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Part Two

Individual Transportation Industries

Chapter 4

Steam Railroads

Despite some use of electric traction and the recent adoption of Diesel power on a fairly large scale, all rail carriers — except only wholly electrified local systems — are still officially described as 'steam railroads'. This usage will be followed here.

Steam railroads move more than half the passenger and nearly two-thirds of the freight traffic carried by intercity transportation agencies. Of two million transportation workers within the United States and on ocean-borne American-flag vessels, about half are employed by our railroads.

Relatively speaking the railroads are old, for among forms of carriage considered in this book only waterways have a longer history. Moreover, railroads are distinguished from all other transportation agencies in that they constitute, from the physical and traffic standpoints, a unified system. Although operated by several hundred distinct companies, they have long enjoyed standard track and loading gauges, interchangeable locomotives and cars, and uniform couplers and air brakes. From the traffic viewpoint, joint rates and through routes allow passenger travel and freight shipments from one end of the country to the other.

Our definition of the steam railway industry includes the line-haul roads, the switching and terminal companies, the Pullman Company, and the Railway Express Agency or its predecessor companies.[1] Since 1911 the ICC has classified line-haul companies on the basis of operating revenues, those of class I having annual revenues above $1,000,000, class II above $100,000 but

[1] Excluded activities which might possibly be considered part of the industry are buslines owned by railroads and freight-forwarding concerns. The former are here considered part of the bus industry; data on the latter are scanty.

below $1,000,000, and class III below $100,000.[2] Line-haul carriers provide most of the switching and terminal services required by their operations; the remainder is furnished by specialized switching and terminal companies.[3] The functions of the Pullman Company and the Railway Express Agency are familiar. In 1939 line-haul companies constituted more than nine-tenths of the entire steam railroad industry (Table 15).

Table 15

STEAM RAILROADS: VALUE OF PRODUCT AND NUMBER OF EMPLOYEES, 1939[a]

	Operating Revenue in 1939 (mil. $)	*Percentage of Total*	*Employees in 1939* (th.)	*Percentage of Total*
All line haul companies	4,050	93.9	1,007	90.5
Class I	3,995	92.6	988	88.8
Class II	47	1.1	15	1.4
Class III	8	0.2	4	0.3
Switching & terminal companies	90	2.1	42	3.8
Class I	61	1.4	30	2.7
Class II and III	29	0.7	12	1.1
Pullman Company	61	1.4	21	1.9
Railway Express Agency	112	2.6	42	3.8
TOTAL, ALL COMPANIES	4,313	100.0	1,112	100.0

[a] Interstate Commerce Commission, *Statistics of Railways in the United States, 1939.*

THE CONCEPT OF PHYSICAL OUTPUT

The output of any industry, with minor exceptions, is sold on the market. By appealing to the judgment of the market place we can combine the outputs of different commodities (or units of trans-

[2] The relative importance of class I line-haul carriers has slightly expanded since 1911, in which year they contributed 96.5 percent of the operating revenues of all line-haul companies; corresponding percentages were 98.6 for 1939 and 98.8 for 1946. Any index of output based on class I statistics, as ours must be in some years of the period, therefore requires a small adjustment to eliminate a slight upward bias.

[3] Switching and terminal companies may also operate bridges and ferries and transport regular freight and passenger traffic, although such activity on their part is small.

portation service, as in the present instance) in a reasonably unambiguous fashion. We add apples and oranges by summing their values in constant prices; that is, by valuing physical quantities in terms of a system of prices derived from the market place. The prices chosen are constant in the sense that their time reference is the same, not only for all commodities in the summation, but for output at all dates for which any given comparison is made. The time reference in question is called the 'weight base', and may be a single year or group of years. In this study within the railroad industry we have used the Edgeworth formula, which rests on the average price of the commodity (e.g., average revenue per passenger-mile) for each pair of years considered. In combining the outputs of the various transportation industries we have used 1939 weights.

So long as we are willing to accept its judgments, the phenomena of the market place also afford criteria for testing the adequacy of any unit, or system of units, we may select for measuring the output of a single commodity.[4] It is convenient to regard amounts of output, produced simultaneously, as equivalent to each other when the value the market sets upon them is the same. A simple extension of this notion leads to the requirement that the physical unit we choose, in measuring output from one period to another, shall satisfy the following condition: namely, that quantities of output measured in terms of this unit shall, at any given moment, be proportional to the money values assigned to them by the market. The use of this criterion of course leads to results that are a function of the institutional character of the market itself. For instance, where the price of output is administered, or where monopoly conditions prevail, the result may be quite different from that under conditions of perfect competition. We have no certain knowledge as to how price and output would behave if the character of the market were different

[4] If no conceivable system of units will satisfy the test to be proposed, we are bound to regard the output in question not as a single commodity but as a group of distinct commodities. If the classification is sufficiently fine, we can presumably always find units that meet the test: in that case the problem is reduced to one of the availability of statistical detail and of the patience of the computer.

from what it is: consequently the criterion just outlined appears to furnish the sole objective basis available for distinguishing between different possible physical units of measurement.

The strict application of this principle would force us to take full account of product differentiation wherever the latter gives rise to price differentials. Not only variations in quality, but quantity discounts, and varying conditions of service or delivery, would force us to classify as separate commodities portions of output that are otherwise similar. However, in the case of most concrete goods it is not hard to find an attribute, such as weight or volume, for which the condition indicated — a proportional relationship between quantity and value — is approximately fulfilled. In considering the output of services, it is often much more difficult to find a satisfactory unit. The product is intangible; and peculiarities of pricing may cast doubt upon procedures that in other industries would appear acceptable. In particular, transportation services are sold in a market that, although somewhat more competitive than it once was, is still highly monopolistic at some points, and in which prices are frequently settled by *fiat*. The use of such prices for weighting an index of transportation output, as in this book, perhaps needs explicit justification. The points at issue are discussed at greater length in Appendix A.

The units of passenger and freight output adopted here are the passenger-mile and ton-mile respectively. In the case of passenger traffic we are comparatively fortunate. For years since 1922 the available statistics allow us to divide the sum total of passenger-miles among (1) parlor and sleeping car, (2) coach (noncommutation), and (3) commutation traffic. For any given year revenues per passenger-mile differ sharply between these three classes, but within each are practically constant and do not depend on length of journey.[5] Accordingly, we have constructed our index of output for passenger transportation by combining the three passenger-mile series mentioned, using revenues per passenger-mile as weights.

[5] However, since 1932 coach passengers have paid lower rates in the south than elsewhere, and reductions for round-trip tickets have been instituted in many parts of the country. Some traffic also moves at tourist or excursion rates.

In the case of freight traffic the situation is much less favorable. Except for the isolated year 1932, we have no breakdown of ton-miles, by revenue per ton-mile or by commodity. The statistics treat a ton of fresh vegetables shipped a hundred miles as the equivalent of a ton of coal shipped a like distance. Yet we know that fresh vegetables earn a higher revenue per ton-mile than coal. Equally the summation of ton-miles gives to a single ton carried a hundred miles the same significance as a hundred tons carried one mile, although revenue per ton-mile is commonly lower for long than for short hauls. Evidently two quanta of transportation, each comprising one hundred ton-miles, may sell for widely differing prices. No definite, least of all any proportional, relationship exists between the amount of output and its value. This difficulty could be overcome only through the use of ton-mile figures classified simultaneously by commodity and by length of haul, but no such statistics exist.[6]

This deficiency in the ton-mile suggested the possible use of the ton originated (i.e., shipped) as an alternative unit for measuring freight traffic. Unlike ton-miles, tons originated (and revenue per ton originated) are available by individual commodities. In using these data, therefore, it would be possible to take account of *differences* in rate per ton-mile and length of haul *between commodities.* On the other hand, an index based on tonnage originated can pay no attention to *changes* in the length of haul — a substantial factor. For this reason we rejected tons originated as a basic measure of freight output. We preferred to base our measures on a summation of (unweighted) ton-miles, making subsidiary calculations to suggest the bias introduced by the lack of an appropriate weighting system.[7] In these calculations it is shown, for example, that — on plausible assumptions — our (unweighted) ton-mile index understates by some 5 to 10 percent the decline in freight traffic between 1919 and 1939 that would

[6] The error introduced into our index of freight traffic by our failure to discriminate *between* groups of commodities can be estimated, granted certain assumptions; see Appendix C.

[7] Still another alternative might possibly be deflation of freight revenue by an index of freight rates; however the worth of the result would be difficult to appraise.

be reported by an appropriately weighted index, i.e. the unweighted index has an upward bias during the years indicated.[8]

We turn now to the actual indexes, first for passenger traffic, then for freight traffic, and finally for railroad transportation as a whole.

PASSENGER TRAFFIC

Railway passenger traffic falls into three well defined categories: (1) commutation, (2) other coach, and (3) parlor and sleeping car service. Commutation traffic is the smallest of the three, contributing less than 18 percent of passenger-mileage and only 9 percent of passenger revenue in 1939. Coach travel is quantitatively the largest, making up about one-half of total passenger-miles in 1939; its revenue contribution, however, was somewhat less than that of parlor and sleeping car service, which accounted for nearly half of the revenue total but only one-third of total passenger-miles (Table 16).

Table 16

STEAM RAILROADS: PASSENGER TRAFFIC, 1939[a]

	Passengers (mil.)	*Passenger-miles* (bil.)	*Revenue* ($ mil.)	*Revenue per Passenger-mile* (cents)
Commutation	231	4.01	41	1.02
Coach (other than commutation)	200	11.12	200	1.80
Parlor and sleeping car	20	7.53	224	2.98
TOTAL	451	22.66	465	2.05

[a] *Statistics of Railways;* see also Appendix Table B-3. Figures relate to class I roads only. Parlor and sleeping car revenue includes Pullman charges.

The index of passenger traffic (Table 17 and Chart 10) is constructed in three segments. For years after 1922 it employs the tri-partite division just noted. For 1911-22 it is based on a simple division between coach (including commutation) traffic on the

[8] The choice between ton-miles and tons originated as a basis for the measurement of freight traffic is explored more fully in Appendix C, where the calculations mentioned are given in detail.

one hand, and parlor and sleeping car traffic on the other. Prior to 1911 the index represents unweighted passenger-miles. The difference in movement between weighted and unweighted indexes, for the period for which both can be computed, is slight.

Trends in Passenger Traffic

Rail passenger traffic reached peak levels in 1919 and 1920— levels which were not surpassed until World War II (Chart 10). The movement over the five decades 1889-1939 suggests a rather clear case of retardation in growth. Indeed an upward trend prior to World War I seems to have given place to a downward trend during the interwar period. The significance of the change in trend which occurred about 1920 is clear enough. During World War I automobile production first attained a really large scale.[9] Not until the war was over did the full impact of the private automobile and the unfolding public highway network make itself felt.[10] Once wartime shortages were safely in the past, and the brief but sharp business collapse of 1920-21 had been surmounted, the private passenger automobile quickly became the chief competitor of rail passenger service. Nor must we overlook the motorbus and the airplane. Buslines, which had hastened the decline of electric railways, came in the 1920's to compete with rail coach traffic, as their range of operations widened. Finally, commercial airlines, whose seeds were to be found in the expansion of aviation during World War I, emerged in the 1930's as a competitor of rail parlor and sleeping car traffic. Some of these rival transport agencies will be considered in later chapters.

Against this background, the vast expansion of passenger traffic during World War II may be viewed as a partial and temporary return to an earlier output trend — the trend which had prevailed before World War I. During 1942-46 private automobile travel was severely restricted by rubber and gasoline shortages; and the expansion of intercity buses and commercial airlines was checked. As a result, the smaller railroad mileage of 1944 carried far more

[9] Almost 2 million cars and trucks were produced in 1917, about ten times as many as in 1910.

[10] See Joseph L. White, *Transportation and Defense* (University of Pennsylvania Press, 1941), p. 21.

Table 17

STEAM RAILROADS: INDEXES OF PASSENGER, FREIGHT, AND TOTAL TRAFFIC, 1890-1946[a]
1939 : 100

Year Ending June 30	*Passenger*	*Freight*	*Total*	*Calendar Year*	*Passenger*	*Freight*	*Total*
1890	50.4	22.7	27.1	1920	207	123.4	136.7
1891	54.9	24.5	29.3	1921	164.2	92.3	103.9
1892	56.5	26.5	31.3	1922	157.9	102.0	110.8
1893	59.9	28.1	33.2	1923	169.9	124.1	131.0
1894	60.1	24.2	29.8	1924	161.4	116.9	123.6
1895	51.8	25.9	30.1	1925	161.3	124.5	129.9
1896	55.3	29.0	33.3	1926	159.6	133.4	136.9
1897	52.0	28.8	32.6	1927	150.7	128.8	131.5
1898	56.6	34.6	38.3	1928	141.3	130.0	131.2
1899	61.6	37.5	41.6	1929	138.2	134.2	133.7
1900	67.6	42.8	47.0	1930	117.8	115.0	114.6
1901	73.0	44.3	49.2	1931	94.3	92.8	92.5
1902	82.8	47.4	53.3	1932	71.1	70.2	70.0
1903	88.0	52.1	58.2	1933	69.2	74.7	73.6
1904	92.7	52.6	59.3	1934	77.8	80.6	79.8
1905	100.8	56.3	63.7	1935	80.3	84.6	83.7
1906	106.6	65.2	72.2	1936	98.2	101.7	100.9
1907	117.3	71.4	79.2	1937	108.7	108.2	108.1
1908	122.6	65.3	74.8	1938	95.5	87.0	88.1
1909	122.5	65.4	74.8	1939	100.0	100.0	100.0
1910	136.0	76.1	86.1	1940	103.6	111.9	111.0
1911	139.6	75.7	86.3	1941	129.5	142.4	140.5
1912	139.8	78.7	88.9	1942	243	191.1	195.4
1913	146.2	90.0	99.0	1943	390	218	236
1914	149.2	86.1	96.1	1944	425	221	244
1915	138.1	82.6	91.3	1945	409	204	229
1916	146.6	102.4	109.1	1946	288	177.4	192.9
Calendar Year							
1916	151.1	109.2	115.4				
1917	172.7	118.8	127.2				
1918	184.4	121.9	131.0				
1919	204	109.5	124.1				

[a] Based on data in Appendix B. The freight index represents unweighted ton-miles on class I, II and III roads. For 1890-1911 the passenger index represents unweighted passenger-miles on class I, II and III roads. For 1911-46 the passenger index shows weighted passenger-miles on class I roads and the Pullman Company. Wherever two or more series are combined, the Edgeworth method was used (i.e., weights are average unit revenues for each pair of years compared). For any segment, the terminal years were compared, and the results of year-to-year comparisons were adjusted to the terminal year comparison by distributing of the small discrepancy. In constructing the passenger index 1911-22, 1922-29 and 1929-39 were treated as such segments. (Thus the

comparison between 1922 and 1931 involves three Edgeworth comparisons: 1922-29, 1929-30 and 1930-31, the two latter including the small adjustment mentioned.) The passenger index prior to 1911 and the freight index throughout are simple aggregates. The passenger and freight indexes were combined using segments: 1890-99, 1899-1909, 1909-19, 1919-29, 1929-39. Comparisons for years after 1939 use 1939 unit revenues as weights (Laspeyres' index). In order to include uniformly all line haul, and switching and terminal companies, the Pullman Company and the express companies, the index was multiplied by an index of coverage (which varied only slightly from 100 percent) based on the ratio of operating revenues of all companies to revenues of companies included in the index before adjustment for coverage.

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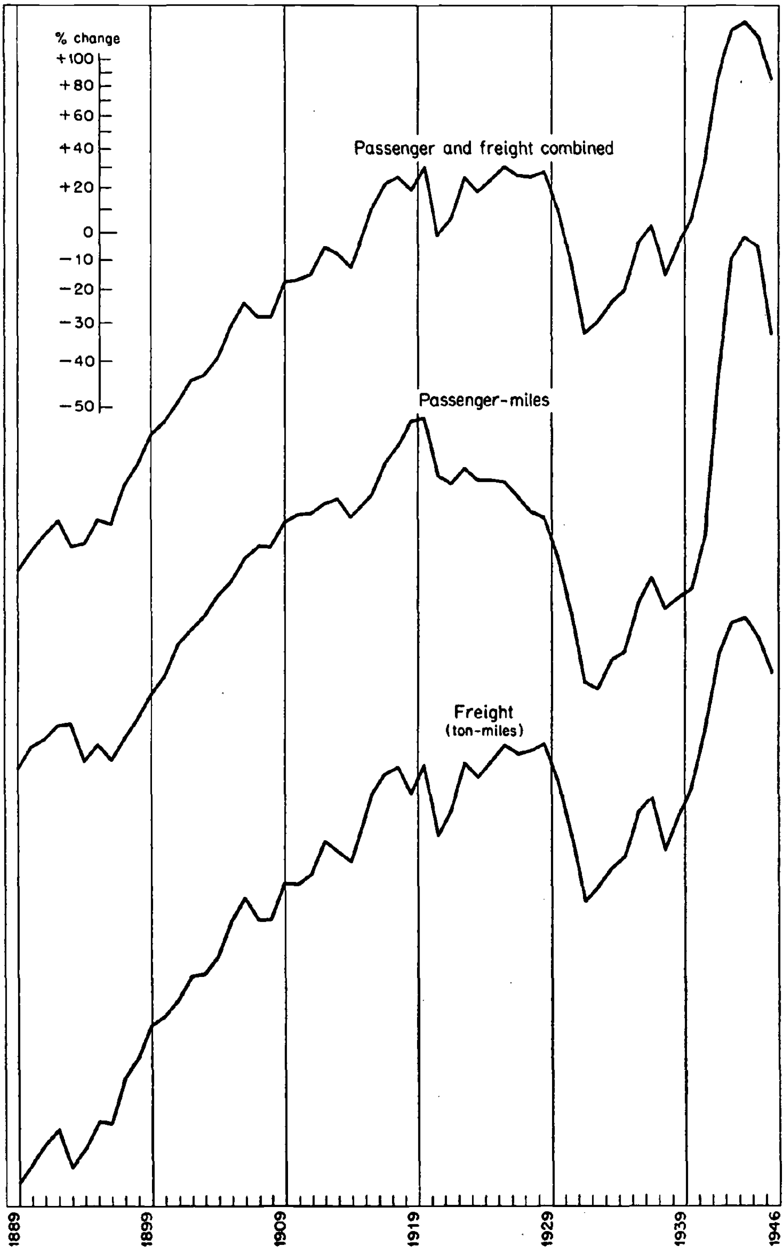
traffic than moved in 1920. Indeed growth of railroad passenger traffic between 1920 and 1944 (omitting the intervening years) was almost as rapid as it had been before 1920 (Chart 10). The practical cessation of growth after 1920 in peacetime passenger traffic must evidently be attributed mainly to the rise of newer modes of travel.

No breakdown of passenger traffic is available for the first decade of the century, but it is likely that all classes of traffic shared in the general expansion. At the turn of the century fears had indeed been expressed that the rapid rise of the electric railway might retard the future expansion of the passenger traffic of steam railroads; the difficulties of the rail passenger service in the previous decade when, especially in the 1893-97 depression, passenger-mileage declined sharply, had been attributed to this factor.[11] However, with the purchase of new equipment and the electrification of suburban trackage, the railroads successfully met what proved to be but the first of several new competitive threats. Commutation traffic was first reported separately from other coach traffic in 1922, when it amounted to 6 billion — or about one-sixth of total — passenger-miles (Chart 11). It rose moderately throughout the 'twenties to nearly 7 billion passenger-miles in 1929; meanwhile other coach traffic was already declining rather sharply.

Coach travel (other than commutation) fell nearly 7 billion

[11] See *Statistics of Railways,* 1897, p. 61, and 1898, p. 68. On the effects of electric railway competition, see also Thomas Conway, Jr., 'Traffic Problems of Interurban Electric Railroads', *Journal of Accountancy,* Oct. 1908, pp. 427-8; and Edward S. Mason, *The Street Railway in Massachusetts* (Harvard University Press, 1932), pp. 63-4.

Chart 10
STEAM RAILROADS: PASSENGER, FREIGHT, AND COMBINED TRAFFIC

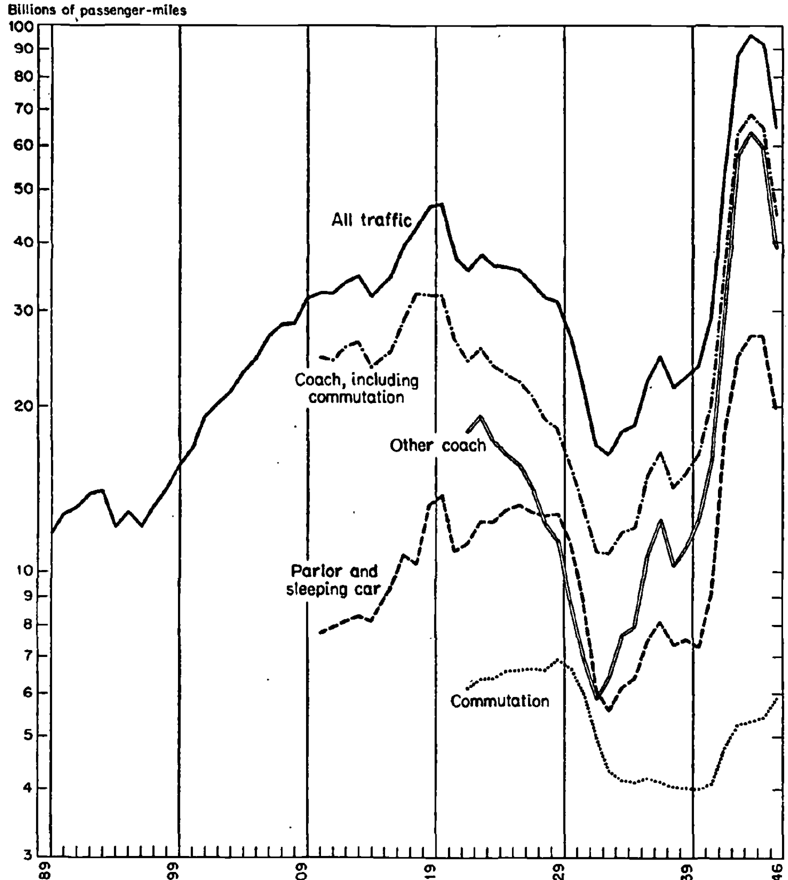


Source: Table 17

Ratio scale

passenger-miles between 1922 and 1929, and measured about the same in 1939 as in 1929. It is plain that the private automobile, furnishing several hundred billion passenger-miles of travel annually, has mainly called forth 'new business' which never could have moved by rail. Doubtless a substantial part of intercity bus travel (10 billion passenger-miles in 1939) consists of coach traffic lost by the railroads, but it too must have reached layers of demand not tapped by rail transportation. If the newer agencies have

Chart 11
STEAM RAILROADS: PASSENGER TRAFFIC



Source: Appendix B

Ratio scale

predominantly encouraged travel which the railroads could not or would not develop, it seems certain that the cessation of growth in railroad coach travel must be attributed to the automobile and intercity busline.

Small amounts of Pullman traffic, which quantitatively had begun to outrank coach by 1929, were lost to the commercial airlines during the 1930's. Yet in 1939 airlines still accounted for well under a billion passenger-miles, although rail Pullman service had apparently lost six or seven times that amount of traffic during the decade. Obviously the privately owned passenger car had become the dominant factor in intercity travel, both for commercial and domestic purposes; moreover intercity bus transportation was now a substantial factor in the picture. Most of the diversion of traffic from the railroads to the airlines has occurred during and since World War II.

Before leaving the subject, we may note changes in the length of the average rail journey. These changes suggest that, at least up to 1939, the railroads chiefly lost short-haul traffic. Thus the average journey per passenger increased from 28 miles in 1899 to 50 in 1939, a gain of nearly 80 percent. Since 1922 passengers in the three groups have traveled the average distances in the accompanying table.

Of the entire increase in length of journey since 1899 some part may reflect settlement of the Pacific Coast and the continued growth of transcontinental travel. Since 1922 commuters may have journeyed further in part because of suburban expansion.

AVERAGE JOURNEY[a] (miles)

	1922	*1929*	*1939*	*% gain 1922-39*
Commutation	14.3	15.1	17.4	22
Other coach	35.7	40.2	55.6	56
Parlor and sleeping car	259	288	379	45

[a] The Pullman Company reports a considerably longer journey than that shown here for parlor and sleeping car passengers (e.g., 542 miles in 1939) because its figures relate to the purchase of accommodations for an entire trip, regardless of the number of separate railroad companies involved. The figures quoted here refer to the average journey over any single railroad. The reported increases in length of journey, therefore, reflect railroad consolidation, but the effect has been minor.

Yet it seems plain that the growth of the average length of the rail journey mainly reflects greater diversion to other agencies of short than of long distance traffic.

To summarize: railroad passenger traffic reached a peak in 1919-20, a peak surpassed only by the rush of business during World War II. During the 1920's regular-fare coach traffic declined rapidly but commutation and parlor and sleeping car traffic remained remarkably stable. Although all forms of traffic fell off during the depression, coach traffic suffered no further net decline during the 1930's. But commutation traffic did not recover from depression levels, and parlor and sleeping car traffic also stood lower in 1939 than in 1929. Because of loss of short haul traffic, and for other reasons, the average journey steadily lengthened.

FREIGHT TRAFFIC

The ideal measure of freight traffic would involve a summation of shipments (i.e., tons originated), each shipment being weighted by the revenue it earned during some base period. That is, all shipments of commodity A between points X and Y (or, less accurately, all shipments of commodity A with a specified length of haul) — but no larger aggregate — should be treated as homogeneous. The resulting total (whether of tons or ton-miles is unimportant) would then be weighted by its average revenue in the base period. This is a counsel of perfection. Shipments are not classified by length of haul; and — except for the isolated (and atypical) year 1932 — no division of the ton-mile aggregate by commodities is available. Yet if we wish to allow for changes in length of haul — and there is ample evidence that hauls are longer than they used to be — then we must use the ton-mile as our unit, despite the fact that we have no means of segregating high revenue from low revenue ton-miles. Accordingly, our basic index for railroad freight traffic is a simple (unweighted) ton-mile aggregate. (Tables 17 and 18 and Chart 12.) Unlike passenger traffic, which reached a peak in 1919-20 and then declined, freight traffic continued to grow, reaching its pre-1940 peak in 1929. Between 1889 and 1929 ton-miles rose not quite sixfold, declined some

Table 18

STEAM RAILROADS: INDEXES OF FREIGHT TRAFFIC, 1890-1940
1929 : 100

Year Ending June 30	*Basic Index* Ton-miles, unweighted[a]	*Alternative Indexes* Tons originated, unweighted[b]	*Alternative Indexes* Tons originated, weighted[c]
1890	16.9	....	....
1891	18.0	....	....
1892	19.6	....	....
1893	20.8	....	....
1894	17.8	....	....
1895	18.9	....	....
1896	21.2	....	....
1897	21.1	....	....
1898	25.3	....	....
1899	27.5	35.3	37.8
1900	31.4	41.1	43.0
1901	32.7	41.1	43.4
1902	34.9	46.3	48.4
1903	38.5	50.4	53.5
1904	38.8	50.3	53.4
1905	41.4	55.3	57.1
1906	47.9	63.1	64.9
1907	52.5	68.9	70.3
1908	48.5	61.3	61.6
1909	48.6	62.1	62.6
1910	56.6	72.3	71.3
1911	56.4	70.7	71.9
1912	58.7	72.7	73.9
1913	67.0	83.3	84.1
1914	64.1	79.6	80.2
1915	61.6	72.1	76.5
1916	76.3	89.0	91.2
Calendar Year			
1916	81.3	92.8	95.0
1917	88.5	97.4	97.7
1918	90.8	97.0	97.8
1919	81.6	83.8	89.0
1920	91.9	96.0	97.1
1921	68.8	71.7	75.3
1922	76.0	78.3	83.0
1923	92.5	97.8	97.5
1924	87.1	90.7	92.5
1925	92.7	95.2	96.2
1926	99.4	101.4	100.2
1927	96.0	96.7	96.2
1928	96.9	96.6	97.4
1929	100.0	100.0	100.0

Calendar Year	Basic Index Ton-miles, unweighted[a]	Alternative Indexes	
		Tons originated, unweighted[b]	Tons originated, weighted[c]
1930	85.7	86.0	85.2
1931	69.1	66.6	68.2
1932	52.3	47.8	50.6
1933	55.7	51.7	53.2
1934	60.0	56.5	57.9
1935	63.0	58.6	59.9
1936	75.8	71.3	70.9
1937	80.6	75.8	74.9
1938	64.8	57.8	60.0
1939	74.5	67.3	67.5
1940	83.4	75.3	73.4

[a] Data from *Statistics of Railways;* see Appendix Table B-1. Index covers class I, II, and III line-haul companies for 1907-39; and the same, together with switching and terminal companies, for 1890-1907. This index is the same as that shown in Table 17, except that data have not been adjusted for coverage prior to 1911.

[b] Data from *Statistics of Railways;* not available prior to 1899. Index covers class I, II, and III line-haul companies; for 1899-1907, some small amounts of tonnage originating on switching and terminal companies may be included, but no adjustment was possible on this account.

[c] Data from *Statistics of Railways;* not available prior to 1899. Index is based on commodity breakdown for class I traffic, as follows; 6 classes, 1899-1924; 66 classes, 1924-28; 157 classes, 1928-40. Comparisons used revenues per originating ton as follows: 1899-1928, 1928; 1928-29, average 1928 and 1929; 1929-40, average 1929 and 1937. Revenue data were used to adjust the index to include traffic on class II and III roads, the assumption being that the ratio of revenue per ton on class I to revenue per ton on class II and III roads did not alter.

25 percent on balance between 1929 and 1939, then more than doubled during World War II.

Trends in Freight Traffic

Although for the reason indicated the ton-mile aggregate will be treated as basic, indexes derived from tons originated are also shown (Table 18). The latter appear to be biased downward, since they do not take account of the lengthening average haul. Thus over the period 1899-1939 the average annual increase is only 1.6 percent for tons originated but 2.3 percent for ton-miles. In discussing the changing composition of railroad freight traffic, we shall have to use originating tonnage series and bear this bias in mind.

It is obvious that freight traffic, like passenger traffic, has been subject to marked retardation of growth, at least over the period 1889-1939 (Chart 10).

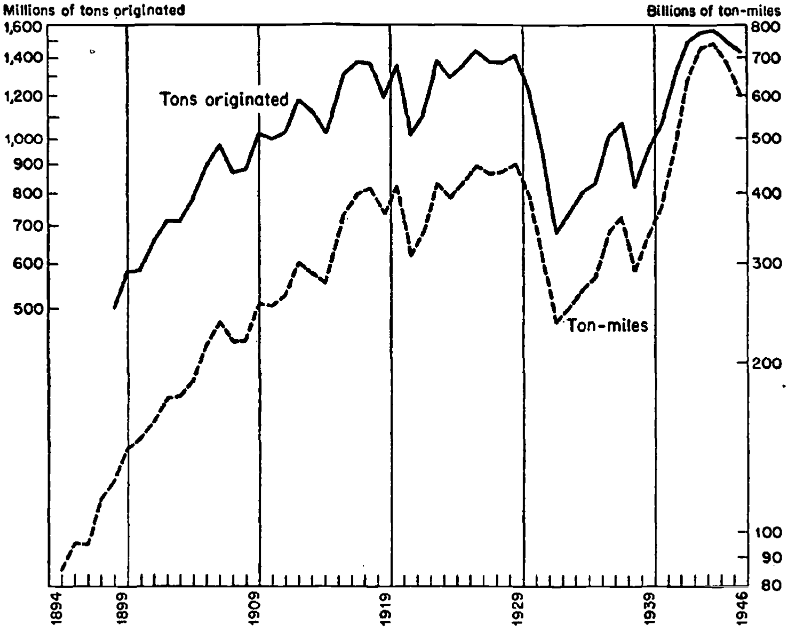
The substantial advance of railroad ton-mileage in the first two decades of the century accompanied the expansion of the national market. The railroad network, now approaching completion, served to connect manufacturing centers with the source of raw materials, and urban consumers with areas of food supply. The pre-World War I era was generally characterized by a business optimism engendered by a steadily rising commodity price level, increasing industrial and agricultural production, and the opening of new markets at home and abroad. In this era, the railroads enjoyed an unchallenged position in the country's transportation system. Preceding decades had seen the virtual supersession of rivers and canals by the railroad, while mechanical highway transportation was still in its infancy.

Already evidence of the railroad industry's maturity was to be found in the falling off in the construction of new lines. Total rail mileage under operation (excluding switching and terminal companies) stood at 188,000 in 1899 and rose at an average annual rate of 2 percent to a peak in 1916; thereafter it maintained itself at a level of 260,000 until 1930, when an average annual decline of one-half percent set in. During the period after 1916, the small construction of new lines balanced the abandonment of unprofitable lines. The construction of additional trackage and sidings continued throughout the 'twenties, although this too declined after 1930. Railroad investment in the period under review tended more and more toward amplification rather than extension of the existing network.

Yet during World War II the railroads carried more freight traffic than ever before. As in the case of passenger traffic, though in lesser degree, we may regard the wartime peak in freight traffic as a partial and temporary return to a previous trend. The practical cessation of growth of freight traffic after 1920 (the peak did not actually come till 1929) is not due to any single factor: the growth of motor trucking and pipelines played a part; so did the bulk transportation by water of such products as petroleum.

During World War II trucking and coastwise shipping were sharply inhibited. As a result freight traffic in 1944 approached, but did not reach, the level it would have done, had the rate of growth before 1920 continued thereafter.

Chart 12
RAILROAD FREIGHT TRAFFIC:
TONS ORIGINATED AND TON-MILES



Source: Appendix B and *Statistics of Railways*

Ratio scales

The preceding remarks are based upon the movement of the (unweighted) ton-mileage aggregate which, as already explained, is our basic measure. Data for the computation of a weighted ton-mile index do not exist. Yet we still can inquire how our unweighted index would be modified, were we able to weight each ton-mile by its revenue in constant prices.

The Federal Coordinator of Transportation arranged for a classification by commodities of the entire carload ton-mileage total for 1932. A summary of this breakdown (Table 19) shows considerable dispersion among mean revenues per ton-mile for different commodities.[12] The existence of this dispersion makes for the possibility that a weighted ton-mile index would show a different result from that indicated by the unweighted index. In fact, the railroads have lost to competitors especially less-than-carload and other freight customarily moving at a rather high rate per ton-mile. Such reasoning suggests that a weighted index would rise less rapidly, or decline more rapidly, than the (unweighted) ton-mile index shown in Tables 17 and 18.

Table 19

STEAM RAILROADS: DISTRIBUTION OF TON-MILES BY REVENUE PER TON-MILE, 1932[a]

Revenue per Ton-mile (cents)	*Ton-miles* (million)	%
0.5 to 1.0	108,977	44.9
1.0 to 1.5	84,713	37.2
1.5 to 2.0	23,468	10.3
2.0 to 2.5	3,129	1.4
2.5 to 3.0	52	[c]
3.0 to 3.5	0	0
3.5 to 4.0	7,239[b]	3.2
TOTAL	227,578	100.0

[a] See Appendix Table C-2; for coverage of data, see note a to Appendix Table C-1. Based on a distribution by commodities; since all traffic for each commodity was assigned the average revenue per ton-mile for that commodity, a somewhat different distribution would result from a classification of individual shipments by revenue per ton-mile.

[b] Includes 6,590 million ton-miles of less-than-carload freight.

[c] Less than 0.05.

Another unit which provides an alternative measure of freight traffic volume is the ton originated, or ton of traffic shipped by rail. Available for years since 1899, the total number of tons originated is represented by the index in the second column of

[12] The tabulations published by the Federal Coordinator do not tell us anything about the corresponding dispersion for a single commodity, occasioned by the varying length of haul among shipments of that commodity. But even a slight acquaintance with rate scales suggests that this dispersion, too, must be considerable.

Table 18. It is obvious on casual inspection that this index does not rise as rapidly between 1899 and 1929 as our ton-mileage total, and that between 1929 and 1940 it declines further than does the latter. The evidence shows that the average haul, which can be calculated by dividing ton-miles by tons originated, increased rather steadily, at least during the first four decades of the present century. Whether this trend reflects a general lengthening of the distance individual commodities are hauled, or a shift from short haul to long haul commodities, we shall inquire presently.

Table 20

STEAM RAILROADS: DISTRIBUTION OF FREIGHT TONNAGE ORIGINATED BY LENGTH OF HAUL, 1932[a]

Haul (miles)	*Tonnage Originated* (th. tons)	%
0 to 200	159,628	24.9
200 to 400	333,080	51.9
400 to 600	102,060[b]	15.9
600 to 800	28,938	4.5
800 to 1,000	7,462	1.2
1,000 to 1,200	3,342	.5
1,200 to 1,400	1,115	.2
1,400 to 1,600	194	[c]
1,600 to 1,800	458	.1
1,800 to 2,000	273	[c]
2,000 to 2,200	3,470	.5
2,200 to 2,400	225	[c]
2,400 to 2,600	948	.1
TOTAL	641,193	100.0

[a] Computed from Appendix Table C-1; for coverage of data see note a to that table. Based on a distribution by commodities; since all traffic for each commodity was assigned the average length of haul for that commodity, a somewhat different distribution would result from a classification of individual shipments by length of haul.

[b] Includes 15,115 th. tons of less-than-carload freight.

[c] Less than 0.05.

Unlike the ton-mileage total, which cannot be broken down except for the single year 1932, the number of tons originated is distributed each year among commodities transported. The classification has gradually become more detailed, and in 1928 extended to 157 commodity groups. Using these data to weight tons originated by the revenue received per ton, we can allow for differences between one commodity and another, not only in rate per ton-mile, but also in length of haul. (Some idea of the dispersion of the latter may be gained from Table 20). For most years the weighted index constructed in this manner differs only slightly from the corresponding unweighted index (Table 18). This is not altogether surprising, for the composition of traffic, at least by broad commodity classes, has not changed greatly during our period (Chart 13). Moreover, although it takes some account of variations in the relative importance of short and long haul commodities, the weighted originated-ton index makes no more allowance for changes in the length of haul of individual commodities than does the corresponding unweighted index. Like that index, it shows a downward movement in relation to the ton-mile index.

The Composition of Freight Traffic

Just as we can think of the growth or contraction of railroad freight traffic in terms either of ton-miles or of tonnage originated, so the same choice is open to us in appraising its composition. However, 1932 is the only year for which we can compare the two classifications (Table 21).[18]

The first four classes listed — Products of Agriculture, Animals and Products, Products of Mines, and Products of Forests — include many raw or unprocessed commodities, although there also appear such processed goods as flour and other mill products,

[18] Identified with the nadir of the depression, 1932 was in many respects an unrepresentative year. Thus the relative importance of farm products was greater, and of forest products and manufactures was less, in 1932 than in other years. This may be seen if the distribution of tonnage originated for 1932 (see Table 21) is compared with its average distribution for 1929-38.

	PERCENTAGE DISTRIBUTION OF TONNAGE ORIGINATED	
	1932	*Average 1929-38*
Products of Agriculture	13.0	10.1
Animals and Products	2.8	2.1
Products of Mines	55.1	55.8
Forest Products	4.3	5.5
Manufactures and Miscellaneous	22.5	24.3
Less-than-carload	2.4	2.2

Table 21

STEAM RAILROADS: FREIGHT TRAFFIC, BY COMMODITIES, 1932[a]

	Tons Originated		*Ton-miles*		*Freight Revenue*		*Revenue per Ton-mile*	*Average Haul*
	(mil.)	%	(bil.)	%	($ mil.)	%	(cents)	(miles)
Products of Agriculture	83	13.0	43.0	18.9	480	19.0	1.12	517
Animals and Products	18	2.8	11.4	5.0	191	7.5	1.68	625
Products of Mines	353	55.1	98.7	43.4	732	28.9	.74	279
Forest Products	27	4.3	12.4	5.5	108	4.3	.87	455
Manufactures and Misc.	144	22.5	55.4	24.4	768	30.4	1.39	385
Less-than-carload	15	2.4	6.6	2.9	251	9.9	3.81	436
TOTAL	641	100.0	227.6	100.0	2,529	100.0	1.11	355

[a] See Appendix Table C-1; for coverage of data, see note a to that table.

leather, meats and lumber products. By contrast, Manufactures and Miscellaneous and Less-than-carload freight are predominantly fabricated, although unprocessed items such as cotton sometimes fall in the latter category. The distinction between low- and high-grade traffic is somewhat less clear. In the sense that the revenue per ton-mile obtained from their transportation is relatively low, minerals and forest products, and to some degree farm products, can be called low-grade traffic. On the other hand live animals, many manufactures, and less-than-carload freight move at a relatively high rate per ton-mile. Judged by this standard, the lowest-grade traffic — bituminous coal, metallic ores, flour and meal[14] — yields 0.6 or 0.7 cents a ton-mile. The highest grade of freight consists of manufactures or of less-than-carload traffic: for instance, furniture, 2.4 cents; trucks, 2.8 cents; automobiles, 3.7 cents; explosives, 3.8 cents; and all less-than-carload traffic, 3.8 cents a ton-mile.[15]

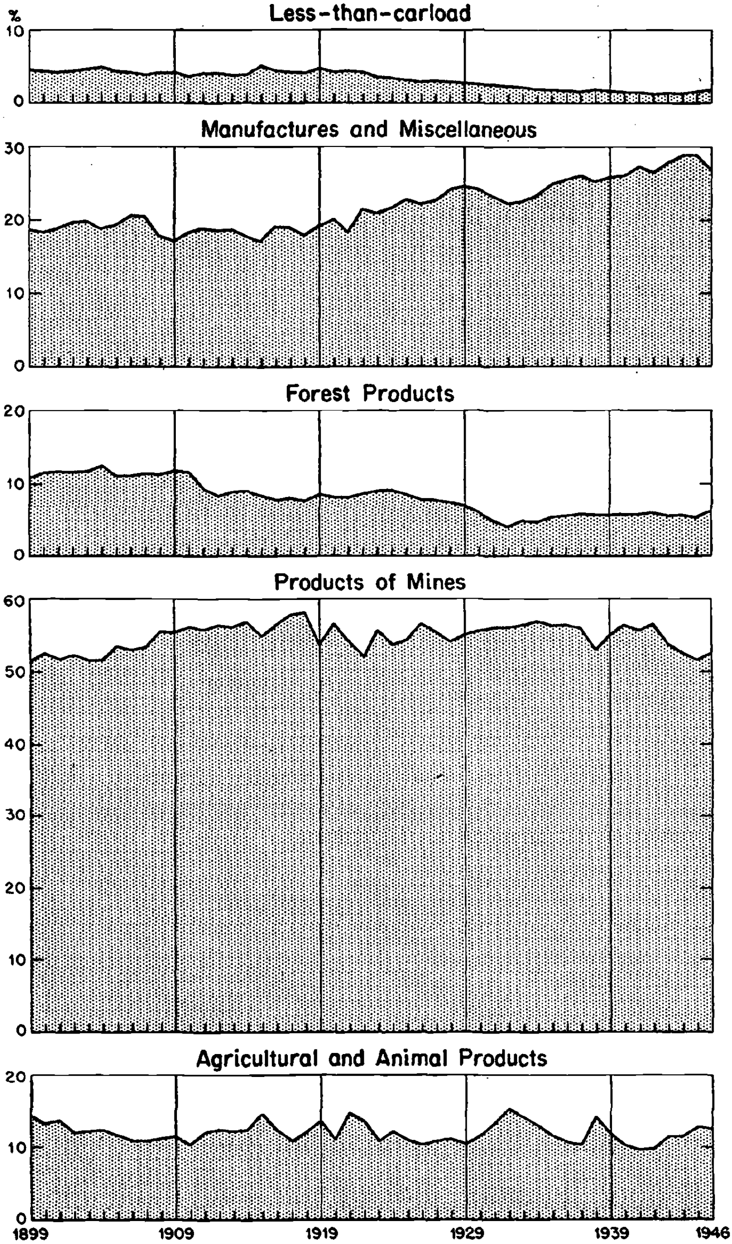
[14] However, the haul of flour and meal is artificially lowered by the existence of in-transit privileges.

[15] See Appendix Table C-1. Unfortunately less-than-carload traffic cannot be classified by commodities even for the year 1932.

Chart 13

STEAM RAILROADS: PERCENTAGE COMPOSITION OF FREIGHT TRAFFIC

Tons originated



Source: *Statistics of Railways*

The distribution of traffic among the six classes of commodities shown in Table 21 differs markedly according to the criterion employed. Thus in terms of tonnage originated — i.e., amount of freight shipped — minerals contributed over half total freight traffic. But their haul tends to be short: under 300 miles on the average, compared with 355 miles for all commodities. Hence minerals contributed a much smaller fraction of total ton-miles than of tons originated. Since their revenue per ton-mile is also low, their contribution to total freight revenue is still smaller. For opposite reasons animals and animal products and less-than-carload freight — both less important than minerals by every criterion — contribute a larger fraction of revenue than of ton-miles, and a larger fraction of ton-miles than of tonnage originated.

How have the relative importance of these six broad commodity groups varied over time? Such a detailed analysis as that given for 1932 is possible for no other year. Nevertheless, we can compute the percentage contributions of different groups to tonnage originated for the period since 1899.[16] It will be seen from Chart 13 that changes have not been striking and that the nation's mines and quarries have for long been the most important source of railroad shipments. The products of American farms, mines and forests have apparently always constituted more than two-thirds of all tonnage shipped by rail, and at the beginning of our period comprised more than three-quarters of the total. On the whole the shares of forest products and of less-than-carload freight have declined, and the share of manufactures and miscellaneous has increased. The relative decline in the movement of lumber, and the increasing importance of manufactures doubtless reflect shifts visible elsewhere in the nation's domestic production and foreign commerce, shifts from primary production toward fabrication. In the case of lumber, too, the rise of production in the Pacific Northwest and the opening of the Panama Canal allowed movement by

[16] The percentages for the years prior to 1918 may be subject to some slight error because of fluctuations in coverage. In 1899 only 88 percent of total tonnage originated was distributed into commodity groups, although the proportion rose to 96 percent in 1911 for all operating roads. Data for years after 1911 relate to class I roads only, and for this group coverage rose from 96 percent in 1911 to 100 percent in 1917 and later years.

water. However, agricultural products have pretty well maintained their relative position. The decline in less-than-carload traffic dates only from 1921, and is clearly associated with the rise of motor trucking. Some decline in the animals group is also apparent in recent years, and this, too, must be attributed to diversion to highway transport, rather than — as with lumber — a decline in the importance of the commodity in the transportation picture as a whole.

Length of Haul

As we have seen, the unit of output adopted here for the measurement of freight transportation — the ton-mile — is a resultant of the amount of tonnage offered to the rails by shippers and the length of haul associated with each shipment of goods; thus, tonnage shipped being given, changes in the average length of haul have a significant effect on trends in rail output.[17]

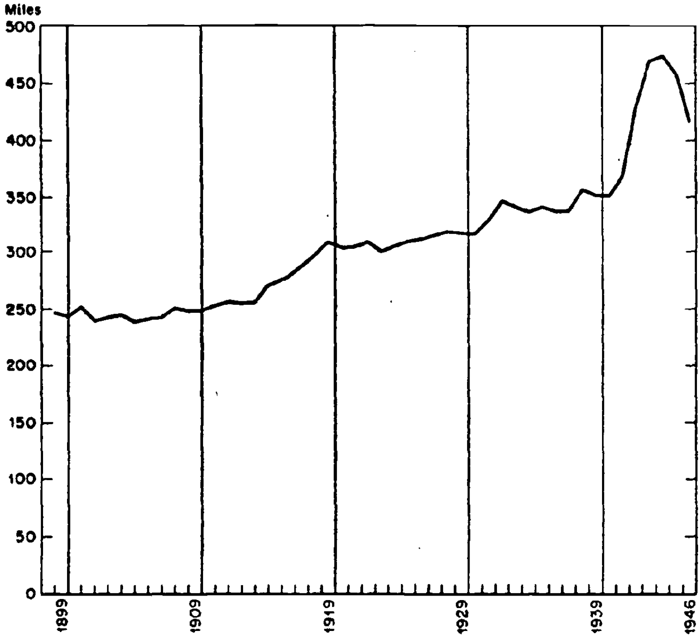
The average haul for a ton of freight increased, for all steam railroads, from 247 miles in 1899 to 351 miles in 1939, i.e., by some 42 percent (Chart 14).[18] No significant rise occurred during the first decade of the century, but an upward movement set in during the second decade, particularly during the war years. Thus in 1919 the average haul stood at 309 miles, or 23 percent above the 1909 figure (251 miles). The ICC attributed the lengthened haul, especially the marked increase after 1914, to "fundamental economic changes, such as the development of the Western States,

[17] When the national ton-mileage total is divided by the total amount of *tonnage originated,* an average haul figure is obtained for all carriers considered as a system. This should be distinguished from the (less significant) average haul for individual railways obtained when the total of all *tons carried* is used as a divisor. Changes in both averages reflect the impact of such economic factors as the expansion of market areas and the shift in centers of production and consumption, but the movement of the latter average reflects also a slight tendency toward consolidation within the railroad industry, a factor unrelated to the volume of rail output, which is our primary concern here. Accordingly, we shall center our attention on the movements of the average haul for the rail network as a single system.

[18] Length of haul for class I railroads, not available for years before 1911, is slightly above the figure for all roads, being 370 miles in 1939. Data for originated tons were not collected prior to 1899; but, on the basis of tons carried, average haul for all roads regarded as one system may be estimated at 225 miles in 1890.

growth of exports, and shifting of centers of production and consumption."[19]

Chart 14
RAILROAD FREIGHT TRAFFIC: LENGTH OF HAUL
Class I, II, and III roads regarded as one system



Source: Appendix Table C-3

The principal ways in which average haul may lengthen we can safely group into three categories. First, greater dependence on distant markets for the purchase of materials or the sale of a product must have been rather generally experienced as the nation spread across the continent and became more fully industrialized. Second, some tendencies toward greater regional specialization led to the rise of articles specifically designed for consumption in areas

[19] *Statistics of Railways, 1921,* p. XXXV. It may be noted that in the previous year, the Commission had suggested that part of the increase in haul may have been accounted for by the "extension of through billing," referring to the possibility that originated tonnage totals are subject to duplication because rebilled carloads may be reported as originating a second time. The elimination of rebilling may have accounted for some increase in the average haul figure; such a change does not of course reflect a real lengthening of the haul.

remote from the point of production. This can be documented by noting the growing traffic in certain commodities with long average hauls: citrus fruits (2,154 miles) and other fresh fruits (1,442 miles) and vegetables (1,744 miles), poultry (1,225 miles) and eggs (1,353 miles).[20] Third, diversion of short-haul traffic to truck transportation will plainly lengthen the average haul of railroad freight traffic.

To what extent can we distinguish statistically between these three kinds of influence? We can test how far the lengthening of the average haul for all commodities is associated with (1) a general increase in the hauls of all or most commodities, or (2) a shift in the composition of traffic in favor of those commodities with long average hauls. This classification does not exactly fit the categories of the preceding paragraph. Yet we would expect the first influence (geographical widening of the market) to affect short as well as long haul commodities, and so roughly to correspond with (1). By contrast the second influence (growth of commodities specially designed for distant markets) should be reflected mainly under (2). Again, although transcontinental truck lines are not unknown, mainly short haul traffic has been lost to the highways. Such lost traffic could have included short haul shipments of commodities with a wide dispersion of haul, or representative shipments of commodities with a short average haul. The former kind of shift would figure under (1), the latter under (2) above. What we know of truck traffic suggests that the latter may have outweighed the former.[21]

These considerations lead to the hypothesis that lengthening of haul during the earlier part of our period was due primarily to a general increase in the hauls of individual commodities, but that this gave way to a lengthening from a shift in traffic composition as the period advanced. There is no real doubt that the lengthening of haul in the first two decades of this century repre-

[20] Hauls quoted are for 1932, the only year for which ton-mile data for individual commodities have been collected. See Appendix Table C-1.

[21] That the latter factor will explain *cyclical* changes in the average length of haul, has been ingeniously demonstrated by Thor Hultgren, at least for recent cycles ('Railway Freight Traffic in Prosperity and Depression', *Occasional Paper 5,* NBER, 1942, pp. 40-43; *American Transportation in Prosperity and Depression,* NBER, 1948, pp. 17-18).

sented a general increase in average distances most commodities were hauled. The question is how the further lengthening of haul during the third and fourth decades is to be explained.

Almost the whole of the increase in average haul since the close of the first World War occurred during the decade 1929-39. Let us therefore begin by comparing the terminal years of this decade. If we apply the hauls observed in 1932 to the actual tonnage of individual commodities originated in 1929 and in 1939, we find that the average haul for freight traffic as a whole would have increased about 4 percent, even if the average haul for each of the 157 commodity classes had remained at the 1932 level through-

Table 22

STEAM RAILROADS: AVERAGE HAULS, 1929 AND 1939, AS COMPUTED FROM 1932 DATA AND AS ACTUALLY OBSERVED

	Average Haul (miles)		
	1929	*1939*	*% Change*
Computed[a]			
Products of agriculture	498	502	+1
Animals and products	585	658	+12
Products of mines	255	270	+6
Forest products	410	401	−2
Manufactures and miscellaneous	370	383	+4
Less-than-carload traffic[b]	436	436	....
ALL COMMODITIES	326	339	+4
Observed			
ACTUAL AVERAGE HAUL, ALL COMMODITIES	334	370	+11

[a] Class I roads only. Computed on the assumption that the average haul for each of the 157 commodities distinguished in the statistics was the same, both in 1929 and 1939, as in 1932. Thus the actual number of tons originated in 1929 (or 1939) were converted into ton-miles using the 1932 hauls, and the ton-mileage totals so obtained were divided by the corresponding tons originated to yield the hypothetical hauls shown in the table. The changes resulting reflect only shifts in the relative importance, measured in tons originated, of different commodities.

[b] In the official statistics less-than-carload traffic is treated as a single commodity. Consequently it is impossible to report the change in average haul (if any) associated with shifts within this classification.

out the decade. This calculation gives us a measure of the increase in haul associated with shifts in the character of railroad freight traffic from short to long haul commodities (Table 22).

Amounts of tonnage originated were in general lower in 1939 than in 1929, and numerous changes occurred in the relative importance of shipments of different types of freight. The greater decline in the shipments of short- than of long-haul commodities undoubtedly reflects, at least in good part, the unequal results of motor truck competition. For example, the 12 percent lengthening that would have occurred in the average haul of animals and products, even with constant hauls for individual commodities, reflects a relative decline of live animal shipments (which have short hauls) and a corresponding growth of shipments of meat and poultry products (which have long hauls). We know that the movement of livestock to market has shifted from the railroad to the highway to a larger extent than any other form of traffic, except possibly, less-than-carload freight. In the case of the other groups also, some at least of the decline in the relative importance of short haul traffic must be attributed to diversion from railroad to highway. Obviously forest products form an exception to the general tendency, for here traffic would have registered a slight decline in average haul, had hauls for individual commodities remained unchanged. Where other groups lost short haul, forest products lost significant amounts of long haul traffic to other agencies.

In brief, something under one-half of the 11 percent rise which actually occurred between 1929 and 1939 in average haul can be imputed, in the manner indicated, to shifts in the relative importance of different commodities or commodity groups. But it would be unsafe to regard this as even the roughest measure of the degree to which short haul traffic has been lost to other transportation agencies. In the foregoing calculation we were able to take account only of the effect of shifts between commodities. The lengthening of haul not so accounted for, we must plainly impute to longer hauls of individual commodities. Since 1932 is the only year for which we can measure the haul commodity by commodity, we have no means of discovering which items moved longer distances (on the average) and which did not. Nonetheless it is plain that the average haul of a given commodity may lengthen, not only through a general lengthening of the customary haul of individual shipments, but also through the loss to rival agencies of short haul traffic in that commodity.

We should also remember that we have no breakdown of less-than-carload tonnage. This traffic is not of course a homogeneous category from any viewpoint. It includes commodities drawn from almost the entire freight classification, although less-than-carload shipments are relatively high grade and long haul in nature in comparison with the general run of carload traffic. Our knowledge of the drastic losses to motor trucking suffered by the less-than-carload traffic of the railroads suggests that its average haul has probably increased greatly.[22]

The presumption that the increase in average haul in recent years is due in large measure to shifts in the composition of rail traffic rather than to general expansion of market areas is further strengthened by the fact that the method of Table 22, if applied to the interval 1920-29, reveals a somewhat different picture. In this period the average haul of all class I freight increased from 327 miles to 334 miles, or just over 2 percent. Applying the known 1932 hauls to the tonnage originated in those commodity classes in 1920 and 1929 which are comparable,[23] we obtain average hauls for all carload traffic that show a *decrease* of 1.2 percent. Obviously the changes are too small to warrant definite conclusions except of a negative sort. If a significant lengthening of haul

[22] Tonnage of less-than-carload traffic originated between 1929 and 1939 declined nearly 60 percent. How much of this decline represents a diversion of traffic to other transportation agencies is difficult to determine, for it must be attributed in part to the development of 'forwarding' agencies during the 'thirties. These agencies consolidate small shipments at various points into full carloads to obtain carload rates, and usually also provide 'store-door' delivery. While most forwarder shipments are carried by the railroads, motor trucks and inland waterways are also employed by these agencies. See K. T. Healy, *Economics of Transportation* (Ronald, 1940), p. 28.

[23] The ICC commodity classification was revised in 1928 to exhibit greater detail, but to retain comparability we had to use the cruder 1920 classification for our 1920-29 comparison. The latter is therefore less precise than the 1929-39 comparison, based on the more detailed classification, whose results are reported in Table 22.

occurred during the 1920's it was a very small increase; nor can it be explained by shifts in traffic composition.

To summarize, length of haul was about the same in 1914 as in 1899. Between 1914 and 1919 it increased sharply. This increase appears to have been due to a widening of the market, perhaps associated with industrial expansion during World War I. Between 1919 and 1929 average haul increased only slightly. The widening of the market slowed down or came to an end, but appreciable amounts of short haul traffic were not yet diverted to the highway. Between 1929 and 1939 a further substantial lengthening of haul occurred, due chiefly to loss of short haul traffic to competing agencies.

RAILROAD TRAFFIC AS A WHOLE

The measure of total railroad traffic (Table 17) required two further steps. First, the indexes already constructed for freight and passenger traffic respectively were combined. Second, a small adjustment was made for variations in coverage.

To combine freight and passenger output, we used revenue per ton-mile and per passenger-mile as weights in the Edgeworth formula, changing the weights appropriately for each comparison. The coverage of the completed index, which can readily be assessed in terms of revenue, varies slightly over the period. Accordingly a small adjustment was made in order that the series should consistently represent the output of all line-haul roads and switching and terminal companies, of the Pullman Company, and of the Railway Express Agency, i.e., the entire steam railroad industry.[24]

As was to be expected, the index of total rail output (Table 17

[24] For a detailed account of the procedure, see note a to Table 17. Previous indexes of total rail output have been based on a fixed relationship between the passenger-mile and ton-mile. Thus, Witt Bowden in 'Productivity, Hours, and Compensation of Railroad Labor' (*Monthly Labor Review,* Dec. 1933, pp. 1277-8) equated one revenue passenger-mile to 2.6 revenue ton-miles, the latter figure representing the average ratio of receipts per passenger-mile to receipts per ton-mile over the period 1916-32. For that period the change in the ratio was not great enough (ranging from 2.9 in 1916 to 2.1 in 1932) to introduce any significant divergence between the Bowden index and our own. The use of a fixed weight even for the entire period 1899-1939 would not have resulted in a wide divergence, mainly because of the dominating influence of the ton-mileage component.

and Chart 10) does not diverge greatly from that of freight output, its dominant component. One effect of the inclusion of passenger traffic is to emphasize the element of retardation. The pre-1940 peak in total rail output is seen to have occurred in 1926, three years prior to the peak in freight output. However, the 1926 level is not significantly higher than the figure for total output attained in 1920, when rail passenger travel had marked an all-time high. Like its components, the total index shows rather clear retardation of growth, at least during 1889-1939, and an all-time peak in 1944.

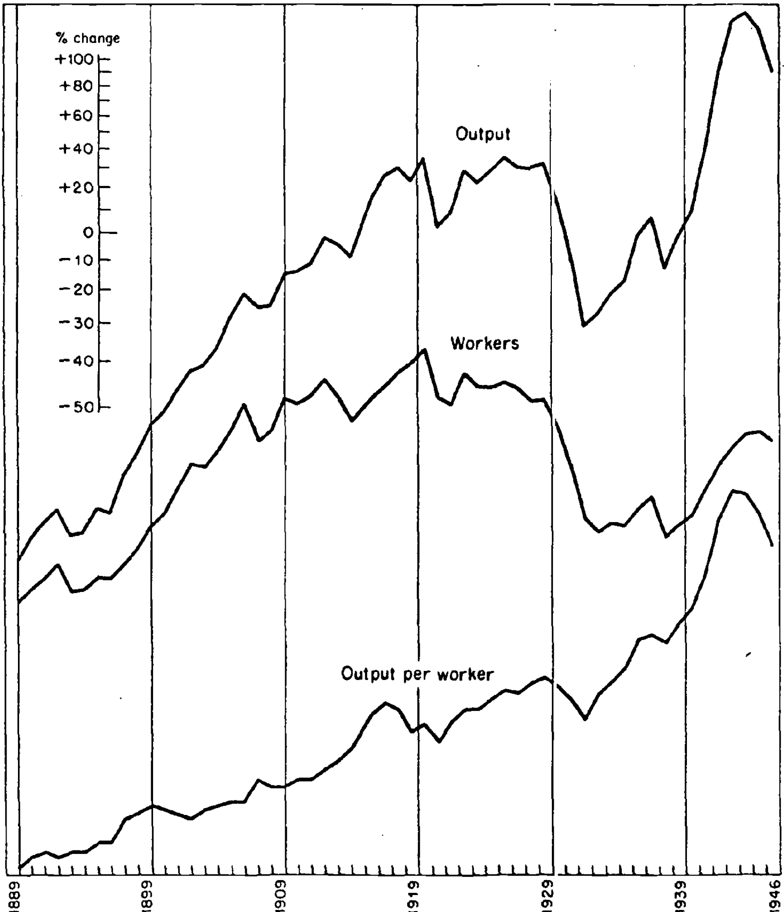
EMPLOYMENT AND PRODUCTIVITY

In 1939 the railroad industry employed about one million persons. Rail employment reached an all-time peak in 1920, when class I railroads alone employed over 2 million persons; thereafter a decline set in that brought rail employment down to the level obtaining at the turn of the century. Peak employment during World War II, about 1.4 million, was still well below the level of the 1920's.

Many different factors have influenced the draft made by railroads upon the nation's labor force. First and foremost are variations in rail output. Yet other factors have been important also. Throughout railroad history technology has scored noteworthy advances. During our period the decline and practical cessation of new railroad construction probably lessened the need for labor in the 'way and structures' departments.[25] Again, consolidation of railroads, for instance in the combination of terminal facilities, made for economies in labor. It is probable, too, that the efficiency of the average railroad employee has varied, not only through technological change, but for other reasons also. Apart from the slow increase of education and formal training among the general population from which railroad workers are recruited, declining employment in the industry has led to the practice of retaining men with the longest service. It has been argued that the

[25] Although extensions of line practically ceased around 1915, intensive construction continued; moreover it is possible that contractors were less used than formerly. These reasons mitigated the net decline in construction activity by the railroads themselves.

Chart 15
STEAM RAILROADS:
OUTPUT, EMPLOYMENT, AND PRODUCTIVITY



Source: Table 23

Ratio scale

application of the principle of seniority, endorsed by both labor and management, has raised the level of experience of the average worker, and thereby also his competence.[26] On the other hand it frequently is alleged that restrictions by unions on the use of labor by management, particularly those embodied in the so-called

[26] See testimony of Byrl A. Whitney, Temporary National Economic Committee, *Hearings* (1940), Part 30, p. 16903.

'featherbed rules', have to some extent lowered the worker's effectiveness.

The net outcome of these various influences was to leave the number of workers in 1939 about the same as in 1899: but these workers worked fewer hours[27] and produced far more — about twice as much — output.

This comparison conceals the fact that both output and employment rose to a peak during our period from which they then declined; while the upward movement of output per worker, although by no means perfectly steady, continued throughout the four decades considered. In fact to say that output per worker doubled is to understate the rise which has occurred in the productivity of labor. In 1900 the railroads were still expanding. Not only had they to be fully maintained; some employment was no doubt concerned with adding to plant and equipment — additions which of course nowhere appear in our measure of output. At the end of our period, on the other hand, few new facilities were under construction, and some track and equipment were candidates for abandonment, perhaps inducing a temptation toward undermaintenance. For these reasons, the indicated increase seems a minimum estimate for the change in output per worker over four decades.

Output per worker increased rather steadily at an average rate of 1.9 percent per annum (Chart 15), compared with 2.2 percent for transportation as a whole (Table 13 above).

Reasons have sometimes been advanced for anticipating a slackening of the rate of productivity growth as the age of an industry advances.[28] Such might be the case if the rate of technological change were slower, or the opportunities for technological advance more restricted, in an old industry than in a young one. However, the trend in output per worker, measured logarithmically, does not vary significantly from a straight line. Output per worker in the

[27] Data on average weekly hours in the railroad industry do not appear to exist even for recent years. Average annual hours (computed from Appendix Table B-1) declined from 3,100 in 1916 to 2,500 in 1921, and have since fluctuated between 2,200 (in 1932-33) and 2,600 (in 1943-45).

[28] Solomon Fabricant, 'Factory Employment and Output since 1899', *Occasional Paper 4,* NBER, 1941).

Table 23

STEAM RAILROADS: OUTPUT, EMPLOYMENT, AND PRODUCTIVITY, 1890-1946
1929 : 100

Year Ending June 30	*Output Comparable with Workers*[a]	*Number of Workers*[b]	*Output per Worker*	*Output Comparable with Manhours*[c]	*Man-hours*[c]	*Output per Manhour*
1890	20.4	44.3	46	....	....	....
1891	22.1	46.4	48	....	....	....
1892	23.6	48.6	49	....	....	....
1893	25.0	51.6	48	....	....	....
1894	22.5	46.1	49	....	....	....
1895	22.7	46.4	49	....	....	....
1896	25.1	48.9	51	....	....	....
1897	24.6	48.7	51	....	....	....
1898	28.9	51.7	56	....	....	....
1899	31.3	54.9	57	....	....	....
1900	35.4	60.2	59	....	....	....
1901	37.0	63.3	58	....	....	....
1902	40.2	70.3	57	....	....	....
1903	43.8	77.6	56	....	....	....
1904	44.6	76.6	58	....	....	....
1905	48.0	81.7	59	....	....	....
1906	54.3	89.9	60	....	....	....
1907	59.6	98.9	60	....	....	....
1908	56.3	84.9	66	....	....	....
1909	56.4	88.8	64	....	....	....
1910	64.8	100.5	64	....	....	....
1911	65.0	98.7	66	....	....	....
1912	66.9	101.5	66	....	....	....
1913	74.6	108.6	69	....	....	....
1914	72.5	101.4	71	....	....	....
1915	68.9	91.8	75	....	....	....
1916	82.2	98.0	84	80.7	118.1	68
Calendar Year						
1916	86.9	100.7	86	85.3	123.5	69
1917	95.5	105.8	90	93.9	129.5	73
1918	98.7	111.9	88	97.4	135.5	72
1919	93.3	116.1	80	92.1	119.7	77
1920	102.4	123.0	83	101.1	129.5	78
1921	77.7	101.2	77	76.7	97.4	79
1922	82.8	98.5	84	82.1	99.8	82
1923	97.9	111.6	88	97.3	114.3	85
1924	92.5	105.6	88	91.7	105.4	87
1925	97.1	105.3	92	96.5	105.2	92
1926	102.4	107.3	95	101.9	107.8	95
1927	98.4	104.6	94	98.0	104.2	94
1928	98.1	99.8	98	97.7	99.2	98
1929	100.0	100.0	100	100.0	100.0	100

Calendar Year	Output Comparable with Workers[a]	Number of Workers[b]	Output per Worker	Output Comparable with Manhours[c]	Manhours[c]	Output per Manhour
1930	85.7	89.6	96	85.6	86.3	99
1931	69.2	75.9	91	69.0	69.6	99
1932	52.3	62.2	84	52.2	54.2	96
1933	55.0	58.7	94	54.9	50.8	108
1934	59.7	60.9	98	59.5	54.4	109
1935	62.6	60.3	104	62.3	54.4	115
1936	75.5	64.7	117	75.1	60.8	124
1937	80.8	67.8	119	80.3	63.6	126
1938	65.9	57.5	115	65.4	52.8	124
1939	74.8	60.4	124	74.2	56.3	132
1940	83.0	62.8	132	82.3	59.1	139
1941	105.1	69.6	151	104.5	67.6	155
1942	146.2	77.4	189	146.8	77.2	190
1943	176.8	83.1	213	178.0	86.0	207
1944	182.7	87.6	209	183.3	89.9	204
1945	171.2	88.2	194	170.9	89.0	192
1946	144.3	84.9	170	142.2	81.0	176

[a] 1921-39, adjusted to cover class I, II, and III line-haul roads, switching and terminal companies, the Pullman Company, and the Railway Express Agency. Prior to 1921 we do not have employment data for switching and terminal companies, and the Railway Express Agency (or its predecessor companies). Therefore, for 1899-1921 the index here shown is adjusted only to include class I, II, and III line-haul roads and the Pullman Company.

[b] Comparisons 1921-39 cover class I, II, and III line-haul roads, switching and terminal companies, the Pullman Company and the Railway Express Agency. Comparisons 1911-21 include class I, II, and III line-haul roads and the Pullman Company. Comparisons 1890-1911 are based on class I, II, and III line-haul roads. For recent years data are mainly averages of monthly counts; for earlier years, employment on June 30 (see note d to Appendix Table B-1).

[c] Data relate to class I line-haul roads and the Pullman Company.

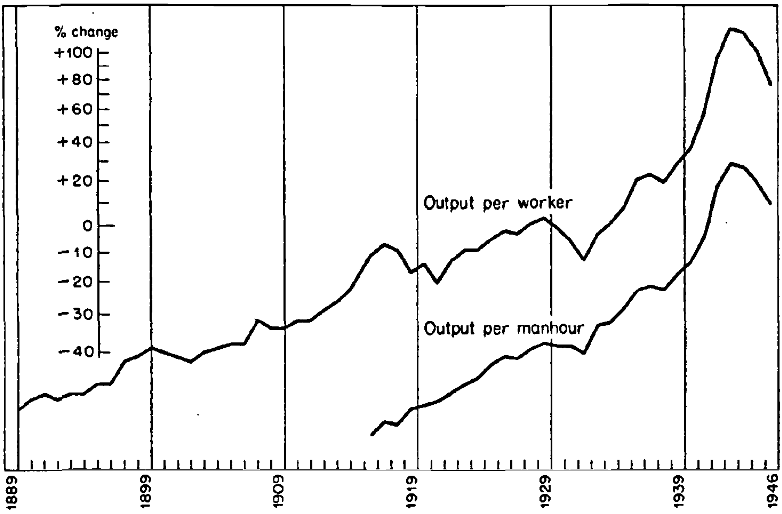
railroad industry does not appear to be subject to retardation — at least to the present time.

Manhour Productivity

For manhours, as distinct from number of workers, we have data only since 1916. In that year the average workday was about ten hours. It fell sharply as a result of the Adamson Act (1918) and again during the 1930's. As a consequence output per manhour increased considerably faster than output per worker (see Table 23 and Chart 16). On a 1916 base comparison may be made as follows:

Year Ending	Output per Worker	Output per Manhour
June 30, 1916	100	100
Calendar Year		
1920	99	114
1929	119	146
1939	148	193
1946	202	259

Chart 16
STEAM RAILROADS:
OUTPUT PER WORKER AND PER MANHOUR



Source: Table 23 Ratio scale

THE AMOUNT OF EQUIPMENT

We have seen that output increased more rapidly than employment. We should like to examine also the relation between output and the amount of capital used by the railroads. In any comprehensive sense the latter is difficult to measure, and we shall content ourselves by noticing some changes in the amount and capacity of movable equipment employed.

The stock of equipment units (locomotives, passenger cars, and freight cars) weighted by the average cost of each type was larger in 1920 than in 1903 (earlier data are not available), but in 1939 and 1946 had fallen back almost to the level at the opening of the century (Table 24). The number of equipment units, that is to say, changed in roughly the same fashion as employment. Output per equipment unit rose with roughly the same speed as output per worker. Evidently the equipment became more efficient in producing transportation, although it still needed about the same amount of manpower to operate each unit. Locomotives are known to have become more powerful, and freight cars to have larger capacities than formerly; we have no record of any change in the size of passenger cars (although they now offer greater comfort).

Let us approximately allow for these changes by measuring the

Table 24

STEAM RAILROADS: OUTPUT, EMPLOYMENT, AND THE VOLUME OF EQUIPMENT, 1903-1946[a]
1903 : 100

	Year Ending June 30		*Calendar Year*			
	1903	*1916*	*1920*	*1929*	*1939*	*1946*
Output: Passenger & freight traffic combined	100.0	187.6	235.1	229.9	172.0	331.8
Number of equipment units (weighted)[b]	100.0	142.8	148.3	140.3	102.1	105.4
Output per equipment unit	100	131	159	164	168	315
Aggregate equipment capacity (weighted)[c]	100.0	192.8	213.0	226.2	178.4	191.7
Output ÷ equipment capacity	100	97	110	102	96	173
Number of workers	100.0	126.3	158.5	128.9	77.8	109.4
Equipment units per worker	100	113	94	109	131	96
Equipment capacity per worker	100	153	134	175	229	175
Output per worker	100	149	148	178	221	303

[a] Data cover all line-haul and switching and terminal companies. For indexes of output and employment, see Table 23; figures for the number and capacity of equipment units come from general summaries in the *Statistics of Railways.*

[b] Index represents numbers of locomotives ($17,321), passenger cars ($7,883), and freight cars ($973), weighted by the unit values in parentheses. These unit values are the average cost of equipment owned on June 30, 1916 shown in ICC valuation reports for the following roads: Pennsylvania, New York Central, Southern, Santa Fe, New Haven, Northern Pacific, Chesapeake and Ohio, Burlington, and Boston and Maine.

[c] Index represents aggregate locomotive tractive effort ($.535 per lb.), number of passenger cars ($7,883), and aggregate freight car capacity ($24.0 per ton), weighted by the unit values in parentheses. For source of unit values see note b.

locomotive stock by its aggregate tractive power and of freight cars by their aggregate capacity; passenger cars we shall measure as before by number. The resulting index of capacity (instead of units) of equipment roughly doubled during the period. By and large the same amount of labor is needed to operate a large as a small piece of equipment. In fact the doubling of equipment, in terms of capacity, compares with a threefold expansion of output and also of output per worker. We may say therefore that larger equipment contributed to the growth in output per worker and per manhour, but does not completely account for this growth. To be sure, more powerful locomotives could pull heavier trains; but, as we shall see in the next section, many other technological changes, unconnected with capacity of equipment, also helped to save labor.

CHANGES IN TECHNOLOGY AND THEIR EFFECTS

Among factors influencing the amount of labor required to produce a unit of railroad output, changes in technology obviously rank high. I shall first discuss some cases where the influence of such changes upon particular branches of railroad employment can be traced, and then take up the question of railroad technology from a more general standpoint.

Table 25 shows percentage changes in the number of railroad workers by seven broad divisions. The decline from 1923 to 1939 was especially marked in maintenance personnel. Thus, in the period 1923-39 losses in maintenance employment were of the order of 53 percent, as compared with 40 percent for transportation service employees and administrative personnel. This could indicate either that technological displacement affected maintenance employment most severely, or that the industry as a whole has been characterized by undermaintenance.

During 1923-29 employment declined nearly 11 percent. Administrative employment suffered least; indeed, the number of executives, officials, and staff assistants increased slightly. Professional, clerical and general employment, however, declined by 5.9 percent, perhaps reflecting the extended use in this period of office machines — a trend characteristic of all business activity. In the railroad industry the introduction of office machinery has been closely connected with the trend toward office centralization.[29]

Table 25

RAILROAD TRAFFIC AND EMPLOYMENT, 1923-1939[a]

	Employees 1923 (thousand)	PERCENTAGE CHANGE *1923-1929*	*1929-1939*	*1923-1939*
Passenger and Freight Traffic Combined	....	+2.8	–25.8	–23.7
Total Employment	1,858	–10.6	–40.5	–46.8
Administrative Personnel, total	299	–5.4	–38.1	–41.5
Executives, Officials, staff assistants, etc.	16	+3.8	–29.7	–27.0
Professional, clerical and general	282	–5.9	–38.7	–42.3
Maintenance Personnel, total	983	–12.8	–45.6	–52.6
Way and structures	398	+2.2	–50.4	–49.3
Equipment and stores	585	–23.0	–41.4	–54.8
Transportation Service, total	576	–9.6	–33.4	–39.8
Other than train, engine and yard	213	–9.4	–35.4	–41.5
Yardmasters, switch tenders, and hostlers	26	–17.8	–42.2	–52.5
Train and engine service	337	–9.1	–31.6	–37.8

[a] Class I line haul roads.

Maintenance employment, as we have indicated, declined most. The drop of 13 percent in the period 1923-29 is to be attributed to declines in the employment of men charged with the maintenance of equipment and stores. The number of men engaged in the maintenance of way and structures increased somewhat, reflecting in part the nature of railway investment in this period. While relatively little new mileage was added to the rail network in the 'twenties, there was a considerable amount of construction activity,

[29] In testimony before the Temporary National Economic Committee in 1940, Mr. George Harrison, president of the Brotherhood of Railway Clerks, commented on this point as follows: "The machine could not be utilized under the old method. When the machine was introduced it was necessary to centralize the work, and so the work has been removed from many offices along the railroad line and consolidated and centralized in, ordinarily, the headquarters or general office building of the railroad." See TNEC, *Hearings,* Part 30, p. 16613.

reflected in increased employment in maintenance of way and structures.[30] Some transcontinental mileage was double-tracked; also additional yard track and sidings were built, terminal facilities were extended, and considerable sums were spent on the relocation or improvement of existing trackage.[31] To some extent heavier equipment and faster speeds made higher standards of maintenance necessary.

Among the technological improvements on which maintenance employees were engaged in the 'twenties were the laying of heavier rails, the introduction of chemically treated ties, and the use of improved ballast and tie-plates. In large part, this activity reduced future maintenance requirements, as indicated rather vividly by the fact that such employment was cut in half in the succeeding decade, although some of the latter decline may have been due to more or less deliberate undermaintenance rather than technological displacement. Most of the technological advances associated with the 41 percent decline in employment on the maintenance of equipment and stores in the period 1929-39 were designed to increase the running time of locomotives and cars in relation to time and labor required for service repairs. This was accomplished by the application of metallurgical advances to locomotive construction, the adoption of cast-steel frames integral with the cylinders, the chemical treatment of locomotive water supply, better lubrication, the gradual introduction of roller bearings, and the introduction of longer-lived, rust-resisting steel cars. In addition, in the railroad shops very considerable savings of labor were accomplished by the introduction of such modern

[30] Most such construction doubtless was undertaken by contractors, yet some additions and betterments probably were built by railroad maintenance employees. Whether built by contract or not, subsequent responsibility for maintenance fell upon railroad employees.

[31] Among western roads to which sections of second main track were added may be mentioned: the Union Pacific in Idaho and Wyoming between 1917 and 1922; the Santa Fe in New Mexico, Arizona and California in 1923; and the Southern Pacific across the Sierra Nevada in 1926. After 1930, not only did traffic decline, but construction of second track was rendered less necessary, for the development of centralized traffic control allowed the capacity of busy sections of single track to be increased sharply. Since 1930 construction has been practically confined to the relocation of existing trackage, to the reduction of grades or curves, or to the elimination of grade crossings.

machine tool apparatus as multiple planers, improved drill presses, and tapping machines, and by the more efficient use of the assembly line system for locomotive and car repair.[32]

Some of the same technological advances that have reduced the need for maintenance have also displaced employees in the train and engine service; for example, the advent of the modern locomotive which requires less servicing and has higher tractive power. The more significant advances affecting employees engaged in transportation service, however, are those relating to dispatching, communications, freight handling, etc. The installation of automatic block signal devices facilitating the automatic control of train movements has been one of the most significant innovations in rail transportation technique.

Among employees performing transportation service, the small group comprising yardmasters, switch tenders and hostlers has contracted most sharply since 1923. Many of these workers have been displaced through the progressive mechanization of switching operations. 'Hump yards' have a long history, but their further elaboration in recent years has significantly affected the employment of this class of rail worker. Here must be included the centralized control of switching operations and the general introduction of car-retarding devices.

SOME TECHNOLOGICAL ADVANCES

Looking back over the past half century we can see that railroad technology has undergone numerous changes. It is not easy to summarize these changes briefly; still less easy is it to indicate accurately either the contribution to efficiency each has made or the degree to which each has become standard practice.

Most of the instances of technological advance we shall be able to cite can be brought within one or another of the following four broad categories: changes in design and organization that have taken place rather gradually and have merged into each other; economies of scale; rather straightforward instances of mechanization; and applications of chemical and metallurgical

[32] Cf. Redesign of the C.C.C. and St. L. shops at Beech Grove and the New Haven shops at Readville (*Railway Age,* Oct. 27, 1923, pp. 767-70).

discoveries, most of which originated in other industries. The sources of changes in railroad technology are therefore exceedingly diverse: some developments depend upon true inventions, of a kind potentially subject to patent rights; others are related rather to the mere passage of time, the growth of traffic, or the accumulation of experience both within and without the industry.

Instead of attempting to classify these changes directly along the lines just indicated, however, it is perhaps more convenient to adopt a functional approach, and to consider separately, first, the operation and maintenance of rolling stock; second, the maintenance of track and other fixed equipment; and third, the general organization and operation of the railroad undertaking as a whole. Of these the first — the application of power to the movement of passengers and freight — has undergone by far the most dramatic, and probably also the most quantitatively significant, series of changes.

Rolling Stock

Despite the gradual introduction of Diesel power, first for switching and later for main line work, at the end of our period the steam locomotive still remained by far the most important source of motive power.[33] But the steam locomotive itself had changed. Larger and more powerful units have rendered possible economies of scale through hauling longer and heavier trains — economies both of fuel and labor. The average tractive effort of all steam locomotives in service rose from 20,000 pounds in 1902 to 36,000 pounds in 1920 and 54,000 pounds in 1946.[34] It has been claimed that over a period of twenty years or so weight per horsepower was cut in half and thermal efficiency doubled: this statement of

[33] The distribution of available equipment in terms of tractive effort at the end of 1946 was: steam, 87.2 percent; electric, 2.1 percent; Diesel electric, 10.7 percent. Since the average utilization of Diesel power is more intensive than steam, these figures understate Diesel performance in terms of car-miles or ton-miles.

[34] Tractive effort is a theoretical measure of pulling power based on boiler pressure and cylinder and driving wheel dimensions. The mean tractive effort of all locomotives (including electric and Diesel) did not differ appreciably from that for steam locomotives alone.

course applies to locomotives available for replacement, not to the locomotive stock owned by the railroads at the two dates.[35]

Such economies represent more than the mere result of doing things in a bigger way. The increase in tractive effort has been associated with a long series of innovations, most notable of which are the superheater, the feed-water heater, the force-feed lubricator, the mechanical stoker, and power reverse gear. Some of these — especially the superheater and the feed-water heater — have also contributed economies in fuel consumption. All may be said to date from the period since 1899, and collectively they have made possible the large modern main line power plant.

While in most respects progress in design and the adoption of improvements in the steam locomotive have followed a continuous line of development, the history of compounding forms an interesting exception. There is no doubt that fuel consumption may be reduced through the multiple-expansion principle — by using the expansive properties of steam more than once in a series of cylinders: the universal use of compounding in the practice of marine reciprocating engines is sufficient evidence of this. In fact compound locomotives were introduced in the late 1880's, and by 1900 appeared to many likely to become standard practice in this country for main-line work. From about 1910, however, a reversion to the two-, three- or four-cylinder single expansion locomotive began. By the 1920's even articulated locomotives, traditionally built as compounds, were being designed for single expansion.

The rise and subsequent decline of compounding offers an interesting example of an innovation promising large economies, especially in fuel consumption and boiler repairs, that almost became standard practice, then virtually disappeared from the scene. For the eclipse of the compound locomotive no entirely convincing explanation is forthcoming, but it appears to have been connected with the elaboration and more extended use of superheating. The compounds of forty years ago used saturated steam and realized undoubted economies, especially in fuel and water consumption. But similar economies are available through the use

[35] National Resources Committee, *Technological Trends and National Policy* (1937), p. 192.

of superheated steam in a single set of cylinders by cutting off the supply of steam at a very early stage of the piston stroke. The expansibility of saturated steam is insufficient to allow of this: but if the steam is superheated it will continue expanding long after it is no longer being admitted to the cylinders. Consequently, if the steam is superheated, less of it is required per piston stroke. In theory no doubt, these economies should be cumulative, and one might regard the superheated compound locomotive as the acme of efficiency. In practice it appears that the effect of superheating — now almost universal — has been to supplant compounding rather than to be combined with it. Insofar as the two devices are regarded as alternatives by designers, it is easy to see why superheating should have been preferred, for unlike compounding it requires no additional moving parts. Higher boiler pressures — 300 instead of 200 pounds per square inch — also appear to have favored the superheater over the compound engine. Other disadvantages of compounding were high maintenance costs, and the excessive size to which the low pressure cylinders grew in a non-articulated compound locomotive as its capacity was increased.

While therefore the steam engine has undergone very marked improvement in recent decades, and while it is still the principal form of motive power on the railroads, two newcomers should be mentioned — the electric locomotive and the Diesel engine. Electrification has so far been confined to areas of high density traffic or where peculiar operating conditions, such as tunnels (New York terminals of the Pennsylvania and New York Central) or sharp grades (Norfolk and Western), occur combined with dense traffic. Capital cost of equipment is high and, although fuel economies are marked, main line electrification has made little progress in this country. Diesel power was first introduced in the 1920's for switching and for the operation of rail motorcars. At first transmission difficulties limited power output; soon electrical transmissions, though expensive, removed this restriction. In 1934 the Burlington and the Union Pacific introduced Diesels for main line passenger work, and thereafter their use spread both for passenger and freight operation. Principal advantages are the ease with which several units can be combined, the long runs possible between stops for servicing, and the reduced wear on the track at high speeds due to the absence of heavy reciprocating parts.

Higher speeds and heavier trains — especially large-capacity freight cars — have been only partially offset by the use of aluminum and of metallurgical discoveries which lighten the weight of steel. While modern alloys have played a dramatic role in the advent of the streamlined passenger train, traveling at high speeds, often with Diesel power, the high cost of the new metals has prevented their use to date for ordinary freight car construction. Potential reduction in the weight of rolling stock through the use of the newer — but still more expensive — methods of construction is undoubtedly large, but has yet to be realized.[36]

Improvements in the maintenance and servicing of rolling stock have been no less considerable, if less dramatic, than in the equipment itself. The chemical treatment of feed water and the sludge remover have diminished the frequency with which boilers must be washed out and lengthened their life. Mechanical coaling equipment and conveyors for removing cinders have reduced the labor involved in servicing. Improved brakes and draft gear have lengthened the time between repairs; while within the last ten years better lubricants (as well as better-designed bearings and other factors) have cut sharply the risk of contracting a hot box.[37] Meantime technological developments in railroad repair shops have paralleled changes in machine shop practice elsewhere — for example in the general use of welding, of spraying machinery for painting, and in improvements in plant layout. Repairs have been concentrated in fewer and larger plants.[38] Partly through the less

[36] Cf. Evidence of J. H. Parmelee, TNEC, *Hearings,* Part 30, pp. 16602-3.

[37] On the Milwaukee the frequency of reported hot boxes was as follows:

	THOUSAND MILES PER HOT BOX	
	1929	*1940*
Freight cars	128	462
Passenger cars	242	1,166

(President's Emergency Board, 1941, 'Hearings', mimeo, p. 1975.)

[38] Cf. the concentration of repair work on the Delaware and Hudson in 1911-12 from Carbondale, Oneonta and Green Island to Colonie near Albany (*A Century of Progress: History of the Delaware and Hudson Company, 1823-1923,* J. B. Lyon, Albany, 1925, pp. 362-3). On the Pennsylvania between 1920

frequent need of repairs, partly through shortening a locomotive's stay in the shops, the proportion undergoing repair has been reduced.[39]

Track and Fixed Equipment

Rather striking improvements have been made in the maintenance of track and fixed equipment. The burden placed upon those concerned with permanent way has of course increased through heavier and faster trains: these have necessitated heavier rail,[40] strengthened bridges and relocated tracks. However, the reduction of grades and elimination of curves involved in the relocation of track have made for operating economies, while the installation of automatic highway crossing signals and the elimination of grade crossings have reduced the need for watchmen. In the maintenance of existing track — a continuous operation that must be carried on year in, year out — substantial improvements have also been effected. As recently as the early 1920's less than half of all replacement ties were chemically treated: treated ties, which may last three times as long as untreated, now comprise more than four-fifths of all ties laid.[41] The use of longer rails and the heat treatment of rail ends to withstand battering also decrease the need for maintenance. Finally in the actual operations of relaying track and replacing ballast a high degree of mechanization has been achieved.[42]

and 1934 locomotive repair shops were reduced from 26 to 3, passenger car shops from 12 to 3, and freight car shops from 16 to 11 (George H. Burgess and M. C. Kennedy, *Centennial History of the Pennsylvania Railroad Company,* P.R.R., 1949, p. 597).

[39] Cf. Charles B. Going, *Methods of the Santa Fe* (The Engineering Magazine, 1909), pp. 57-8; Henry S. Haines, *Efficient Railway Operation* (Macmillan, 1919), pp. 63, 73. See also evidence of J. H. Parmelee, TNEC, *Hearings,* Part 30, pp. 16601-2.

[40] On class I roads the average weight of rail per yard of main track rose from 82 pounds in 1920 to 95 pounds in 1939 and 99 pounds in 1946. The percentage of all track with rail heavier than 100 pounds per yard rose from 13 percent in 1920 to 50 percent in 1946, *(Statistics of Railways).*

[41] TNEC, *Hearings,* Part 30, p. 16563; President's Emergency Board, p. 1903; P. Harvey Middleton, *Railways and the Equipment and Supply Industry,* (Railway Business Association, Chicago, 1940), pp. 18-9.

[42] Cf. TNEC, *Hearings,* Part 30, pp. 16594-16601. Power machinery is available for adzing ties, drilling rails, tightening bolts, driving and pulling spikes, and cleaning ballast (President's Emergency Board, p. 1977). Rail laying, tie renewal, ballast work, and ditching have been largely taken away from regular section gangs and given to gangs specially mechanized for these purposes.

General Operation and Maintenance

As in the case of equipment and track, in the field of general operation and maintenance the railroads have partly borrowed from the experience of other industries and partly developed specialized devices to meet their own peculiar problems. In accounting and office routine they have shared in developments that mainly originated elsewhere; and the same might be said of the improvement of communications but for the very special role played by the telegraph and telephone in railroad operation. The transmission of information concerning train movements was indeed one of the earliest applications of electrical communication. The installation of block signal systems, designed to enforce a space interval between trains, was primarily a contribution to safety. It belongs, as do the first interlocking machines, to the very beginning of our period. The function of interlocking is of course to harmonize the movements of signals and switches and to prevent the giving of contradictory indications. In their original form these inventions were purely mechanical in character, although operated in conjunction with the electric telegraph. Before long, however, electricity was applied to block signaling itself. First, from about 1879, the track circuit began to be used in conjunction with interlocking. Human operation of signals and switches still was necessary, but it could now be made physically impossible to direct traffic onto a section of track already occupied. Second, fully automatic block signaling, already widely adopted for main line operation by about 1910, was due originally to city subway practice.[43] Now for the first time the signals were directly controlled by the trains themselves. During the 1920's fully automatic interlocking plants to protect crossings began to be installed.[44] Finally, where manually operated signaling remains indispensable — as at junctions and terminals — switches and signals alike may be remotely controlled over great distances. Closely allied and sometimes combined with these developments must be mentioned centralized traffic control. It consists in directing from a single point all traffic movements over a wide area of railroad territory

[43] On the introduction of automatic block signaling, see *Railway Age,* March 20, 1903, pp. 536-8 and Jan. 15, 1909, pp. 118-9.

[44] Cf. *Railway Age,* Dec. 12, 1931, pp. 890-2.

and eliminates the ordinary business of dispatching by means of train orders. That is to say, train movements are directed entirely by signal indication, the signals being operated from a central point, so that operators at way stations are eliminated. Train movements are reported on an indicator board which may cover thirty, forty or more miles of track; all switches and signals are controlled from a single desk. The function of CTC is not only to eliminate local control of signals (from towers or otherwise), but also enormously to enlarge the elasticity of the time table by rerouting and rearranging traffic at a central headquarters to suit the conditions of the moment. By increasing the effective capacity of equipment and track, CTC has produced large economies in many cases. Perfected originally on eastern roads with dense traffic, it has been applied even to such single-track sectors as those of the Missouri Pacific, Denver and Rio Grande Western, and Southern Pacific: in the last case it is said to have increased track capacity by as much as 50 percent.[45] Perhaps the most notable installation to date is that consisting of four sections of the Union Pacific aggregating some 600 miles between Los Angeles and Salt Lake City. Yet CTC is fairly expensive to install and in 1942 was used to control only about 3,000 miles or perhaps 1½ percent of all main track.

TECHNOLOGY AND OUTPUT PER WORKER

Enough has been said to show that technological changes on the railroads are numerous and diverse, and that they have a complex history. Accurately to date the general introduction of any individual innovation is difficult; to appraise quantitatively its labor-saving value would require elaborate and specialized study. Yet the combined influence of these many changes (not all of which are here listed) conditioned the rise in output per worker and per manhour (Chart 16).

Perhaps the most remarkable aspect of the upward trend of labor productivity in the railroad industry is its continuity and persistence. The average technological situation in such an industry as the railroads, the representative way of doing things, changes

[45] *Fortune*, June, 1942; see also *Railway Age*, Sept. 12, 1931, pp. 388-90.

only slowly. Sharp rises in output per worker, or its relative stagnation for a few years, must be traced to varying degrees of utilization of working force and fixed equipment, or to short term variations in maintenance activity. The steadiness and persistence of the influence of technological change, as evidenced by the practically linear movement of output per worker (measured on a ratio scale) over more than half a century can be attributed to two characteristics. In the first place, most innovations are themselves gradual in nature. Modern Diesel power or the hump classification yard as we know it today — to pick two instances — each embody numerous features successively introduced over a time span of several decades. In the second place the introduction into general practice even of a perfected and seasoned improvement must inevitably be a gradual affair. Not only must the idea be sold to many separate managements; often its introduction must await replacement. Continuous rail or treated ties may be worth installing, but only if replacement is anyhow in prospect.

Such considerations go far to explain the continuity of the upward trend of productivity; they do not explain the lack of evidence of any slackening of growth. Why the rate of technological change in the railroad industry — or at least of its measurable effects — should vary so little from decade to decade poses an interesting problem for the solution of which little evidence is at hand.