THE EFFECTS OF SCALE IN THE RAILROAD INDUSTRY

KENT T. HEALY

T. DEWITT CUYLER PROFESSOR OF TRANSPORTATION

YALE UNIVERSITY

COMMITTEE ON TRANSPORTATION

YALE UNIVERSITY

1961

ACKNOWLEDGEMENTS

Particular credit must go to Professor John P. Miller for providing the stimulus to push this study to completion. The author is deeply indebted to Professors Miller and John R. Meyer and Dr. Edward Margolin for criticizing the manuscript at various stages. Though the final draft incorporates many of their suggestions, it is entirely the responsibility of the author. For help on the statistical aspects of the study the author is grateful to Dr. C. I. Bliss, Messrs. D. D. Hester and M. J. Huber, and Professors J. Tobin, H. W. Guthrie, R. Summers, and in particular, H. W. Watts.

Thanks are due to Mr. T. B. Ellsworth for the burden of statistical compilation and to Mrs. L. Albert for the typing of the various revisions. For unpublished and privately circulated data credit is due to Messrs. Lloyd W. Dorsey, S. Towne and D. A. Watts. The author is indebted to a number of officers of both large and small railroad systems for discussions concerning various aspects of the study.

The greatest debt of all is due my wife who has read both manuscript and proof numerous times and has given invaluable moral support all through the study.

KENT T. HEALY

New Haven, Connecticut
May 1961

TABLE OF CONTENTS

CHAPTER I INTRODUCTION AND CONCLUSIONS

INTRODUCTION

The effect of size or scale on economic performance is a key aspect of the economics of business enterprise and industrial organization. The trend with the passage of time for companies to become larger through mergers as well as growth makes it of particular interest to obtain objective measures of the economies or diseconomies and other effects of increasing scale. Economists have long been tempted by the possibilities of empirical studies of these effects but have been frustrated by the inadequacy of data, the difficulty in defining the terms of the problem and the limitations within industries in the number and the range in scale of individual companies. Railroads offer some of the best possibilities for analysis of this sort because of the relatively large number and wide range in scale of companies and because more complete data are published for them than for any industry except gas and electric utilities and air carriers.

The fact that the railroad systems, as do most industry units, produce different service mixes raises the most difficult problems of all for analysis. The railroads not only provide the obvious mixtures of passenger, express, baggage and less-than-carload and car-load freight services. In addition, within each of these categories, there are mixtures of dissimilar services. For instance, in the case of carload freight, there is the hauling of coal, steel ingots, cantaloups and automobiles. Further the service provided by any particular system may vary all the way from merely transferring cars in line haul from one adjoining system to another, to providing complete originating and terminating services including supplying of empty cars for loading, in addition to the line haul. The difficulty of obtaining a measure of output under these circumstances is obviously great. Revenue, corrected for system extremes in unit freight revenue level, is used as the measure of composite output best reflecting the differences in mix of service.

The railroads of the United States provide for analysis a sample of 37 independent systems with over 2000 employees. These systems have reasonably homogeneous characteristics, the sample having been reduced to 37 by excluding systems which are predominantly coal or passenger carriers or are closely associated with a single shipper.

Scale in this study is considered to be system size as gauged by operating revenue, capital investment and the number of employees. Thus scale is the characteristic of size in the sense of the extent of organizational lines of communication, the size of the labor force and physical facilities, and the volume of services performed. A typical small railroad would be one with 3,000 employees, a net investment of $75,000,000 in road and equipment and an annual operating revenue of $30,000,000. A big system would be one with 75,000 employees, $1,400,000,000 investment, and $650,000,000 revenue.

System scale is a function of both length of road and traffic density per mile of road. A system of very long road mileage but light density with a large number of employees may be considered large scale but so may one of shorter mileage with heavy density which has the same number. The effects of traffic density are considered separately from those of scale though there is obviously some interdependence of the two characteristics. The effect of density on utilization of capital and labor inputs can be quite separate from the effects of scale as defined here. Possible gains from high utilization of track and equipment with heavy density traffic, for instance, are available to small scale as well as to large scale systems. There are in fact systems with under 6000 employees which have traffic densities as high as many systems with over 40,000 employees. In the analysis any density effects must be and are accounted for before considering possible scale effects.

CONCLUSIONS

For western systems up to but not including those of very highest traffic density the analysis indicates that capital requirements, wages and transportation (train, yard and station operations) expense per unit of composite output all decline with increasing density while rate of return on capital increases. For southern systems there is a suggestion of a decline in unit capital but there are no statistically significant relationships with density, except for an increase in rate of return with increasing density. For eastern systems, most of which operate at densities higher than do those in the other two regions, there is no relation between density and any of the measures of performance. This last can also be said for the entire sample regardless of region at densities of over $50,000 annual revenue per mile of road.[1]

After taking into account these density relationships, scale itself can be considered. First, for the smaller systems with from 5,000 to 19,000 employees there is a lower capital investment per unit of composite output than for the larger systems. The difference tends to be as much as 14% in favor of these smaller systems. For scales below 5,000 employees the unit investment is higher.

Second, as scale increases, wages per unit of output increase. The trend suggests a 13% increase with an increase in scale from 10,000 to 80,000 employees. In this case the trend is continuous from the smallest to the largest scale.

With respect to the wage-capital ratio, the above two relationships are counter-balancing so that this latter ratio is not affected significantly by scale. The higher unit wages associated with increasing scale are paralleled by greater unit capital requirements.

Next, considering expenses by broad functional categories, the maintenance share of revenue is so greatly affected by factors other than density and scale that no significant relationship with scale is demonstrated. There is some suggestion of a rise with increasing scale, and in no case evidence of the opposite. Another measure of mainte-

[1]c.f. G. H. Borts, "The Estimation of Rail Cost Functions," **Econometrica**, XXVIII, No. 1, p. 116, ". . . long run increasing costs prevailed only in the Eastern region, while long-run decreasing or constant costs occurred in the South and West." This statement was made in a different context, involving a study of just freight service cost characteristics, and without a differentiation between density and scale.

nance is its relation to capital investment and here again there is no significant association in one direction or the other with scale.

On the other hand, with increasing scale there is increased transportation expense per unit. The trend suggests a 12% increase in unit expense going from 10,000 to 80,000 employees.

Two much smaller functional categories of expense are for administration and sales. They are the only categories in which the relationship is that of decrease with increasing scale. Together their trend lines show a 3% point decrease in share of expense with an increase in scale from 10,000 to 80,000 employees. However, three of the four subcategories of administrative expense are included in maintenance and transportation expenses already considered.

Finally, a resultant of all these relationships and the variations in revenue level is decreasing return on capital with increasing scale above 10,000 employees and a decrease also below 5,000. This relationship, like the others just reviewed, is after taking into account regional differences and the effect of traffic density. The relationship holds also if the heavier passenger carrying systems are eliminated from consideration. The trend lines of the scale-return relation suggest that return on capital for a scale of 10,000 employees is at least 3% points higher, or over 100% greater, than for a scale of 80,000 employees.

In summary, the analysis indicates that an increase in scale above 10,000 employees is associated with an increase in wages and transportation expenses and with lower rates of return, and above 19,000 with an increase in unit capital requirements. These conclusions are strengthened by the fact that where there is inter-dependency between ratios, namely the capital-wage ratio and the rate of return as they relate to the other ratios, there is complete consistency.

Finally, consideration can be given to the causal factors that may account for these significant relationships. First it should be noted that with few exceptions there are few gains with increasing scale by way of ability to use larger labor or capital saving physical operating units. For instance any of the railroad systems in the sample do, as conditions other than scale warrant, use the heaviest locomotives or rail, and centralized traffic control and all use the same freight cars and similar passenger cars. The intensity of their use may vary with density, however. But the analysis suggests that once a certain average density of traffic is reached, around the $40,000 to $50,000 level of annual revenue per mile, there are no opportunities for further density advantages.

On the output side increasing size might be expected to provide greater control over the market, with resultant higher prices and greater shares of the market. Rates are in fact the same regardless of size. The analysis of revenue offers no evidence that divisions of through rates have been usually in favor of the larger systems. As to shares of the market, obviously a large system tapping four times the economic activity of the country than a smaller system does, will have, other things being equal, four times the traffic. But beyond that it is common knowledge that where lines are in the same territory and parallel, smaller systems have often by their superior service been able to attract traffic away from larger ones. The more intimate contact possible between shippers and the whole railroad organization in the case of smaller systems can lead to better communication, faster response and more mutual understanding and working together. All this can in turn be credited with reinforcing employee morale.

Finally, coming to what may be the heart of the problem, the larger organizations by more layers in the vertical and vastly wider spread in the horizontal lines of authority and communication introduce frictions and inertia that make for slower responses, less sense of urgency and responsibility, less individual initiative, and more of what are known as bureaucratic tendencies. Esprit is harder to build up and maintain, leadership is more difficult to establish and convey through the ranks. For a manufacturing enterprise these problems can be more readily compensated for by physical quality control and rejection of what does not come up to standard. For a railroad which is performing a service, the delays cannot be shunted off and the human aspects of performance are an integral part of the service.

The differences between manufacturing and railroading may be further stressed. A characteristic of the railroad industry in contrast to manufacturing, for example, is that labor costs are a substantially higher proportion of revenue. Wages alone are nearly 50% of revenue. Also a large share of labor is more decentralized, not working under close supervision within the confines of a building. Much of labor is also not machine paced as it is with manufacturing. All this provides the opportunity for serious adverse results in railroads with large scale organization resulting in poorer morale or esprit and reduced control over performance.

These are the likely causes for the empirical showing that increasing scale for railroads beyond some 10,000 employees leads to poorer performance. Together these conclusions have important policy implications. They suggest that the wave of enthusiasm for creating vast railroad systems needs critical examination. Consolidation proposals are advocated on the grounds of cost saving and they also involve consideration of gain in ability to garner traffic and diversify regionally as well as in type of freight carried. The snowballing of railroad consolidation proposals to an important degree grows out of a supposed need on the part of one carrier or group of carriers to defend their market position against the threat of the consolidation of other carriers. The proposals are also in response to an over-all change in transport technology with a decline in the railroad share of the total picture, and with changing technology in railroading itself. But the 40 or 37 railroad systems of this study are almost without exception the result of earlier consolidations. These were consolidations decided upon after studies of possible economies, competitive gains in shares of traffic, and need for defense against other consolidations, much the same factors as are now operative. Financial factors and personal ambitions also had their part, as they do now.

The conclusions of this study suggest two things. First, for roads of low traffic density, consolidation which transforms low density systems into a single system with traffic density in the higher ranges will offer economic benefit if the resultant system scale does not get so large that scale losses offset density gains. To avoid this hazard much more serious consideration should be given to the alternatives of co-ordination, for instance joint-track operation with abandonment of one or the other company's lines, to increase density without incurring the disadvantages of increased scale. Second, where density is already high, enlargement of scale above a level of some 10,000 employees will most likely be accompanied by real diseconomies.

CHAPTER II CHOICE OF RAILROAD SYSTEMS FOR ANALYSIS AND THEIR GROUPING BY SCALE LEVELS

The basic economic unit in United States railroading is typically a parent company with subsidiaries, leased or otherwise integrated, all with a common top management. Such a combination comprises what may be called a railroad system. The relevant systems for this analysis are those which are, as a whole, independent decision-making units, having, solely for their own purposes, a president and a full set of department heads and staffs for operation, sales and other customary functions. Companies jointly managed by two or more controlling systems are excluded. Ownership of a system's outstanding stock by another system is not considered a bar to autonomy so long as the general organizational specification is met. Thus the data used in this study relate to the combination of the parent company and class I railroad subsidiaries solely owned or leased by it. A number of smaller operating companies considered as class I operating companies for the collection of I.C.C. data and sometimes dealt with as independent sample units in economic studies are thus included with their parent companies in this study. The fact that there is of necessity a certain amount of arbitrary allocation of revenue and expense between a smaller company and its parent makes separate consideration of the former questionable.

For the period under consideration in this study, 1954 to 1956, there were in the United States 53 autonomous railroad systems with over 2000 employees each. The bottom level of 2000, which coincides roughly with $20,000,000 annual operating revenue, is chosen because smaller roads than that are excessively influenced by movements of particular commodities and local community or regional factors which tend not to be typical of general railway operations.

To provide reasonable limits on heterogeneity among systems the Elgin, Joliet & Eastern; Bessemer & Lake Erie; Duluth, Missabi & Iron Range, are excluded because they are predominately suppliers of service to particular manufacturing or related concerns, and the Long Island, because it is largely a metropolitan transit operation. The Chesapeake & Ohio; Norfolk & Western; Western Maryland; and Virginian, have unusually high proportions of coal traffic, each deriving over 40% of its freight revenue therefrom. Three of these four have unit revenue of 1.0¢ per-ton mile which is markedly below the range of other carriers. Because of their substantially different character it seems desirable to exclude these four from the sample. There are also five carriers, the New York, New Haven & Hartford; Boston & Maine; Delaware, Lackawanna & Western; Central of New Jersey; and Florida East Coast, whose passenger train-miles are over 55% of total train-mile miles. Four of these five also have revenue per ton-mile above 2.20¢, markedly higher than the general range of 1.22¢ to 1.65¢ for the remaining other carriers. Because of these important differences from other carriers these five are also excluded leaving a total of forty.

A further possibility of attaining homogeneity is to remove systems with unusually short freight traffic hauls. There are three, the Reading, Maine Central, and Chicago&Eastern Illinois, with under 150 mile freight hauls (the range of the rest is 170 to 612 miles), as well as other atypical characteristics which suggest the reduction of the sample to thirty-seven systems for much of the analysis.

The table on the following pages arrays the forty systems of the basic sample in order of employment and presents other relevant measures of size. The forty are divided into five groups. The range of size for each scale group except for the smallest and largest, was chosen so that the upper end of the range is twice that of the lower in terms of employment. This relation also turned out to apply roughly to some of the other measures of scale. These groupings by chance provide more often than not substantial gaps between number of employees and other measures of size of the top system in one group and the bottom system in the next largest group.

Scale is associated with the number of levels in operating organizations as well as number of geographically separate so-called operating divisions. It is to be noted that all the systems in the largest scale group, I, have regional staffs between the division level and the central management. The number of operating divisions with one exception ranges from 13 to 19. Group II systems typically also have a regional organization layer, but with one exception have only 7 to 15 divisions. Group III systems have the regional layer for only the three largest and except for the system of shortest mileage have a range of 5 to 9 divisions. For Group IV there are no regional intermediate organization stages, and except for the two largest systems there are from 3 to 2 divisions. The single division systems, each with less than 5000 employees, all fall in group V. The organizational differences within and between groups are explained of course not only by variations in size, but also by differences in managerial policies and techniques and in the nature of relationships with subsidiaries.

The various measures tabulated on the following pages of the scale of systems all give close to the same ordering of systems. The number of employees is chosen as the index of scale to be used because it reflects more than any other the magnitude of the problem of controlling labor costs which are the biggest single input involved in producing railroad service.

TABLE 1 — RANK ORDER OF 40 SYSTEMS BY VARIOUS INDICES OF SIZE

Scale	System	Employees (thous)	Oper. Revenue (mill)	Frt. Revenue (mill)
		(Average Annual, '54-'56)		
I	Pennsylvania	103	$925 (1)	$708 (1)
	New York Central	82	750 (2)	555 (3)
	Southern Pacific[1]	74	657 (3)	577 (2)
	Atchison, Topeka & Santa Fe	57	564 (4)	471 (4)
	Union Pacific	49 (5)	502 (5)	434 (5)
	Baltimore and Ohio	46	425 (6)	377 (6)
II	Illinois Central	34	283 (10)	240 (9)
	Chicago, Burlington & Quincy[2]	31	291 (9)	240 (10)
	Missouri Pacific[3]	30	293 (8)	254 (8)
	Southern[4]	28 (10)	353 (7)	308 (7)
	Chicago, Milwaukee & St. Paul	28	246 (12)	205 (12)
	Great Northern	27	266 (11)	235 (11)
	Chicago & North Western[5]	27	226 (13)	181 (13)
	Northern Pacific	23	181 (16)	160 (15)
	Louisville & Nashville	22 (15)	197 (14)	173 (14)
III	Chicago, Rock Island & Pacific	19	192 (15)	157 (16)
	Atlantic Coast Line	19	159 (19)	129 (20)
	Erie	18	163 (17)	144 (18)
	Seaboard Air Line	15	155 (21)	130 (19)
	Reading*	15 (20)	122 (23)	108 (23)
	New York, Chicago & St. Louis	14	160 (18)	153 (17)
	St. Louis & San Francisco[6]	14	126 (20)	111 (21)
	Wabash[7]	12	125 (22)	111 (22)
IV	Gulf, Mobile & Ohio	8.9	83 (24)	73 (24)
	Soo[8]	8.9 (25)	74 (28)	68 (27)
	Missouri, Kansas & Texas	8.4	73 (27)	64 (29)
	Texas Pacific	7.8	80 (25)	69 (26)
	Lehigh Valley	7.8	68 (30)	62 (30)
	St. Louis Southwestern	6.4	65 (31)	62 (31)
	Denver & Rio Grande	6.0 (30)	78 (26)	72 (25)
	Delaware & Hudson	5.8	53 (32)	49 (32)
	Kansas City Southern[9]	5.6	72 (29)	65 (28)
V	Central of Georgia	4.6	43 (34)	38 (34)
	Western Pacific	4.6	52 (33)	48 (33)
	Nashville, Chattanooga & St. Louis	4.2 (35)	34 (36)	29 (36)
	Chicago & Eastern Illinois*	3.5	35 (35)	29 (37)
	Maine Central*	2.8	29 (38)	23 (38)
	Chicago & Great Western	2.5	34 (37)	32 (35)
	Minneapolis & St. Louis	2.4	21 (40)	20 (39)
	Monon	2.0 (40)	22 (39)	19 (40)

*Not in 37 system sample.

[1]Includes Texas & New Orleans. [2]Includes Colorado & Southern and Fort Worth & Denver City. [3]Includes Beaumont; Sour Lake & Western; New Orleans, Texas & Mexico; San Antonio Uvalde & Gulf. [4]Includes Alabama & Great Southern; Georgia & Florida; New

(as of 2/31/55) Orig. Invest. Minus Deprec. Plus Working Cap. (mill)	Reprod. Cost Minus Deprec. Plus Working Cap. (mill)	No. of Oper. Regions	Divisions	(12/31/55) Miles Road Operated	Abbrev. for System
$2448 (1)	$4202 (1)	3	18	10006	P
1885 (2)	3095 (2)	5	19	10613	NYC
1383 (3)	2111 (3)	2	15	12439	SP[1]
1217 (4)	2111 (4)	3	18	13147	ATSF
996 (5)	1695 (5)	3	8	9804	UP
998 (6)	1584 (6)	3	13	6021	BO
656 (12)	1306 (9)	—	9	6531	IC
790 (8)	1362 (7)	4	12	10561	CBQ[2]
712 (10)	1024 (14)	3	11	9662	MP[3]
807 (7)	1292 (10)	3	18	7630	S[4]
734 (9)	1355 (8)	2	15	10641	CMStP
636 (13)	1115 (11)	2	8	8285	GN
705 (11)	1095 (12)	4	10	9452	CNW[5]
599 (14)	966 (15)	2	7	6865	NP
589 (15)	1035 (13)	—	8	4732	LN
503 (16)	870 (16)	2	7	7920	CRI
414 (17)	634 (18)	2	9	5287	ACL
391 (18)	636 (17)	2	7	2338	E
361 (19)	564 (21)	—	5	4064	SAL
348 (20)	578 (20)	—	3	1307	R*
278 (22)	443 (22)	—	5	2178	NYCStL
341 (21)	600 (19)	—	7	4765	StLSF[6]
259 (23)	353 (23)	—	5	2687	W[7]
195 (27)	346 (26)	—	4	2757	GMO
195 (28)	346 (27)	—	6	4189	Soo[8]
217 (24)	316 (28)	—	3	3241	MKT
180 (29)	251 (29)	—	3	1831	TP
211 (25)	368 (24)	—	2	1150	LV
114 (34)	169 (35)	—	2	1502	StLSW
202 (26)	347 (25)	—	3	2155	DRG
139 (32)	213 (31)	—	3	792	DH
146 (31)	238 (30)	—	3	1645	KCS[9]
120 (33)	196 (33)	—	3	1764	CG
150 (30)	213 (32)	—	2	1192	WP
112 (35)	172 (34)	—	3	1043	NCStL
86 (37)	135 (37)	—	1	868	CEI*
73 (38)	120 (38)	—	1	949	MC*
97 (36)	162 (36)	—	1	1470	CGW
64 (39)	105 (39)	—	1	1397	MStL
47 (40)	75 (40)	—	1	541	M

Orleans Northeastern and Cincinnati, New Orleans & Texas Pacific. [5]Includes Chicago, St. Paul, Minneapolis & Omaha. [6]Includes St. Louis San Francisco of Texas. [7]Includes Ann Arbor. [8]Includes Wisconsin Central. [9]Includes Louisiana & Arkansas.

CHAPTER III THE DATA FOR ANALYSIS OF EFFECTS OF SCALE

A. GENERAL CHARACTER OF DATA

The railroad system performances to be analyzed represent the result of long term adjustment of systems to their overall environment both from the side of demands for the varying services and the side of the supply of the inputs necessary to together produce those services. The 40 and 37 railroad systems forming the samples are all mature organizations built up by mergers of smaller units, except for a few in the smallest scale group, and have had several decades to adjust to the environments in which they operate. On the underlying demand side these systems have been affected by the nature of commerce flowing through the territories served; by the competitive and monopolistic aspects of their markets and price associations; and by governmental control both at the administrative regulatory level and the broader political level. Some of these factors have been arbitrarily fixed for a particular system, as for instance the location of critical raw materials or large population centers, others have been subject to modification by carrier management. Individual systems can develop bargaining strengths in varying degrees in relation to their share of traffic and to the prices they obtain within the broader market situation. On the side of supply, systems have varying physical conditions to contend with, some inherent in location. Certainly managerial abilities vary. Level of maintenance is at once recognized as a flexible aspect of input, particularly over short and intermediate periods of time. Quality of service is another variable item, a most intangible one as far as mensuration is concerned, but one which affects inputs and, as well, ability to get shares of traffic. The over-all results are related to the decisions of management as to capital investment and its upkeep, use of manpower and materials together with price and selling policies and standards of service.

To obviate serious distortion of data due to temporary changes in maintenance standards and to disasters, strikes and other chance events which may distort one year's accounts, use is made of average data for the three years ending with the latest year for which data were available at the beginning of the study.[1] Thus the data are for 1954 to 1956 inclusive. The first of these years, 1954, was one of depressed traffic, revenue ton-miles for the U. S. having been the lowest for any post-war year and 9.5% below the previous year, 1953. The last year, 1956, was a good traffic year, with ton-miles higher than for any year but those during World War II and 1947, and 18% higher than 1954. No general rate increases were applied in these years. There were increases in wage rates under national agrements and material prices rose.

[1]The sources of data are: I. C. C. **Transport Statistics in the United States**, 1954-56; Individual Company, **Steam Railroad, Form A, Annual Reports**, 1954-56; I. C. C., **Selected Elements of Value**, Statement #571, 1957; Moody's Investors Service, **Moody's Transportation Manual**, 1957; H. H. Copeland & Son, **Traffic Interchanged**, various companies and years; A. A. R., **Revenue Freight Carloadings**, Statement CS-54A, 1954-56; **The Official Guide of the Railways — of the U. S. —** June 1955; **The Pocketlist of Railroad Officials**, 4th Quarter, 1957. (For systems made up of more than one company average hauls and ratios of cars originated and terminated to carried were calculated by estimating cars and tons local to the system from figures in **Traffic Interchanged** or from such system figures as were available for single years in the above sources.)

Because capital investment values change little percentage-wise from one year to the next, the measures of capital investment, depreciated reproduction and original values are taken as of December 31, 1955.

To avoid any biases which might arise from preconceived ideas as to what to expect of individual systems, the data will be presented, except in the initial basic tabulations, without system names.

The various analyses of this study are based on measures of the individual and of the average performance of systems by scale groups in relation to size and other variables. Because this study centers on systems as individual decision-making units the indices taken as representative of a scale or other group are the averages of the individual indices of each system in the group rather than the weighted averages for the group. For instance in respect to return on depreciated original value the figure used to depict scale Group I performance is the average of the six individual system returns amounting to 5.1%. The weighted average for the six systems, i.e. their total net income divided by their total net book value, would be 4.6% because the two largest of the six have the lowest returns and weigh more heavily in the totals than the others. This weighted figure would be representative of the industry as a whole, but for a comparative system study the other averages are the significant ones.

B. CONSIDERATION OF CHARACTERISTICS OTHER THAN SCALE

Analysis of the effect of scale involves consideration of variables other than scale that affect performance. This raises the question of what are the important other variables and which of them can be dealt with quantitatively.

1) Non-Measurable Variables

At once it must be recognized that there are some important variables which cannot be evaluated quantitatively. The ability of management is a characteristic that cannot be numerically rated, yet it is recognized generally as one which can make a substantial difference in performance. Several possibilities exist as to how managerial differences may be involved in the analysis. If the differences are unrelated to scale, they may be assumed to have a random distribution among the scale groups and be considered one of the random factors accounting for the scatter of individual system data around any central tendency of performance related to a particular measurable variable under consideration. On the other hand, if managerial differences are related to scale, it must be recognized that their influence cannot be separated out from other scale-related factors and all such factors will be reflected together in measurable variations between scale group performances.

Another such unmeasurable variable is the standard of maintenance. Since maintenance expenses for way and equipment account over-all for some 32% of revenue and 42% of operating expenses, it can make considerable difference in costs and return whether there is over maintenance or under maintenance. In this case there are possible biases that systems with the very lowest returns may be pressing to meet fixed financial charges by lowering maintenance standards and that the very prosperous ones may have higher standards and be spending greater amounts on maintenance than would those in more ordinary circumstances.

2) Measurable Variables

The search for what are the significant measurable characteristics other than scale accounting for performance is greatly influenced by the fact that for the forty or thirty-seven railroads, all but two receive 75% or more of their operating revenues from freight service. Emphasis must be on the revenue and operating characteristics of freight traffic. Freight traffic is made up of two over-all categories, carload and less-than-carload, which are very different in characteristics. Unfortunately, not all statistics are compiled serarately for the two types. In fact, only the tonnage and revenue of each are available independently. The all-important data as to ton-miles and loaded car-miles are available only for the two types together. Loaded freight cars terminated are reported for car-load cars only. However, the facts that less-than-carload traffic for the 1954-56 period accounted for only ½ of one per cent of total freight tons, and less-than-carload revenue for only 3% of freight revenue allow close estimation of carload data.

Revenue received for a unit of freight service is obviously a critical variable. The only available measure of this is the gross one of revenue per ton-mile, there being no separations by type of traffic. The available measures of the physical characteristics of freight traffic are 1) average haul per ton of carload freight, 2) load per carload car as measured by ton-miles per loaded car-mile, 3) the proportion of empty to total freight car-miles, for carload and less-than-carload combined, reflecting the variations in amount of empty return movement involved in a particular mix of traffic, and 4) the amount of originating and terminating handling per car carried (for carloads only), this reflecting the basic terminal work involved.

Because freight service is a composite product made up of origination and destination terminal handling as well as the line-haul significant measures of that service as it is provided by an individual system are difficult to obtain. Ton-miles or loaded car-miles are not a complete measure because a system which provided both origination and destination handling of a particular traffic flow would record no more of these units than a system which carried the traffic the same distance but performed no terminal services, that is it was purely an overhead carrier. Yet the service performed by the former system would involve more labor and capital resources and, other things being equal, its service would produce more revenue than that produced by the latter. Analysis of freight revenue can be undertaken to determine whether it reflects these differences in nature of service well enough to use this revenue as the measure of over-all composite freight output. If revenue does meet these requirements it will also be possible to determine extreme variations in revenue levels due to factors other than just level of output units. Norms of revenue in terms of the physical service units can be established. Deviations from the norms can then be measured and be used to correct individual system revenue figures so that they reflect just output.

Since bituminous coal traffic is so uniformly profitable judging from the experience of the four excluded carriers that have a large share of it, another variable to be considered is the proportion of coal traffic carried of total freight traffic. Since there are no published ton-mile data by commodities for individual systems, this proportion can only be represented by the ratio of bituminous coal to total freight revenue.

The intensity of use of capital plant is generally thought to be significant in respect to costs. For the line haul aspects of freight traffic alone this is commonly measured in annual net ton-miles per mile of road. The above comments on freight traffic suggest revenue per mile corrected for abnormal levels as a better measure of over-all service. The problem of combining freight and passenger and related traffic involves the addition of unlike physical units of service with the uncertainties of a basis for equating them. Annual total revenue per road mile measures these in combination and provides a meaningful ranking and comparison of systems in respect to density. The thinnest traffic system, a western one, has an annual revenue, freight and passenger, of $15,000 per mile of road and the densest in the East has just over six times that, $92,500. This range corresponds roughly to one of from 1,000,000 to 5,000,000 annual net ton-miles per mile of road.

The important influence of passenger and allied traffic also requires consideration and can be measured in various significant ways. The physical measure of the ratio of passenger to freight train-miles offers a rough relative measure both of transportation operating units and use of track capacity as between freight and passenger services. However, this ratio may distort the passenger share in an upward direction for those systems with especially heavy freight train loading or with low proportions of way-freight to through-freight train-miles. Another comparative measure involving only limited uncertainties of accounting allocations of common costs is the ratio of passenger to freight shares of combined equipment maintenance and transportation expenses. For class I railroads as a whole some 80% of these particular expenses are "solely-related" to the two respective services and thus subject to the problems of methods of allocation to only a limited extent. In some analyses it is desirable to eliminate the effects of the very high or low proportions of passenger operations. Eliminating the top 7 and bottom 8 systems as to these proportions leaves 22 systems with the limited range of percent passenger of freight expenses of 21 to 35%.

In addition because there are substantial differences in the topography, commerce and institutions of various parts of the country a non-quantitative variable, region, has to be considered. Because systems generally overlap any but the very largest subdivisions of the country's area, the only usable regional classification is the three-fold one of East, South and West. The boundary between the first two is a line from Hampton Roads across Virginia and thence the Ohio River. Between the first two and the West the boundary is roughly the Mississippi River from the Gulf of Mexico to St. Louis, thence a line to Chicago and finally the west bank of Lake Michigan. Even with these gross regions there is some overlapping, the extreme case being the Wabash. It must be recognized that there can be substantial differences within regions, such as those between the systems mainly in the prairies and those crossing the Rocky Mountains, both of which are considered western.

The distribution of systems among regions for each scale group is of importance because some of the traffic characteristics show marked regional as well as scale differences. Of the 40 systems, half are western, 20% southern and 30% eastern. Of the scale group I systems, half are eastern and half western and none southern. If scale I and II are combined, 50% are western and 25% each eastern and southern, close to the over-all distribution. For scale III half are eastern and the south and west each have a quarter, over weighted toward the east. For scale IV the west dominates, with 6 out of 9 systems. For scale V the west is somewhat under-represented with 3 out of 8, instead of half.

TABLE 2 SCALE GROUP AVERAGES OF VARIABLES OTHER THAN SCALE — 37 SYSTEMS, '54-'56

	Scale Groups				
# Systems	V (6)	IV (9)	III (7)	II (9)	I (6)
Variables					
1) Rev. Per Ton-Mi., CL&LCL	1.37¢	1.39	1.41	1.34	1.41
2) Haul Per Ton, CL&LCL	260 mi.	260	250	291	385
3) Ton-Mi. Per Loaded Car-Mi.	30.0 t.	29.9	28.3	30.8	30.0
4) Proportion Loaded Car-Mi. of Total Car-Mi.	69.6%	66.2	63.1	64.0	62.3
5) Carload Cars Orig. Plus Term. Per Lded. Car Carried	0.80	0.83	0.96	1.12	1.14
6) Prop. Bit. Coal Rev. of Total Frt. Rev.	5.3%	3.8	6.0	10.2	11.4
7) Density of Traffic					
a) Annual Net Ton-Mi. per mi. of Rd. (mill.)	1.93	2.64	2.75	2.12	3.68
b) Annual Rev. per Mi. of Rd. (thous.)	$29.8	32.3	47.8	35.1	63.8
8) Prop. Pass. of Frt. Equip. Main. & Transport. Expenses	18%	21	26	30	35
9) Prop. Pass. Train-Mi. of Frt. Train-Mi.	47%	50	55	66	68

The adjoining tabulation shows the average of each of the characteristics for the five scale groupings of the 37 systems sample. Two of the characteristics might be expected to and do vary directly because of scale. The larger the system the greater the proportion of traffic which would be expected to be local to its line and therefore the higher the ratio of cars originated and terminated to cars carried. Similarly the length of haul might be expected to increase with scale, although this relation proves not to be regular, for the smallest three scale groups show little difference and the largest scale has substantially longer hauls than the next to largest.

The per cent loaded of total car-miles declines with increasing scale while the density of traffic and the percentage of coal traffic increase. Average tons per car and revenue per ton-mile show no variation with scale. The proportion of passenger to freight operations declines continuously with decline in scale.

A comparison of scale I with, for instance, scale IV averages shows the former to have substantial advantage as to length of haul, proportion of coal traffic and density of traffic but disadvantage as to proportion of originating and terminating freight cars, of passenger to freight operations and of loaded to total car miles. On the other hand scale V compared to the other groups has the advantage of the lowest proportion in all three of the last items, but has the disadvantage of the lowest density.

C. ANALYSIS OF UNIT FREIGHT REVENUE

Freight revenue per ton-mile is the most critical of the variables affecting several of the performance ratios to be analyzed in this study. Revenue per ton-mile multiplied by ton-miles gives freight revenue. This revenue is, in all but two cases, over 75% of the total revenue against which expenses and capital investment are compared in later analysis.

Revenue per ton-mile is in part related to some of the variables already considered, in particular, load, haul, terminal handlings per car carried and region. In addition to these, unit revenue also reflects factors which cannot be measured, such as value of commodities carried and degree of market competition between regions and of competition between various modes of transport. Since revenue represents divisions of through rates between systems it also reflects bargaining strength of systems as well as regulatory action in respect to shares of those rates. The extent to which all such factors account for revenue levels above or below the levels determined by basic physical characteristics of traffic must be considered in the assessment of scale group performance. It is necessary to find some general formula by which to estimate the influence of haul, load, etc. Then deviations from the formula estimates can suggest the extent of the effect of the other factors.

To achieve this it is possible to use multiple correlation analysis if few enough of the measurable variables can be found which explain a significantly high proportion of the differences in unit revenue. The number of variables that can be considered is restricted because there are only 37 systems providing data for testing any correlation.

Such an analysis starts with the formulation of how in principle rates are made relative to the physical nature of traffic and then how that may affect revenue per ton-mile. In a general way rates as a unit price for a particular haul are made up of a terminal and a line-haul element, the latter representing a combination of ton-mile and car-mile factors. The terminal element must reflect whether the divisions of the through rate take into account the extent of individual carrier originating and terminating yard and station functions. In terms of these elements revenue per car may be formulated as:

$$\begin{array}{l}\text{Revenue} \\ \text{per car} \\ \text{handled}\end{array} = \underset{\text{(per handling)}}{\text{Term. constant}} \times (\text{orig.} + \text{term. handlings per car}) +$$

$$\underset{\text{(per car mi.)}}{\text{Line-haul constant}} \times \begin{array}{c}\text{miles} \\ \text{hauled} \\ \text{(per car)}\end{array} + \underset{\text{(per ton-mi)}}{\text{Line-haul constant}} \times \underset{\text{(per car)}}{\text{ton-miles}}$$

Substituting abbreviations for constants this becomes

$$\begin{array}{l}\text{Revenue} \\ \text{per car}\end{array} = \text{T}\times (\text{orig.} + \text{term. handlings per car}) + \underset{\text{cm}}{\text{LH}} \times \underset{\text{per car}}{\text{haul}} + \underset{\text{t-m}}{\text{LH}} \times \underset{\text{per car}}{\text{ton-mi.}}$$

For a system as a whole freight revenue can be expressed as

$$\begin{array}{l}\text{System} \\ \text{Revenue}\end{array} = \text{T}\times \frac{\text{cars orig.} + \text{term.}}{\text{cars carried}} \times \begin{array}{c}\text{cars} \\ \text{carried}\end{array} + \underset{\text{cm}}{\text{LH}} \times (\text{lded. car-mi.}) + \underset{\text{t-m}}{\text{LH}} \times (\text{ton-mi.})$$

Cancelling out (cars carried) in the first term this becomes

$$\text{Revenue} = \text{T}\times (\text{cars orig.} + \text{term.}) + \underset{\text{cm}}{\text{LH}} \times (\text{lded. car-mi.}) + \underset{\text{t-m}}{\text{LH}} \times (\text{ton-mi.})$$

System unit revenue or average revenue per ton-mile is obtained by dividing all parts of the above equation by system ton-miles.

$$\begin{array}{l}\text{Revenue} \\ \text{per ton-mi.}\end{array} = \text{T}\times \frac{(\text{cars orig.} + \text{term.})}{\text{ton-mi.}} + \underset{\text{cm}}{\text{LH}} \times \frac{(\text{lded. car-mi.})}{\text{ton-mi.}} + \underset{\text{t-m}}{\text{LH}} \times \frac{(\text{ton-mi.})}{\text{ton-mi.}}$$

Cancelling out ton-miles in the last term this becomes

$$\begin{array}{l}\text{Revenue} \\ \text{per ton-mi.}\end{array} = \text{T}\times \frac{(\text{cars orig.} + \text{term.})}{\text{ton-mi.}} + \underset{\text{cm}}{\text{LH}} \times \frac{\text{lded. car-mi.}}{\text{ton-mi.}} + \underset{\text{t-m}}{\text{LH}}$$

As was noted earlier, the available data do not allow of obtaining all the items in the formula in the same terms. Revenue, ton-miles and loaded car-miles are all available for combined carload and less-than-carload traffic so the best choice is to use the formula with these combined units. Cars originated and terminated can only be obtained for carload cars, but they represent probably 90% of the total so that the effect of leaving out the l.c.l. cars is not likely to cause excessive error.

There may be significant regional variations in unit revenue due to the way divisions of through rates between systems in different regions have been apportioned and to differences in competitive or other factors. This can be taken into account by using separate constants for each of the three regions. The most successful way of doing this in terms of statistical results for the several formulations tested is to give just the first two constants separate values for each region.

The calculations of multiple correlation for the sample of 37 systems indicates that 70%[2] of the variations in revenue per ton-mile

[2]This is the coefficient of multiple determination (R^2) corrected for sample size and number of variables.

are associated with the four variables, i.e. origination plus terminal handlings, loaded car-miles, ton-miles and region. Conversely 30% are associated with other factors not statistically measurable and not represented in the formula, such as competition and commodity value.

The degree of correlation is high and the formula meets the usual statistical tests so that it may be used to calculate the extent to which the system unit revenues deviate from an estimated norm.[3] In these terms actual system unit revenue may be considered high or low in relation to the formula estimated norm and judged as to possible effect upon such a ratio as rate of return. The range of actual unit revenues from highest to lowest of the 37 systems is 0.43¢, centering on an average of 1.41¢. The following table shows the average scale group deviations from the norm. Since the formulation includes evaluation of regional differences, the comparison in terms of the country-wide samples is valid in spite of regional differences.

TABLE 3 SCALE GROUP AVERAGES OF UNIT REVENUE DEVIATIONS FROM FORMULA ESTIMATE

Scale Group	Average Deviation of Rev. per Ton-mi.		Dev. as per cent of Aver. Actual Rev.	
	37 systems	20 western	37 systems	20 western
I	.00¢	+.01¢	0.0%	+0.9%
II	.00	.00	0.0	0.0
III	—.01	—.06	—0.9	—4.9
IV	+.01	+.05	+0.8	+3.2
V	.00	+.03	0.0	+2.0

These data suggest that there is a general tendency for the scale III systems to have lower unit freight revenue and scale IV to have higher than might be expected from their traffic characteristics and regional distribution. The small differences between group averages and the wide deviations of some individual systems, prevent these differences from meeting the tests for significance.

There are ten systems under or exceeding the estimated norm by more than the standard error of 0.068¢ per ton-mile. None are among the scale I systems. For scale II one southern and one western system are under and one southern is above the norm. For scale III one western system is below by more than the standard error. For scale IV one western system is above and one each for the south and east are below. For scale V one each from the south and west are below and an eastern one is above. Corrections for the revenues of these systems are made in subsequent analyses.

[3]The regression equation for the eastern region, for example, is:

$$\text{rev./ton-mi. } (¢) = \$51 \frac{\text{cars orig.} + \text{term.}}{\text{ton-mi.}} + 15¢ \frac{\text{load car-mi.}}{\text{ton-mi.}} + 0.45¢$$

The correlation including all regions meets the confidence level of 1%, that is the chances are only 1 out of 100 that there is no real correlation between these variables. R =.84, corrected for sample size. Six of the seven constants were over three times their standard error and the standard error of unit revenue is 0.068¢, which is 4% of average unit revenue.

CHAPTER IV EFFECTS OF SCALE ON PERFORMANCE

The greatest problem in empirical analysis of the effect of scale on railroad system performance arises from the wide variation between systems in mixes of services. This makes it difficult to obtain meaningful measures of over-all output in direct physical terms. Simple measures of output, ton-miles and passenger-miles, have been used in studies of scale. These units fail to reflect important differences in the nature of output such as those between a system producing ton-miles accompanied by origination and destination services, i.e. providing empty cars for loading and spotting cars for unloading, and one producing ton-miles with no terminal services. Another approach has been to break down output into basic operational units, then to analyze the related detailed cost functions. This avoids much of the lack of homogeneity in the measures of output but fails to take into account the variations in proportions of the operational units used to produce the ultimate units of service to shippers. These units of system output are produced by a combination of a number of detailed functional operations, terminal switching, train operation and station work. The detailed operational cost functions of each of these separately do not show the combined cost function relative to final services output.[1]

A basis for building up an over-all measure of freight service output has been developed in connection with the immediately previous analysis of unit freight revenue. Unit revenue was shown to reflect the variations in basic physical elements of service, such as differences in terminal handling performed by a particular system. Thus total revenue, corrected for important deviations from this role, provides as good a composite measure of freight service in its various aspects as can be obtained. In this study this correction of revenue is applied to those ten systems whose unit revenue was found to deviate more than the standard error from the formula estimates of the previous section.

The common use of way facilities by both passenger train and freight services makes necessary some composite measure of their combined output. A commonly used unit for this purpose is the sum of freight ton-miles and two times the passenger-miles. This not only has the faults already mentioned in respect to measuring freight service, but also ignores the differences in types of passenger train services and in their proportions. Operating revenue provides the only practical measure to combine the widely varying mixes of mail, express, pullman and coach services with equally varying mixes of freight services into a unit of overall output. It is by no means a perfect reflection of all the differences in mixes but it comes nearer to it than any other index. An excessive burden upon this index of reflecting traffic mix differences of the most extreme variety is avoided by the removal from the sample to be studied those systems having the highest proportions of coal and passenger traffic and the very shortest hauls.

The expenses which can be related to output are broken down into many categories, broad and detailed, in the I.C.C. accounts. Because this study is confined to consideration of gross relationships only wages

[1]L. R. Klein, **Econometrics** (1953) pp. 227-234; G. H. Borts, "The Estimation of Rail Cost Functions," **Econometrica, XXVIII,** No. 1, p. 108; J. R. Meyer, et al, **The Economics of Competition in the Transportation Industries** (1959), Chap. III and App. B & C.

as a whole and the broader categories of expenses, maintenance, transportation, administration and selling, are studied in relation to output. The I.C.C. definitions of these expenses and its inclusion of joint facility expenses, both credit and debit, in the totals provide straightforward data. The relationship of investment to output is another area of interest in respect to scale effects. While good valuation data as to capital value, both in original and reproduction cost terms, are available, the common practice of joint use of tracks and interchange of equipment may introduce some distortion. To observe possible effects of this the more extreme cases of systems operating road miles of more than 8% in excess of those owned or leased are identified on the charts.

Finally the analysis of scale effects on rate of return on capital provides an over-all summation of those effects on expenses, capital investment, levels of output and in addition on pricing and general ability to adjust to market situations. At this level some of the distortions that may enter into the measurement of more detailed relationships of individual categories of expense are eliminated because rental charges for use of capital facilities and joint facility expenses are considered in determining return. Thus the most reliable test of scale effects as well as the most comprehensive is in respect to rate of return.

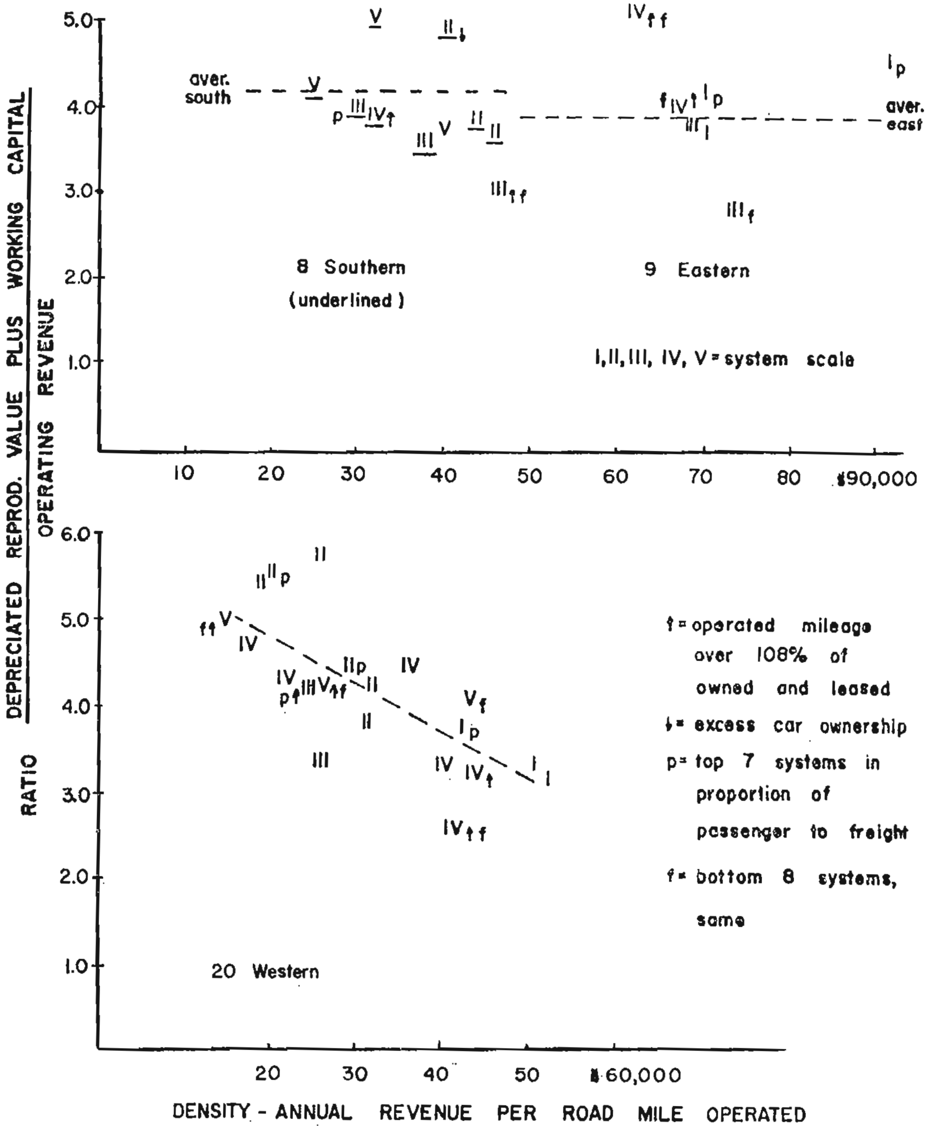
In the course of analyzing these relationships it is inevitable that a wide range of extraneous factors will cause wide dispersion around any central tendencies. Capital investment is affected by the topography and geology of the region traversed, climate and density of population. Some systems may have been able to obtain routes or terminals with lower construction costs than their neighbors. Some have chosen to rent facilities rather than provide them solely for their own use. Obviously managerial skills vary in their ability to minimize investment. Some of these variables affect levels of labor and material inputs. A variety of factors affecting revenue levels has been considered earlier. In the following analysis in addition to scale only traffic density and region will be dealt with as variables whose influence is to be measured quantitatively. Traffic density will be measured by revenue per mile of road so as to combine passenger and freight traffic influences on density. The effects of passenger service proportions will be considered mainly in terms of the contrast between the 37 systems and the 22 of limited range of passenger-freight proportions.

In general it cannot be assumed that there is a straight-line or linear relationship between scale and any index of performance. Nor can it be assumed that the trend of relationship will be continuous in one direction, that is that with increases in scale from the smallest scale to the largest there is always a rising (or declining) index of performance from scale group to scale group. The contours of the relationship presented in each case will be those having the highest correlation.

A. CAPITAL INVESTMENT VERSUS OPERATING REVENUE

The level of capital investment needed to handle a particular amount of traffic is a critical relationship in an industry such as rail-

CHART 1 — SYSTEM CAPITAL-REVENUE RATIOS VERSUS TRAFFIC DENSITY, BY REGIONS



roading where capital requirements are relatively high. Because of the difficulties which varying traffic mixes impose on measurement of over-all traffic volume, operating revenue, corrected for the previously mentioned out of line freight revenues, is used as the best available measure of that volume. Depreciated reproduction value plus working capital is the measure of capital investment. The average capital-revenue ratio for all 37 systems is 4.1.

The variables other than scale to be accounted for before possible scale effects can be observed are passenger-freight proportions, traffic density and region. The adjoining chart shows by regions the relation of the capital-revenue ratio to traffic density as measured by revenue per road mile operated. There is no significant density effect in the East and South. For the West correlation analysis indicates that 47% of the variation in the ratio is associated inversely with density and that density has a statistically significant effect.[2] The average ratios for the East and South are 3.88 and 4.16 respectively, but the difference between the two does not meet statistical tests of significance. The systems with excessive deviations as to passenger-freight proportions from the normal proportions as defined previously, are indicated on the chart. These different proportions have no significant influence.

Possible effects of scale may be determined by relating the size of individual systems to their respective deviations from their norms for the capital-revenue ratio, which norms are taken as the regional averages for the East and South and the density trend line for the West. The average of system deviations for various size groups are as follows:

Scale	Number of Systems	Average of System Deviations from Norms or Capital-Revenue Ratio	
I	6	+.23	+.27
II	9	+.30	
III	7	—.60	—.34
IV	9	—.09	
V	6	+.18	

The variations with size follow no regular pattern. Thus the significance of the differences can only be tested between pairs of scale groups or combination of groups.[3] The statistically significant differences are between scales I and III and between II and III. If scale groups IV and III be combined, including systems from 5,000 to 19,000 employees, there is a significant difference between them and both scales I and II. The smaller scale III and IV systems require on the average some 14% less capital per unit of revenue than the largest II and I do. The smallest scale V tends to have a ratio not significantly different from the largest scale group. For the West by itself there are significant differences between the ratios of scale groups I and IV and

[2]For each correlation analysis in this chapter the R^2 corrected for sample size will be presented in the text as the percent of variation associated with density or scale. The best fitting linear or logarithmic regression equation will be shown in a footnote, in this case:

$$\frac{\text{Deprec. Reprod. Value}}{\text{Oper. Rev.}} = \underset{(.012)}{-.055} \text{ density (thous. \$ rev. oper. mi. rd.)} + 5.94$$

The standard error of the coefficient of density or scale will be shown in ( ) under the coefficient.

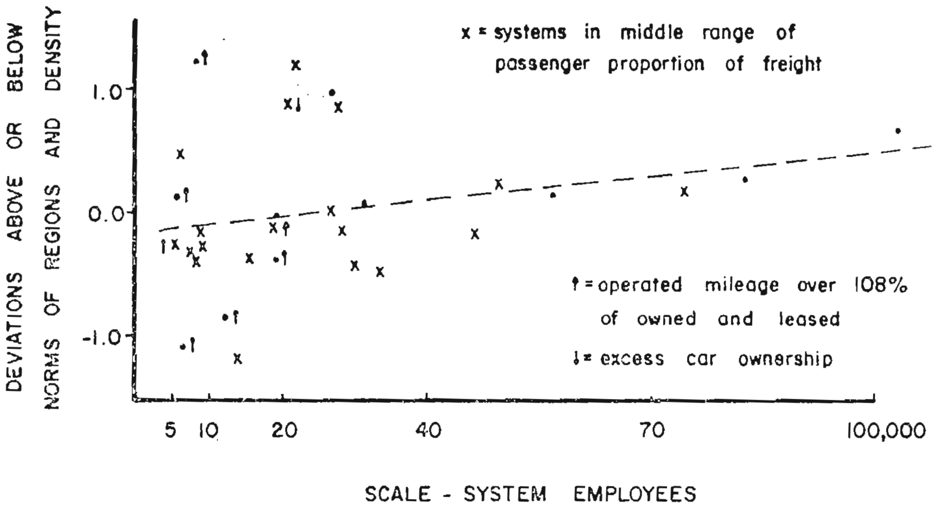
Further, unless otherwise stated, the criterion of significance used throughout this chapter is the so-called 5% confidence level. This implies that judgements as to relationships based on the analysis have only 1 chance in 20 of being incorrect.

[3]In this chapter the significance of differences between group averages will be tested in terms of the null hypothesis using the unpooled procedure. Again the 5% confidence level is used as the criterion of significance.

between II and both III and IV, the smaller scale systems having lower capital inputs per unit than the larger ones, the average for scale III and IV indicating a 14% lower unit capital requirement than for scale I.

The following scatter chart of individual system deviations around regional averages and, for the West the density trend line, shows very wide variation in unit capital for the smaller scale systems, reflecting the substantial influence of differences in topography, standards of construction, etc. For the smaller systems these influences are not averaged out as with the larger systems which tend to encompass a wide variety of conditions. The distribution of the systems with the middle range of passenger proportions shows generally the same relationship to scale as for the larger sample. The effects of variables other than scale and density loom large, but it can be concluded that there is a significantly lower unit capital requirement for the scale of from 5,000 to 19,000 employees than for the larger scales.

CHART 2 — DEVIATIONS OF SYSTEM DEPR. REPROD. VALUE-OPERATING REVENUE AROUND REGION AVERAGE OR TREND LINE

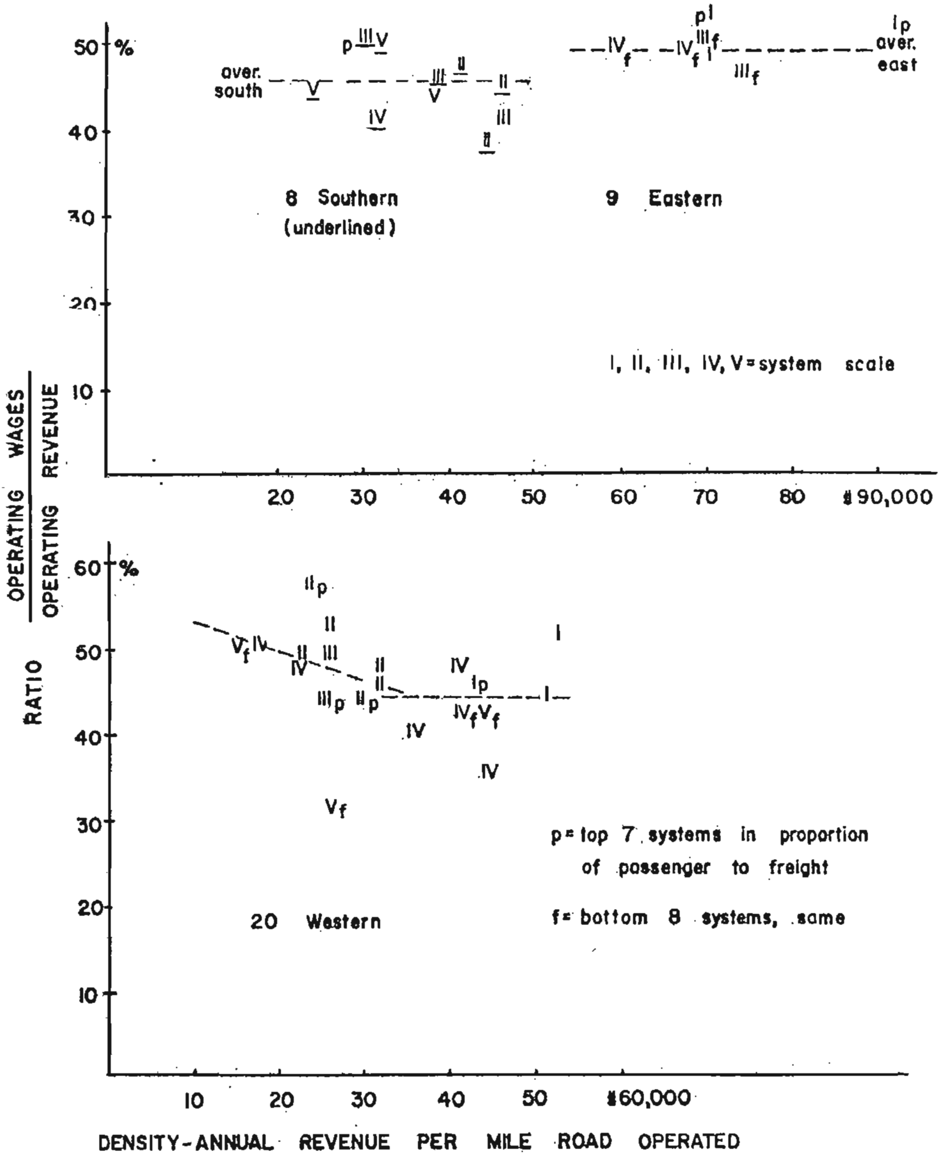


B. WAGES VERSUS OPERATING REVENUES

For all 37 systems wages average 62% of expenses and 47% of revenue. Since wages are the largest single general input factor the possible effect of scale on the wage-revenue ratio is of major importance.

The adjoining scatter charts indicate by regions the system wage-revenue ratios in relation to density and scale. Density has no statistically significant association with the level of wage-revenue ratios in the East and the South. In the West for 18 of the 20 systems, excluding the two with highest density, density increasing from the lowest level of $15,000 to that of $45,000 of annual revenue per mile is inversely related to the wage-revenue ratio. Within this range correlation analy-

CHART 3 — SYSTEM OPER. WAGES-OPER. REVENUE RATIOS VERSUS TRAFFIC DENSITY, BY REGIONS



sis indicates that 24% of the variation in the ratio is associated inversely with density.[4] The extent of this part of the variation is indicated by the fact that from a $25,000 to a $40,000 density level the trend line indicates a decline in the ratio from 48.0% to 42.9%, or 5%

[4] $\frac{\text{Oper. Wages}}{\text{Oper. Rev.}}$ (%) $= -\underset{(.13)}{.34}$ density (thous. \$ rev. per mi.) + 56.5%

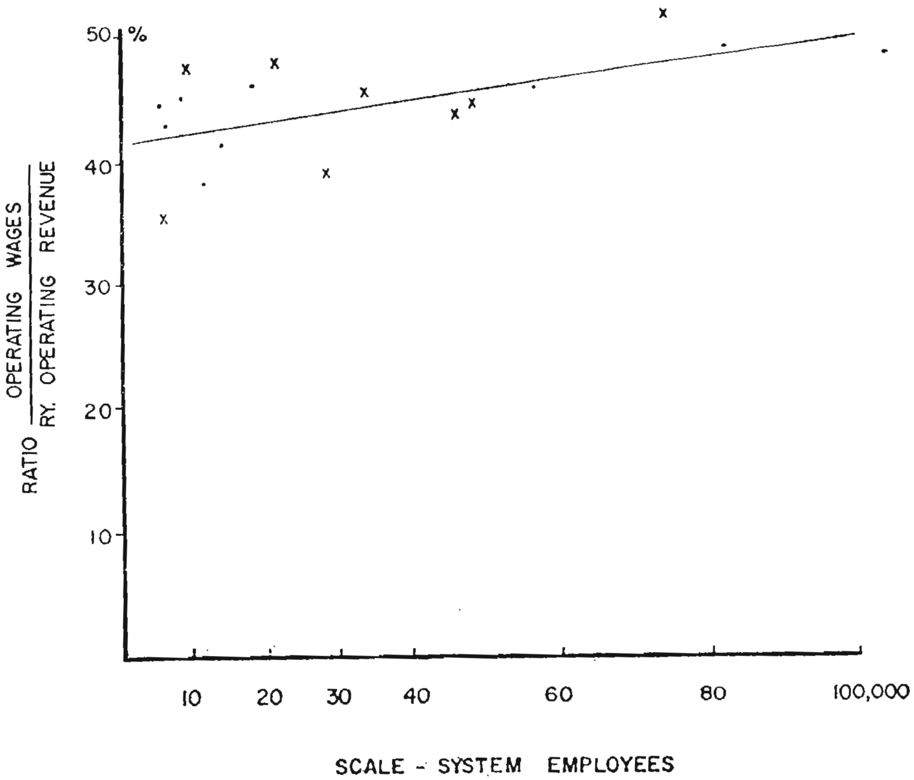
points. At higher than the $40,000 density levels the ratio does not decline.

Regional comparisons of the 17 systems with 5,000 or more employes and $40,000 and higher levels of annual revenue per mile, for which density is not a significant influence, indicate that the South and West are about on a par with respect to the wage-revenue ratio, averaging 44.1 and 44.7% respectively, and the East is significantly higher, 49.2%, 4.7% points above the other two.

After correcting the eastern system ratios for this difference, the individual ratios as related to scale measured by number of employees are shown on the following chart. The systems of limited range of passenger-freight proportions, indicated by crosses on the chart, generally follow the over-all pattern though with wider dispersion around their general trend.

Analysis indicates that the association with scale is statistically significant and on the average it accounts for 29% of the variation of the

CHART 4 — SYSTEM OPER. WAGE-OPER. REVENUE RATIOS VERSUS SCALE, SYSTEMS OVER $40,000 DENSITY AND 5000 EMPLOYEES



wage-revenue ratio.[5] The central tendency is for the ratio to increase at the rate of 0.8%, points for each 10,000 additional employees, which, for instance, corresponds to an increase from 42.6 to 48.2% going from a scale of 10,000 to 80,000 employees and means a 13% increase in wage share.

For the 19 systems under $40,000 per mile density the association with scale is also significant but at the somewhat lower level of accounting for only 20% of the variation.[6] The data cover a range of scale generally lower than the previous analysis, the largest system having only 31,000 employees, and include with one exception just southern and western systems. The analysis is after accounting for the effects of density in the West. The central tendency is for an increase from 7,500 to 25,000 employees to be associated with a 4% point rise in the wage share of revenue.

With increasing scale there is an important rise in the wage share for a given output as measured by revenue. This increasing share leaves a diminishing amount for other inputs, particularly capital, as scale increases.

C. WAGES VERSUS CAPITAL INVESTMENT

The ratio of wages to capital investment is the remaining relationship among the three variables, output, labor, and capital inputs. It is measured in terms of operating wages and depreciated reproduction value. For the 37 systems this ratio averages 12.1%, and for the eastern ones, 13.3%, the southern, 11.6%, and the western, 11.8%. The adjoining chart portrays the individual system ratios in relation to density and scale.

As with the previous ratios there is no significant relation between density and the wage-capital ratio in the East and South. For the western systems there is a statistically significant association, 40% of the variation in the ratio being associated with differences in density.[7]

Taking into account the density effect for the western systems, the wage-capital ratios for different scales are shown by density and regional groupings in the following table. The density above $40,000 annual revenue is the range in which there is no evidence that density makes a significant difference in any of the three regions.

TABLE 5 — AVERAGE WAGE-CAPITAL RATIOS BY DENSITY, SCALE AND REGION
( ) Number of Systems In Each Group

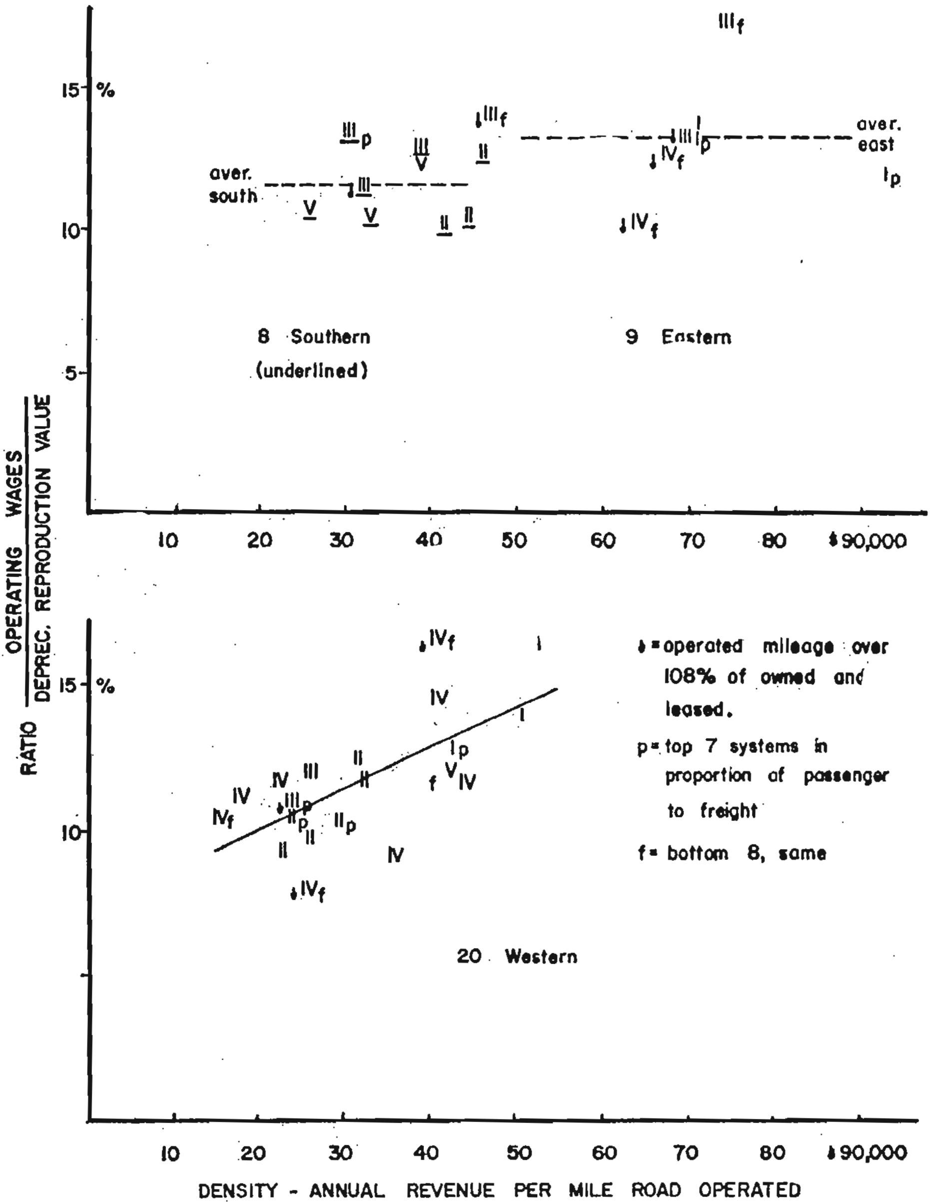
Scale	$40,000 and above density			Under $40,000 density		
	E	S	W	E	S	W
I	13.0%(3)	—	14.4%(3)	—	—	—
II	—	11.2%(3)	—	—	—	10.8%(6)
III	14.9 (3)	—	—	—	13.2%(2)	11.4 (2)
IV	11.5 (2)	—	14.4 (3)	—	11.6 (1)	10.8 (3)
V	—		11.0 (1)	12.6%(1)	10.6 (2)	9.3 (2)
III & IV	13.6 (5)		14.4 (3)	—	12.7 (3)	11.0 (5)

[5] $\frac{\text{Oper. Wages}}{\text{Oper. Revenue}}$ (%) $= \underset{(.028)}{.081}$ scale (thous. employees) + 41.8%

[6] Deviation of wage/rev. (% pts. + 14) $= \underset{(.07)}{.23}$ scale (thous. employees) + 10.2% pts.

[7] $\frac{\text{Oper. Wages}}{\text{Deprec. Reprod. Value}}$ (%) $= \underset{(.06)}{.14}$ density (thous. \$ rev. per mi. rd.) + 7.28%

CHART 5 — SYSTEM OPER. WAGES-DEPREC. REPROD. VALUE RATIO VERSUS TRAFFIC DENSITY BY REGION



The data in the table indicate there are no statistically significant effects of scale on the wage-capital investment ratio. This must be related to conclusions of the two previous sections, A and B, one that capital input per unit of revenue is some 14% lower for the scale III and IV systems than the largest ones, and the other that with a decrease in scale from scale I to a level mid-way between scales III and IV, there is a 13% decrease in the wage share of revenue. Factor proportions, capital versus labor, do not change with scale over this range.

D. MAINTENANCE EXPENSE VERSUS REVENUE AND CAPITAL INVESTMENT

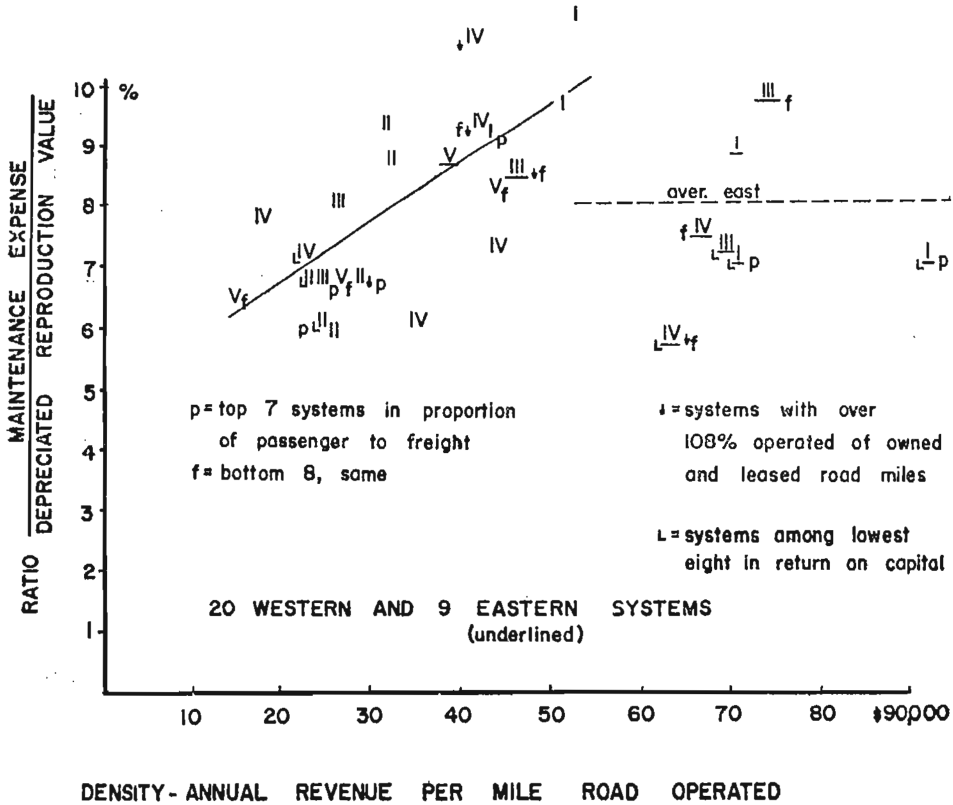
Maintenance of capital plant is a major component of railroad expense, averaging for the 37 systems 32% of revenue and 42% of total expenses. Its relative importance is indicated by the fact that transportation expenses, made up principally of those for crews, fuel and station employees, are not much greater, being 49% of total expenses.

The determination of scale effects in respect to maintenance is more difficult than for the items dealt with previously. As with them there is the independent variable of density of traffic, but its effect may be more complex. Density may enter into the picture not only because with increasing traffic wear and tear will increase, but also because with heavier traffic higher standards of maintenance may be established. Further with respect to track and related maintenance, very high density traffic may interfere with the work to such an extent that unit expense may be increased. Standards of maintenance may also reflect the extent and nature of passenger service.

Maintenance may also be affected by system profitability. A system with near zero rate of return may be presumed to be cutting maintenance to the bone in order to make both ends meet. The converse, that systems with highest levels of profit might be expected to have highest standards of maintenance does not follow as inevitably. There is the possibility that the high return is achieved by cutting maintenance, as well as the more obvious one that a high return involves greater general availability of funds for all expenditures, and for maintenance, for which there is greater latitude, in particular.

The analysis of maintenance in respect to scale may be undertaken in terms of the proportion it takes of revenue. Since maintenance may be expected to have some relation to the investment in plant to be maintained analysis can also be in terms of the ratio of maintenance expense to reproduction value of plant. This latter approach introduces the variable, the ratio of property owned and leased by a system to that used in operation. For the eight systems which operate over a road mileage in excess of 108% of their owned and leased mileage, maintenance expenses include a share for payment to the owning company for maintenance of the excess mileage but their plant value does not reflect the value of the latter facilities used. Thus their ratio of maintenance expense to capital investment would be higher than might otherwise be the case. These eight systems are confined to scale groups III to V inclusive, introducing possible bias in respect to scale analysis.

CHART 6 — SYSTEM MAIN. EXPENSE-DEP. REPROD. VALUE RATIO VERSUS DENSITY, BY REGIONS



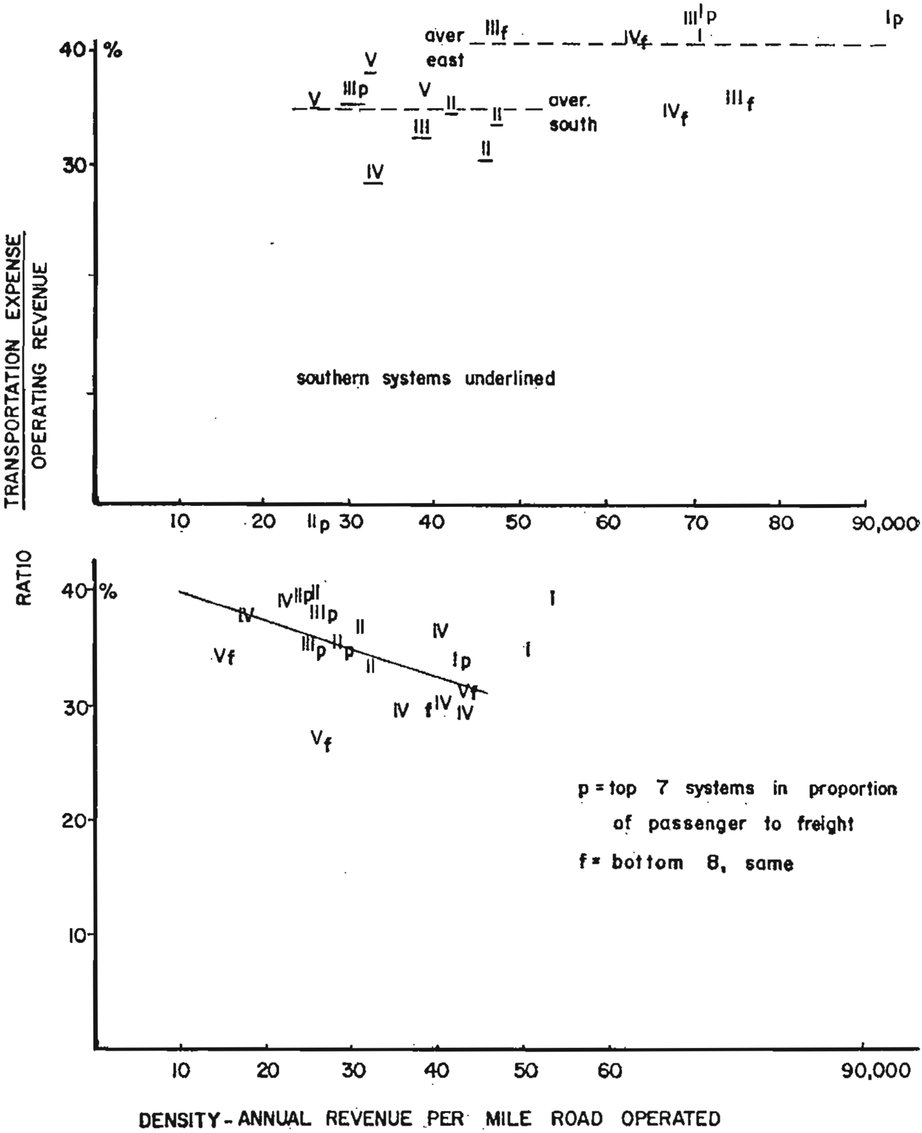
E. TRANSPORTATION EXPENSE VERSUS REVENUE

The other broad functional group of expenses relates to labor, fuel and supplies for running trains, switching cars and carrying on station work. The expenses come under the I.C.C. general accounting classification of transportation expenses. There is no major disturbing extra variable connected with these items such as the standard of maintenance. There is of course the possibility of differences in standards of service provided but this lies within narrower limits. For the 37 systems an average of 36.9% of the revenue goes for transportation expenses, with the highest system figure being 46.3% and the lowest, 29.6%. The ratio is significantly higher for the eastern systems than for the others despite the fact that the eastern ones operate at higher traffic densities.

[8] $\dfrac{\text{Main Expense}}{\text{Deprec. Reprod. Value}}$ (%) $= \underset{(.022)}{.098}$ density (thous. \$ rev. per mi.) + 4.8%

The following chart shows the system transportation expense-revenue ratios in relation to traffic density. There is no density effect apparent for the East. For the South there is a suggestion of decline with increasing density but the association is not statistically significant.

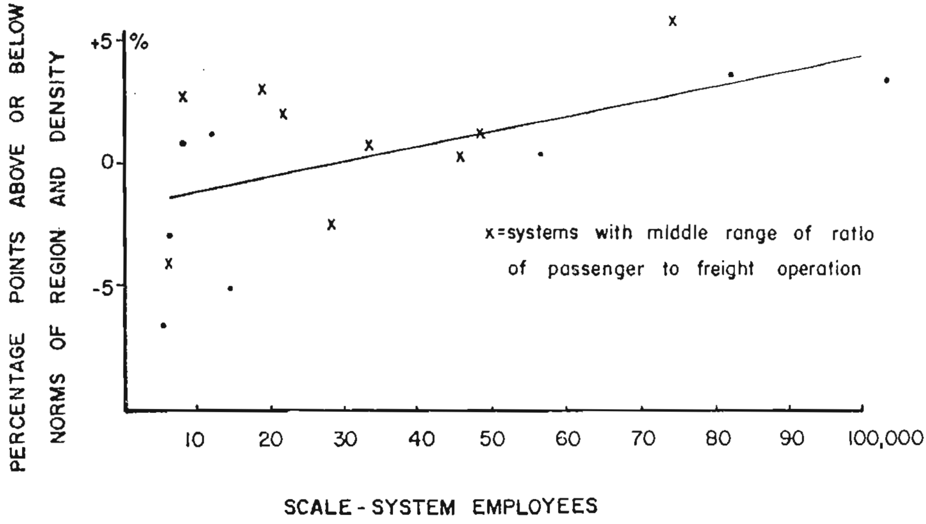
CHART 7 — SYSTEM TRANSP. EXPENSE-OPER. REVENUE RATIO VERSUS DENSITY, BY REGIONS



For the West there is a significant decline in the ratio with increasing density up to but excluding the highest densities. For the 18 systems of from $15,000 to $45,000 annual revenue per mile there is a significant relationship and analysis indicates that 23% of the variation in the transportation expense-revenue ratio is associated inversely with density.[9] For the western systems of over $40,000 revenue density the average of the transport revenue ratios is 33.8%, the same as that for the southern systems in the same density range. The corresponding ratio for the East is 40.9%.

The association of variation in the transportation expense-revenue with scale can be examined in terms of the limited sample of the 17 scale IV to I systems with densities of over $40,000 annual revenue per mile in order to minimize the influence of the effect of density. The following chart shows the relationship for these systems in terms of deviations around the regional averages for the East and South and the trend line for the West.

CHART 8 — DEVIATIONS OF SYSTEM TRANSP. EXPENSE-OPER. REVENUE RATIOS FROM REGIONAL AVERAGES OR DENSITY TREND VERSUS SCALE, SYSTEMS OVER $40,000 REV. PER MILE AND 5000 EMPLOYEES



The analysis indicates that 33% of the variation is associated with scale and that there is a statistically significant association, the larger the scale the higher the transportation expense.[10] The trend line suggests that an increase from 10,000 to 80,000 employees is associated with a 5% point increase in the transportation expense-revenue ratio.

The analysis of the 31 system sample of systems of all densities scale IV to I, in terms of deviations around regional averages for the

[9] $\frac{\text{Transportation Exp.}}{\text{Oper. Revenue}}$ (%) $= -.255$ density (thous. $ rev. per mi.) + 42.9%
(.084)

[10] Deviation of trans. exp./rev. (% pts. + 10) = .063 scale (thous. employees) + 8.1% pts.
(.023)

East and South and around the density trend for the below $40,000 systems for the West, indicates 19% of the variation is associated with scale and there is also a statistically significant association.[11] The introduction of the added systems increases the extraneous variations but makes little difference in the trend line's proportion of increase in the transportation expense share with increase in scale.

This analysis suggests that of the two major functional breakdowns of expense, maintenance and transportation, it is that of transportation, which increases most as scale of system increases above the minimum of 5,000 employees.

F. ADMINISTRATION AND SELLING INPUTS

a) Administration Inputs

The variation of administration expense as an input for railroad system operation is of particular interest in respect to scale effects. The I.C.C. accounting classification provides categories which can be added together to get data reasonably definitive of what are generally known as administrative expenses. First the classification provides a broad category of "general expenses" in which are included the items of "salaries and expenses of general officers," "salaries and expenses of clerks and attendants," "stationery and printing," "general office and supplies," "valuation expenses" and "other expenses." For this study "pensions" and "relief department" are excluded as involving non-administrative expense. "Law expenses" are not included because they relate to varying degrees to non-railroad aspects of the systems. The general office accounting function is included in these items. Second under each of the functional expense groupings of the classification, maintenance of way, maintenance of equipment, transportation, and traffic, there is an item for "superintendence" which covers departmental and divisional administration including such personnel as chief engineer, division engineer, roadmaster, general foreman and assistant train master. Since selling expenses are considered separately the item for traffic is excluded, leaving the other three included. The sum of the "general expense" and the three "superintendence" items is taken as the measure of administration expense. Because this expense is small relative to total expense, variations in its ratio to total expense can be taken as a measure of its magnitude. For the 37 sample systems the administrative expense is 8.2% of operating expenses and 6.3% of operating revenue. The salaries and expenses of general officers included in administrative expenses are only 6% of the administrative expense and thus only 0.4% of revenue.

The adjoining scatter chart indicates the relation of scale as measured by number of employees and the proportion of administrative expenses for each system of the 37 basic sample with over 5,000 employees. There are no significant differences between regions or with variations in density. Analysis indicates that 25% of the variation in the proportion is associated with scale and that there is a statistically significant inverse relation with increasing scale.[12] The obviously wide

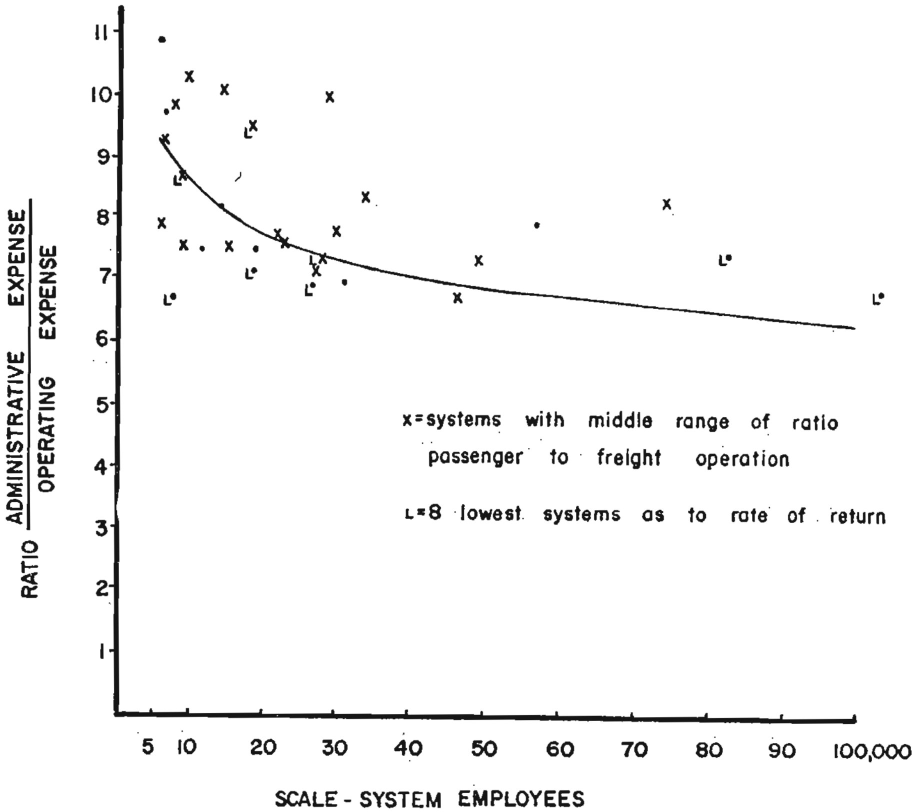
[11] Deviation of trans. exp./rev. (% pts. + 10) = $\underset{(.023)}{.066}$ scale + 8.6% pts.

[12] $\dfrac{\text{Admin. Expense}}{\text{Log Oper. Expense}}$ (%) = $-\underset{(.037)}{.132}$ log scale (thous. employees) + 1.059

deviations from the trend line suggest that other factors have great influence and tend to obscure the degree of the scale effect. The trend line indicates a two percentage point drop from a scale of 5,000 to 50,000 employees, while the points for larger individual systems suggest no further decline. The group averages are for scale IV, 8.8% and for scale I, 7.3% and suggest a 1.5% point difference.

This is the first of the relationships which has shown a gain in favor of the larger scale systems. This particular input is however a very small one compared to the others considered.

CHART 9 — SYSTEM ADMINISTRATIVE EXPENSE-OPER. EXPENSE RATIO VS. SCALE

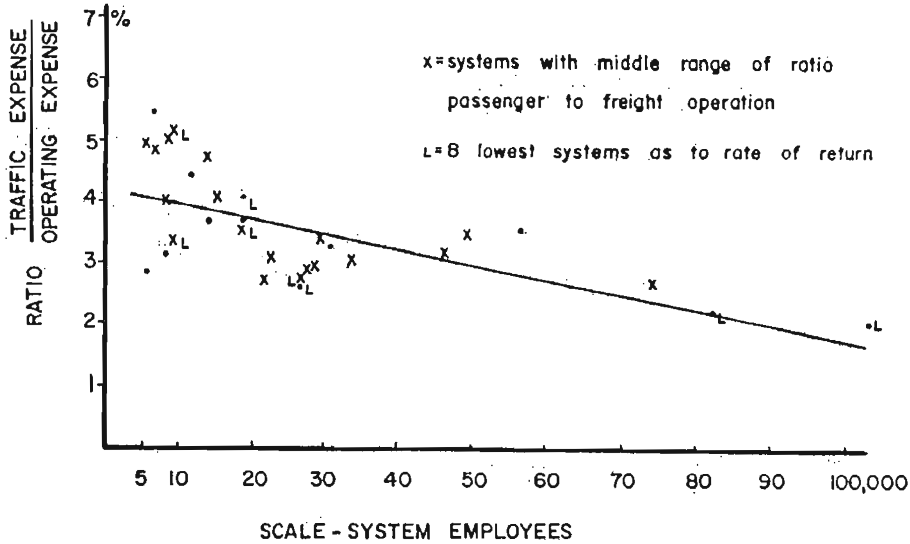


b) Selling Inputs

Selling expense is another input which might be expected to show some scale effects. It is encompassed in the I. C. C. accounting classification, "traffic," which includes those expenses "incurred for advertising, soliciting and securing traffic — and for preparing and distributing tariffs." For all 37 sample systems these expenses amount to 3.6% of total expenses and 2.7% of operating revenue.

There are no significant density or regional effects.

CHART 10 — SYSTEM TRAFFIC EXPENSE-OPER. EXPENSE RATIOS VERSUS SCALE



Analysis indicates that 40% of the variation in the ratio of traffic to operating expenses is associated with scale and that there is a statistically significant inverse relation with increasing scale.[13] The trend line suggests that the ratio decreases about one percentage point with an increase in scale from 5,000 to 50,000 employees and 1.8% points to 80,000.

This is the only other of the relationships studied which shows an advantage for the larger scale systems. Again this input is very small, even smaller than that for administration.

[13] $\frac{\text{Traffic Expense}}{\text{Oper. Expense}}$ (%) $= -\underset{(.0052)}{.0245}$ scale (thous. employees) $+ 4.24\%$

G. RETURN ON CAPITAL

A summation of all the scale effects analyzed up to this point is available in the rate of return on depreciated reproduction value of facilities plus working capital. This ratio reflects the variations from system to system in the value of plant used to obtain revenue, in the wages paid to obtain revenue as well as in the functional expenses related to revenue. The ratio also reflects whatever variation there may be in level of revenue for service provided since the numerator in the ratio is revenue minus expenses, rentals and taxes other than income. In calculating the previous ratios revenue was corrected for significant deviations from magnitudes that reflected the physical units of freight service performed. In the calculating of return the uncorrected revenue levels are used. Thus return reflects any effect of scale on bargaining over divisions of through rates, selectivity in solicitation of traffic, ability to attract industry that provides profitable traffic, as well as ability to shed unprofitable traffic.

For this analysis the measure of return to be used is rate of return before income taxes on depreciated reproduction value plus working capital, though briefly noting the additional indices of return on depreciated original cost plus working capital and the proportion which net railway operating income before income taxes is of operating revenue.

The net railway operating income (n.r.o. income) before income taxes, which is used as the dividend for calculating return, is what is left of railway operating revenue after subtracting operating expenses (in which are included depreciation), rentals for equipment and joint facilities, state and local property and franchise taxes, and federal taxes by way of social security and retirement payments. For a given system rentals may be taken to include the annual costs for the use of capital facilities owned by other systems or companies not accounted for in the reproduction investment values of the given system. Thus analysis of return is better able to take into account use of trackage rights than is the analysis of other ratios.

Income and excess profit taxes are not deducted before determining the return for several reasons. The first is that income taxes accrued in system accounts include taxes on net income from other than just railway operations. Thus for a system with non-railway income the return after taxes would be other than the return which should be imputed to railway operations alone. The second reason is the possible distortion of return for any particular period because of the use of carry-back and carry-forward provisions based on the results of other periods. Using income before income taxes assures that the accounts of one period, as nearly as may be, reflect actual railway operation of that period. Finally, net railway operating income before income taxes represents the accountant's assessment of profit on capital invested for system operation, the taxes being a deduction from that profit for fiscal purposes.

The following table presents the 40 sample systems arrayed in a declining order of their rates of return on depreciated reproduction book value plus working capital. There is a grouping of systems by quintiles indicated by the double-spaced intervals. The top quintile includes those with a return on the reproduction value of just over 5% and also includes all but one with over 8% on depreciated original value. In the bottom quintile are those with a return of less than 2.0% which includes all with less than 3½% return on original value. It is to be noted that of the top eight all but one are among the top eight as to return on net original value. In the lowest group all eight are in the same grouping in respect to both measures and with one exception in exactly the same rank order.

The ratios of return on the depreciated original value to that on reproduction value are close to the same for each of the five quintile groupings by level of return. The ratios range within the narrow limits of 1.54 to 1.63. Likewise the five groupings by scale, I to V, have average ratios within the narrow range of 1.55 to 1.67. The average for all 40 systems is 1.60. Statistically the rank correlation shows a very high relationship, .984 compared to 1.000 for perfect correlation, between returns on reproduction and original values. The consistency of this relationship and the limited deviations from corresponding rankings on the two rates of return suggest simplifying the general analysis by using henceforth the return on depreciated reproduction value alone.

The relation of return on depreciated reproduction values to the ratios of n.r.o. income b.i.t. to operating revenue, also show a considerable degree of consistency. For instance all the eight bottom systems are so ranked by both indices, and all but one of the same top roads are grouped together. Statistically the correlation is also high, with the coefficient of rank correlation of .945.

As to the relation of scale to return, the right hand columns in the array of systems ranked according to return indicate the scale group of each. The top eight with respect to rate of return include none from the largest scale group but include five of the nine IV scale systems. In the bottom quintile there are two from the largest and two from the IV scale groups. Among the top eight systems are to be found 55% of the IV scale systems, but none of the largest scale and only 11% of the next to largest scale. On the other hand among the eight poorest performing systems, there are 33% of the largest scale, 22% of the next to largest, but only 22% of the IV scale.

TABLE 7. — SYSTEM RETURNS AND PROPORTION NET RY. OPER. INCOME BEFORE INCOME TAXES OF OPER. REVENUE

System	Return before income taxes on Deprec. Reprod. Value plus W.C.	Deprec. Orig. Value plus W.C.	Prop. net ry. op. income before inc. taxes of oper.rev.	Scale
StLSW	11.4%	16.9%	29.9%	IV
KCS	9.4	15.3 (2)	31.2 (2)	IV
NYCStL	7.8	12.4 (3)	21.5 (5)	III
S	6.6	10.6 (5)	24.1 (4)	II
DRG	6.5 (5)	11.2 (4)	29.1 (3)	IV
DH	5.4	8.2 (8)	21.4 (6)	IV
SAL	5.3	8.3 (7)	19.3 (7)	III
TP	5.2	7.3 (10)	13.1 (21)	IV
ATSF	5.1	8.9 (6)	19.1 (9)	I
W	4.7 (10)	6.4 (14)	13.3 (19)	III
UP	4.5	7.1 (9)	15.2 (14)	I
IC	4.1	7.0 (11)	17.3 (11)	II
CGW	4.1	6.8 (12)	19.2 (8)	V
LN	3.9	6.3 (15)	18.9 (10)	II
WP	3.9 (15)	5.5 (17)	16.1 (12)	V
StLSF	3.9	5.2 (22)	14.0 (17)	III
GN	3.8	6.7 (13)	16.0 (13)	II
MP	3.8	5.4 (18)	13.2 (20)	II
GMO	3.3	5.9 (16)	13.9 (18)	IV
CIL(M)	3.3 (20)	5.4 (19)	11.5 (27)	V
R	3.2	5.4 (20)	15.0 (15)	III
CBQ	3.1	5.4 (21)	14.6 (16)	II
SP	3.1	4.7 (24)	10.1 (30)	I
CRI	2.8	4.9 (23)	12.8 (22)	III
MStL	2.8 (25)	4.6 (25)	12.6 (23)	V
NCStL	2.6	3.9 (31)	12.6 (24)	V
MC	2.5	4.0 (27)	11.6 (26)	V
BO	2.5	4.0 (28)	9.5 (32)	I
CEI	2.5	4.0 (29)	9.7 (31)	V
CG	2.4 (30)	4.0 (30)	11.2 (28)	V
SOO	2.3	4.1 (26)	11.1 (29)	IV
NP	2.2	3.7 (32)	12.4 (25)	II
E	2.0	3.3 (33)	7.9 (35)	III
ACL	1.9	2.9 (34)	7.4 (37)	III
MKT	1.9 (35)	2.8 (36)	8.3 (34)	IV
NYC	1.8	2.9 (35)	7.6 (36)	I
LV	1.6	2.7 (37)	8.4 (33)	IV
P	1.5	2.6 (38)	7.0 (38)	I
CMStP	1.2	2.2 (39)	6.5 (39)	II
CNW	0.0	0.0 (40)	0.4 (40)	II

A gross view of the relationship between scale and return can be obtained by reviewing the range of returns and the averages for each scale as shown in the following table.

TABLE 8 — AVERAGES AND TWO HIGHEST AND LOWEST INDICES FOR SCALE GROUPS FOR 40 SYSTEMS

Scale Group	# Sys.	Return b. i. t. on dep. reprod. value: 2 lowest	Aver.	2 highest	Prop. n. r. o. income b. i. t. of oper. rev.: 2 lowest	Aver.	2 highest
I	(6)	1.5,1.8	3.1%	4.5,5.1	7.0,7.6	11.4%	15.2,19.1
II	(9)	0.0,1.2	3.2	4.1,6.6	0.0,6.5	13.7	18.9,24.1
III	(8)	1.9,2.0	4.0	5.3,7.8	7.4,7.9	13.9	14.3,21.5
IV	(9)	1.6,1.9	5.2	9.4,11.4	8.3,8.4	18.5	29.9,31.2
V	(8)	2.4,2.5	3.0	3.9,4.1	11.2,11.2	13.3	16.1,19.2

Inspection of the above table with respect to the range of values within each scale group indicates the nature of the variation in individual system indices that accounts for the increase of the averages with decreasing scale through IV. The two lowest items in each group, I through IV, are with a single exception at the same general level. The two highest returns in each increase from I through IV at a greater rate than the averages, with those of Group IV being roughly double those of group I. It is the attainment by some scale IV systems of substantially higher levels that accounts for the group IV achievement.

Although this analysis rests on the 40 and 37 system samples it is desirable to examine the excluded systems to see if there is seriously contradictory evidence to the conclusions in respect to this gross relationship. The following table presents the three year average rate of return for excluded systems of over 2000 employees grouped according to the bases used for exclusion:

TABLE 9 — RETURN BEFORE INCOME TAXES ON NET REPRODUCTION VALUE FOR 13 EXCLUDED SYSTEMS COMPARED TO 40 SAMPLE SYSTEMS

Scale Group	40 System Sample Aver.	Industrial Related or Transit	Bit. Coal Rev. over 40% frt. rev.	Passenger train-miles over 55% of frt. train-mi.	Not autonomous
I	3.1%	—	—	—	—
II	3.2	—	Chesapeake & Ohio 7.1%	—	—
III	4.0	—	Norfolk & Western 6.9	New Haven 0.6% Boston & Maine 1.0	—
IV	5.2	Long Island 0.7%	—	Lackawanna 1.0 Central New Jersey 1.9	Grand Trunk Western 1.0 Pittsburgh & Lake Erie 7.2
V	3.0	Elgin, Joliet & Eastern 7.4 Duluth, Missabe & Iron Range 6.0 Bessemer & Lake Erie 8.6	Western Maryland 6.4 Virginian 9.4	Florida East Coast 1.9	Spokane Portland & Seattle 3.6

The concentration of these excluded systems in the three smaller scale groups, III, IV and V, limits the extent of possible conclusions. Of the predominantly coal carriers the smaller two on the average have returns slightly above the larger two of scales II and III. A similar tendency may be noted with respect to the predominantly passenger systems. All told the performance of the scale IV and V systems, with an average return for the 11 of 5.0% is above those of the same combined scale groups in the 40 system sample. This suggests that the level of returns for the smaller scale systems in the study sample is not exceptionally high. However, the special conditions surrounding the operation of some of the excluded systems makes their particularly high rate of return one that could not be expected generally of small systems.

More refined examination of the relation of returns and scale involves consideration of the effects of the other measurable variables. It has already been stated that while there is for many of the variables no continuous variation with scale, nevertheless the large scale I systems have distinct superiority in density of freight traffic and length of haul, as well as proportion of bituminous coal revenue. As compared to systems in scale IV those in scale I are respectively 40, 48 and 240% better off for these items. On the other hand the smaller scale systems have a lower proportion of carload cars originated and terminated to total carried, of empty to total car-miles, and of passenger to freight expenses and train-miles. Again contrasting scale IV with I, the former is for these items respectively 27, 6, 40 and 27% below the latter. The difference in average revenue ton-miles per loaded car-mile is slight.

The average actual ton-mile revenue exceeds the formula estimate by 0.8% for scale IV and for scale III falls 0.9% below. For the other scales there are no differences. These percentage point differences seem small but the possible leverage of price in respect to level of return is great enough to suggest that these differences are of importance.

The scale group differences favorable and unfavorable to group IV with respect to physical traffic characteristics seem on balance not great enough to clearly account for difference in levels of return. On the other hand levels of unit revenue when compared to a theoretical norm suggest that scale III returns may be low partly because of a low comparative level of unit freight revenue and scale IV returns to a lesser degree may be high partly because of the reverse.

Density of traffic might be expected to be one of the important variables affecting rates of return. The adjoining charts show the influences of density as measured by revenue per road mile which combines freight and passenger traffic densities. Scale is accounted for by identifying each system position relative to return and density by its scale group number. Systems with the previously defined extreme levels of the ratios of passenger to freight expenses are indicated by subscripts to the scale numbers, "p" indicating a high passenger proportion, "f" a low one and therefore predominantly freight. The average return for the eastern systems is 3.4%, for the southern 3.8 and the western 4.1%.

For the eastern systems, which are shown on the upper chart, there is no apparent relation between density and return. The largest scale systems, whether in the upper fifth proportion of the passenger to freight service category or not, are among the lowest in return. The three highest return systems are from scale groups III and IV, and they are also among those in the lower fifth of the systems in respect to passenger proportion of service.

For the southern systems the scatter chart indicates that return is associated with density. Correlation analysis indicates that 51% of the variation in return is related to density, with a confidence level of 1%. The line of average relationship is indicated on the chart.[14] All systems but the one with the lowest return are within the middle range of passenger service proportions.

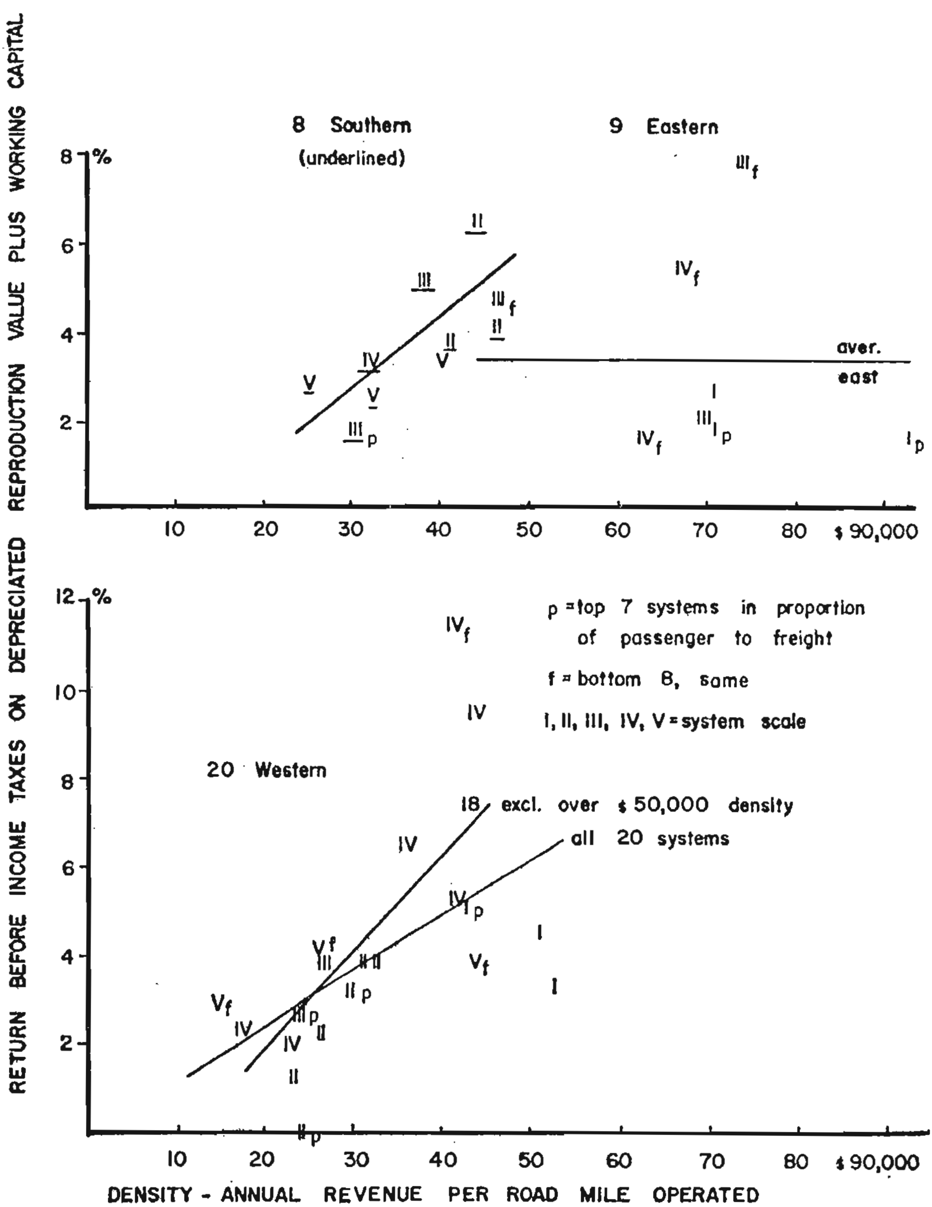
In the case of the western systems return varies with density until the highest densities are reached. If all 20 western systems be considered, correlation analysis indicates that 26% of the variation in return is associated with density. The calculated line of relationship is indicated on the lower chart. If the two highest density systems are excluded the percent rises to 49, but the resultant trend line unduly reflects the high returns of the higher density scale IV systems.[15]

[14]Return (%) = .16 density (thous. $ rev. per mi.) —2.12%
(.05)

[15]Return (20 systems) (%) = .13 density —0.22%
(.045)

Return (18 systems) (%) = .22 density —2.54%
(.05)

CHART 11 SYSTEM RETURNS VERSUS DENSITY, BY REGIONS



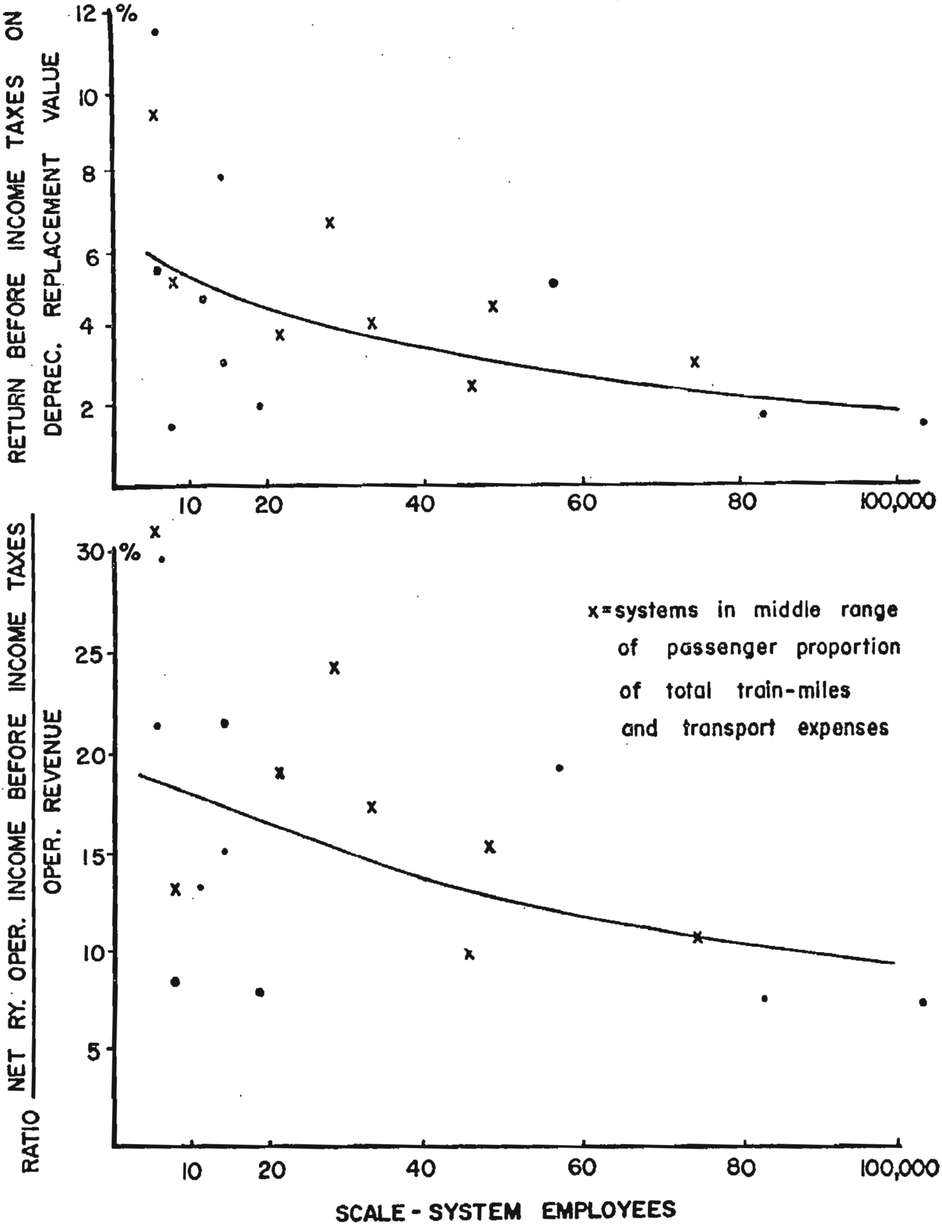
With density shown to have such a marked effect on return in two out of three regions, the effect of scale must be reconsidered. The most direct approach, though only a first approximation because it does not fully account for regional differences, is to compare systems of similar densities. To divide the systems into density groups reduces sample sizes with the consequent reduction in the reliability of any inferences. However this should assess the scale influence if it is strong enough to show through the substantial extraneous influences of region and other factors. An indirect but more definitive approach is to compare system deviations around the trend lines of the density-return relationship for each region. This allows the use of a larger sample and with the regional factor out allows the influence of scale to be more evident.

The density range of over $40,000 annual revenue per road mile operated provides the best opportunity to use the first method because in the West there is reason to believe the effect of density tapers off above the $40,000 level. The adjoining chart shows for the systems of over $40,000 revenue density in scale IV through I, two relationships, that of scale to return and of scale to the ratio of net railway operating income before income taxes to revenue. Statistical analysis indicates that 34% of the variation in return and 27% of the ratio of n.r.o.i. to revenue are associated with scale.[16] The extent of the scale effect is indicated by the trend line slope which at the scale of 10,000 employees is 3% points above that at 80,000 employees, better than double for the smaller than the larger scale chosen for example. The statistical level of confidence is at the 1% level in respect to the relation of return to scale.

[16] $$\text{Log return (\%)} = \underset{(.0016)}{-.0054} \text{ scale (thous. employees)} + .77$$

$$\text{Log } \frac{\text{n.r.o.i.}}{\text{oper. rev.}} \text{ (\%)} = \underset{(.0014)}{-.0038} \text{ scale (thous. employees)} + 1.29$$

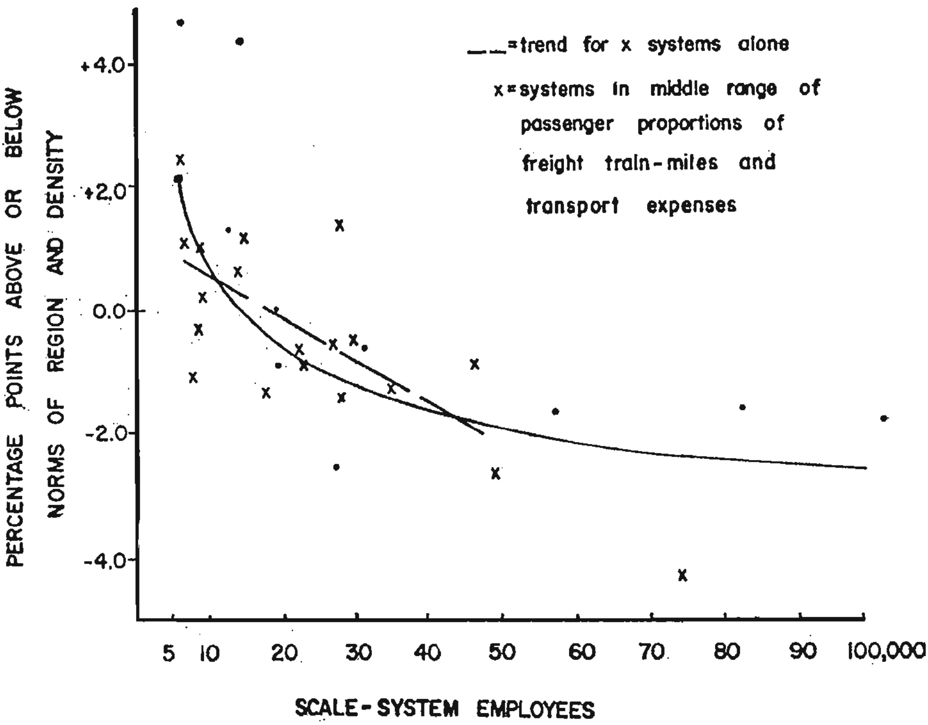
CHART 12 SYSTEM RETURNS ON CAPITAL AND RATIOS OF N. R. O. INCOME/OPER. REVENUE VERSUS SCALE FOR SYSTEMS OF OVER $40,000 ANN. REVENUE PER MILE



The second approach is to use the deviations of return around density and regional norms and relate them to scale. The following chart indicates these data for all 31 systems of scale IV through I. The trend line of best fit is drawn in and the analysis shows 41% of the variation of the deviations to be associated with scale.[17] The trend suggests that for a scale of 10,000 employees, the return is .6% points above the norms for density level and region; for 20,000, 1.6% points below; and for 80,000 2.4% below. Relative to all 31 systems this suggests for example that an average system of a scale of 10,000 employees might expect to have a return before income tax of 3% points above one of a scale of 80,000, taking density and regional differences into account.

Because of the predominance of the seven systems with high proportion of passenger to freight operations among the larger scale systems and of the five with high proportion of freight among the smaller scale systems, a separate analysis of the 19 systems of middle range passenger to freight proportions is in order. For these 19 systems 58% of the variation in return is associated with scale and the dashed trend line slope indicates a loss of 0.7% in return for each increase of 10,000 employees, above 10,000.[18]

CHART 13 DEVIATIONS OF SYSTEM RETURNS AROUND REGION AVERAGES AND DENSITY TRENDS VERSUS SCALE, SYSTEMS ABOVE 5,000 EMPLOYEES



[17]Log (deviation of return) (% pts. + 6.0) = .29 log scale (thous. employees) + 1.10
(.044)

[18]Deviation in return (% pts. + 6.0) = —.068 scale (thous. employees) +7.2% pts.
(.013)

II. PHYSICAL PRODUCTIVITY VERSUS SCALE

It would be desirable to compare some of these conclusions as to unit expenses and input ratios with analysis of data relating to physical productivity. Unfortunately in spite of the vast amount of detailed information collected about the physical performance of railroads it is impossible to make effective use of it for this purpose because of lack of homogeneity in respect to some of the items measured and the lack of completeness of data with respect to others. For instance the regularly published statistics of freight train performance do not separate data of the through-freight which is primarily a producer of linehaul service from data for the local or way-freight train which to a substantial degree performs switching or terminal operations. An example of the second type of gap is one already mentioned, namely the lack of complete system data as to freight cars interchanged, originated and terminated. There is no published count of empty cars interchanged or l. c. l. cars terminated so that not even the total count of cars handled in terminal service is known. These latter deficiencies, for instance, prevent analysis of over-all switching productivity in terms of traffic handled.

One bit of sample data has been collected with respect to train operation which does provide an opportunity to look at system through-freight train physical productivity. These data, based on seven one day samples in 1956 and 1957 covering each of the days of the week, cover gross ton-miles and train miles and do separate out the through freight from the way freight data. The through-freight trains for this sample are considered to be "trains which are operated primarily to move cars in road service between two or more concentration or distribution points or terminals". That they "incidentally perform some switching at way stations" does not classify them as way-freights.[19]

The differences between scale groups with respect to a measure of freight train productivity, gross ton-mile per train-mile of through freights, are indicated in the following Table. The data do not show any traffic density influence on the ratio.

TABLE 10 SCALE GROUP AVERAGES AND HIGHEST AND LOWEST GROSS TON-MILES PER THROUGH FREIGHT TRAIN-MILE, 37 SYSTEMS

Scale Group	2 lowest	Group Average	2 highest
I	3440, 3460 T.	3610 T.	3710, 3770 T.
II	3290, 3470	3900	4270, 4510
III	2880, 3140	3440	3490, 4170
IV	3160, 3640	4150	4730, 5220
V	2740, 3120	3650	4120, 5220

[19]This definition and data are on ICC, Bur. of Accounts, Cost Finding and Valuation, Form, Bud. Bur. 60-R258.1 for the various companies (1956-7)

There are wide variations within most of the scale groups, reflecting different policies as to freight train scheduling and service standards, as well as differences in topography and nature of traffic. There is no continuous trend with scale nor any statistically significant differences between scales, except that scale IV systems are significantly above scale I. The extremes on the high side show that smaller scale systems are able to get the highest train tonnages. In fact the highest tonnages for each of the regions are to be found on systems in the two smallest scale groups.

This single available index of physical productivity shows no gain with increasing scale, but rather that the second smallest scale systems achieve the maximum performance.