEDIAN RAILROAD*

	Type of Cost	Model	Cost per Ton Mile	Elasticity**
1	C_1	I	$.1502	.5720
2		II	.1010	.2402
3	C_{1a}	I	.0444	.6427
4		II	.0318	.5861
5	C_{1a_1}	I	.0265	.6541
6		II	.0216	.5666
7	C_{1a_2}	I	.0135	.6607
8		II	.0102	.4201
9	C_{1b}	I	.0171	.7229
10		II	.0145	.3248
11	C_{1b_1}	I	.0068	.6365
12		II	.0053	.1909
13	C_{1b_2}	I	.0039	.4784
14		II	.0031	-.3260
15	C_{1b_3}	I	.0054	.5463
16		II	.0045	.2504
17	C_{1c}	I	.0557	.5679
18		II	.0352	.2011
19	C_{1c_1}	I	.0230	.4811
20		II	.0153	.3472
21	C_{1c_2}	I	.0024	.6522
22		II	.0019	.4901
23	C_{1c_3}	I	.0035	.5031
24		II	.0027	.2797
25	C_{1c_4}	I	.0344	.1276
26		II	.0237	-.0296
27	C_{1d}	I	.0262	.5232
28		II	.0205	-.1562
29	E_r	I	.0115	.5341
30		II	.0092	.2402

TABLE 6 (continued)

	Type of Cost	Model	Cost per Ton Mile	Elasticity*
31	E_c	I	$.0061	.5442
32		II	.0034	.6141
33	E_t	I	.0206	.4618
34		II	.0123	.2780
35	E_{t_1}	I	.0143	.4373
36		II	.0089	.3067
37	E_{t_2}	I	.0054	.6483
38		II	.0037	.2945
39	E_{rc}	I	.0200	.7069
40		II	.0146	.3320
41	E_{rtc}	I	.0415	.5817
42		II	.0272	.3420
43	$C_1 + E_{rtc}$	I	.1977	.4966
44		II	.1278	.2529

---

*A median railroad of the sample has a volume of 136,142 ton-miles per mile and an average length of haul equal to 14.12 miles.

**These are elasticities of total cost with respect to ton-miles. For Model I, it is:

$$e = \frac{AC - b_1 - b_2}{AC} = 1 - \frac{b_1 + b_2}{AC} .$$

For Model II,

$$e = \frac{a}{AC} .$$

that railroads in different regions of the U. S. do have different cost structures. Accordingly, our 1968 sample[1] was divided into three regions: Eastern (n = 62 roads), Southern (n = 57 roads), and Western (n = 90 roads).[2] Regressions were run for all dependent variables in Table 1 (except that $C_1 + E_{rc}$ was substituted for $C_1 + E_{rtc}$) for each model for each region. The regional cost differences as shown in Table 5 are summarized by calculating cost estimates for each region for our 1968 median railroad[3] and comparing them. These estimates are presented in Table 5 .

This table indicates that Class II railroads in the Eastern region do have substantially higher costs, at given volume and distance, than their counterparts elsewhere in the United States. Borts made this same finding for Class I roads.[4] Furthermore, our results show that costs of Class II railroads in the Southern and Western regions are quite similar. Borts found this to be true for Class I roads also.[5] Most of the difference in regional total costs is shown to be caused primarily by differences in costs of equipment maintenance, transportation-rail line costs, and miscellaneous expenses.[6]

---

[1] The 1973 sample was too small to divide in this manner.

[2] These regional groupings are established by the ICC.

[3] The 1968 median road is slightly longer (distance = 19 miles) and has a higher volume (volume = 141,700 ton miles per mile) than the 1973 median road. Consequently, the costs shown in Table 7 are slightly lower than if we had used the 1973 median railroad. Detailed data of these cost functions are available from the authors.

[4] Borts, op. cit.

[5] Ibid., especially p. 117.

[6] A partial explanation is that the Southern and Western lines are primarily bulk commodity haulers, with heavier loading per car and less frequent service. Many Eastern roads are carriers of manufactured goods with frequent service required. The upward trend in traffic for Western and Southern lines, coupled with the lag in adjustment of certain costs, is another factor.

TABLE 5

ESTIMATED 1968 COSTS PER TON MILE OF A MEDIAN RAILROAD BY REGION*

	Type of Cost	Model	Region		
			East	South	West
1	C_1	I	$.1591	$.1156	$.1228
2		II	.1344	.0616	.0683
3	C_{1a}	I	.0459	.0427	.0332
4		II	.0338	.0204	.0219
5	C_{1b}	I	.0231	.0141	.0138
6		II	.0235	.0085	.0094
7	C_{1c}	I	.0586	.0385	.0551
8		II	.0509	.0205	.0228
9	C_{1d}	I	.0344	.0203	.0217
10		II	.0302	.0118	.0154
11	E_r	I	.0156	.0118	.0128
12		II	.0155	.0077	.0110
13	E_c	I	.0113	.0091	.0169
14		II	.0019	.0038	.0012
15	E_t	I	.0249	.0182	.0271
16		II	.0200	.0125	.0223
17	E_{rt}	I	.0406	.0301	.0398
18		II	.0355	.0203	.0333
19	E_{rc}	I	.0270	.0209	.0297
20		II	.0174	.0115	.0122
21	E_{rtc}	I	.0519	.0392	.0568
22		II	.0374	.0240	.0345
23	C_1+E_{rc}	I	.1861	.1365	.1525
24		II	.1518	.0731	.0805

---

* A median railroad in 1968 was 19 miles long and had a volume of 141,700 ton-miles per mile.

Source: Calculated from parameter estimates in Tables 5, 6 and 7.

Conclusions

1. There is strong evidence of substantial economies of scale for light traffic rail lines, not found for Class I roads.

2. Most of these economies are exhausted at a relatively low volume of traffic--many by 50,000 ton miles per mile of line, almost all by 250,000. These are very low volumes by main line standards.

3. Long run marginal cost, therefore, is well below average cost. This is not an indication of "excess capacity" in the sense of unnecessary fixed plant, since for these single track lines to eliminate trackage would require their demise, and much or all of the traffic is from one end to the other. Rather, these roads adjust plant capacity by reducing maintenance and adjusting amounts of other types of equipment. Still, MC remains below AC.

4. The two largest components of cost, maintenance of way and transportation-rail line, are substantially influenced by volume but not by average length of haul. Only equipment maintenance, equipment rentals (mostly per diem charges for freight cars), and general traffic and administrative expenses are influenced to any significant extent by the length of haul as well as by volume.

5. Overall costs per ton mile are, therefore, not influenced as much as might be expected by length of haul; the economies for short lines from increased length of haul are not as great as might be expected.

6. In the lower volume categories, there is a substantial range of observed average costs, at given traffic volumes, depending upon frequency of operation required, wage rates, conditions affecting maintenance, and management effectiveness.

7. The declining nature of the average cost curve suggests that if traffic is relatively low and volume falls, costs per ton mile will rise to a point at which the line ceases to be economically justifiable.

8. The economic justifiability of a line is a function of the traffic density on the line, the length of haul on the line, the length of haul on the main line, alternative costs of hauling by truck (or water), and the costs of transference between rail and truck, as well as other influences in cost per ton mile. A few generalizations can be made in this area:

(a) Lines with traffic less than 50,000 ton miles per mile typically have costs over 25 cents per ton mile and are likely to be justifiable only if the line is very short--under 10 miles--or special conditions allow very infrequent service, make transfer-to-truck cost unusually high, or allow an unusually high freight rate.

(b) Roads with traffic between 50,000 and 200,000 ton miles per mile may be justifiable, depending on the main line haul, length of the line, and the ability to hold costs down.

(c) Roads with traffic between 200,000 and 800,000 ton miles per mile and under 25 miles in length of haul are almost certain to be economically justifiable unless cost of transference from truck to rail is very low or main line haul is very short.

(d) Roads with traffic over 800,000 ton miles per mile are likely to be economically justifiable even without a main line haul.

9. Since long run marginal cost is less than average cost, optimal rates for traffic on economically justifiable light traffic lines should be below average cost, with the difference subsidized out of governmental

BOUND BY
HNM
1-94

UNIVERSITY OF ILLINOIS-URBANA
3 0112 060296685