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CHAPTER 4

Utilization of Equipment in Freight Service

MEANING AND COMPONENTS OF UTILIZATION

The cyclical variations in traffic described in Chapter 1 have many and various effects on, or at least concomitants in, railway operations, efficiency, and profits. In particular the movement of goods is intimately connected with that of rolling stock. Ton-miles happen in freight cars and behind locomotives.

Each car performs an identifiable share of the aggregate ton-miles recorded each month. Specifiable shipments move in it over nameable segments of road. The size of its accomplishment is the product of three factors which, for brevity, we call load, speed, and useful time. If a car contains, on an average, 25 tons, moves at an average speed of 15 miles an hour, and is engaged in loaded movement 60 hours a month, it serves as the container in which $25 \times 15 \times 60$, or 22,500 ton-miles per month occur. This formula suggests the kind of circumstances that influence the average performance of all freight cars. Do the men who load them have occasion to pile in large cargoes? Are lines uncongested and available locomotives designed for rapid runs? Do cars spend most of their time loaded and moving, standing idle, or moving empty from place to place?

Each locomotive likewise has its identifiable share in the total movement of goods during any month. It hauls specifiable shipments over specifiable branch lines or divisions. (Sometimes, however, two engines are needed to propel a train; when this happens, it would be necessary to credit each by some arbitrary rule with a portion of the ton-miles that result from their joint effort.) The ton-mile performance of a locomotive, like that of a freight car, is the product of three factors which may be called load, speed, and useful time. The first, the average amount of freight behind the engine, depends partly on the loads in the cars and partly on the number of loaded cars in a train. The meaning of the second is obvious. The third can be described more exactly as the number of hours the locomotive spends with loaded cars attached to it. If it trails an average of 1,000 tons of freight behind it, runs at 15 miles per hour, and spends 150 hours of a month pulling loaded cars, it provides the motive power for 1,000 × 15 × 150, or 2,250,000 ton-miles during the month.

HEAVIER CARLOADS IN PROSPERITY

Circumstances under which goods are loaded

Carlot shipments of revenue freight are loaded under circumstances different from those which surround the handling of less-than-carlot shipments and the movement of the railroad companies' own materials and supplies.[1] It is the shippers themselves or their employees who usually place C.L. revenue shipments in the car; both small commercial shipments and company freight are usually loaded by railroad forces.[2] One shipment of the C.L. revenue traffic ordinarily makes a carload; but a single car often contains several L.C.L. consignments, sometimes a mixture of commercial L.C.L. and railroad shipments. A load of the first sort goes through from consignor to consignee under seal, nothing is added or taken out on the way. After a 'merchandise' (L.C.L.) car leaves its starting point some goods are often removed at way stations, and others are sometimes put in. The average load for all freight is the composite result of what happens under these two sets of circumstances; we shall therefore discuss the two types of traffic separately before we consider their over-all average.

Revenue shipments in carlot quantities

The formula according to which load times speed times useful hours equals ton-miles per car per month is strictly true only if the average load is computed by dividing loaded car-miles into ton-miles. For all cars the ratio so obtained is virtually what we would get if we could weigh the contents of each car as it passed each mile-post, add the weights observed for all cars at all mile-posts, and divide by the number of observations. Our average load data for all freight are in fact ratios of ton-miles to car-miles; but we

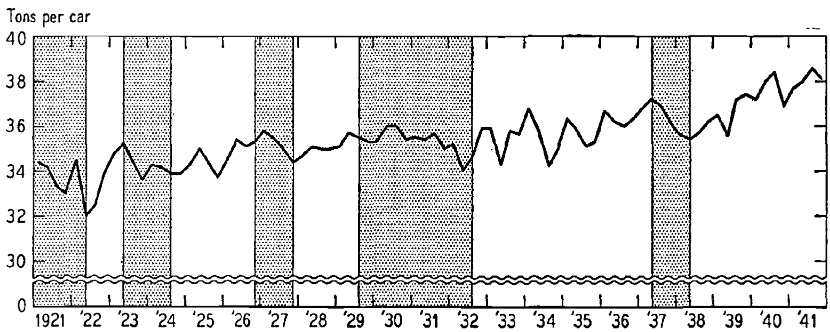
[1] Neither the movement of company freight nor that of cars containing it is included in any of our data when it occurs in work trains (i.e., those engaged in repairing the road, or in distributing railroad materials and personnel exclusively) rather than freight trains.

[2] Vendors of railway supplies, however, commonly do the loading for the movement from their premises to railway supply depots.

have no strict analogue for either carload or less-than-carload traffic, considered separately. In the case of carload freight we have the ratio of tons originated to cars originated—what we would obtain if we could observe the burden of each car at starting point, total the observations, and divide by the number of loadings. If lightly loaded cars go farther than heavily loaded ones, a tons-per-car figure is too high for our purposes; if they do not go as far, it is too low. Ton-mile-per-car-mile figures for carload revenue traffic would probably not fluctuate by exactly the same percentage as the tons-per-car figures we have. But we may reasonably suppose that over a phase of freight traffic they move in the same direction.

CHART 32

Load in a Car, Carload Revenue Freight, First Quarter 1921—Fourth Quarter 1941 (tons originated per car originated)



Shaded periods are contractions in C.L. tons originated.

The tons-per-car ratio is presumably related more closely to fluctuations in carload tonnage originated than to those in other measures of freight traffic. At any rate, the data, which begin in 1921, show that from that year, on the average, cars contained more freight at the end of every expansion in aggregate carload tonnage than at the beginning, and less freight at a trough than at the preceding peak (Chart 32). The general direction of change in each phase is clear, although the curve is rather irregular, and turning points in the load did not always coincide with those in the C.L. tons originated.

The phases in the latter also began and ended at somewhat different dates than those in revenue ton-miles (as represented by quarterly figures). Nevertheless, computations indicate a net rise in tons per car during each expansion of ton-miles, a net fall during each contraction. The average load for carload traffic conformed positively not only to the cycles in that kind of traffic but also to cycles in all traffic.

From all this one might infer that carlot shipments of almost any commodity are smaller in depression than in prosperity. But such a conclusion would apparently be wrong.

It is true that if shippers of each commodity put smaller and smaller loads in cars as contraction deepened, tons originated per car would decline. But on the other hand the average, as actually computed, could also fall even if the average load of every commodity remained unchanged. This might happen if the tonnage of many lightly loaded commodities declined only moderately during a contraction, while the tonnage of heavily loaded articles declined severely. The average load for all carload traffic is related to both the average loads for individual commodities and the relative importance of the various commodities as components of the aggregate tonnage originated.[3]

Changes in the relative importance of some commodities, during any phase, probably tend to raise, changes in the importance of others tend to lower, the over-all average. We can, however, determine the net tendency of all such changes. Because of the enormous labor that would be required to seasonally adjust quarterly figures for 156 commodities, we use annual data to make the determination. We may take the 1929–32 contraction as an example. The over-all average carload fell from 35.39 tons in the first year to 34.92 tons in the last. But if no changes in individual-commodity loads per car had occurred, the 1932 tonnage would

[3] Call the tons of one commodity t_1, those of another t_2, etc. Let T be the aggregate tonnage of all commodities. By the relative importance of any one we mean, e.g., t_1/T. Call the tons per car w_1, w_2, etc., for each commodity respectively. Then total cars, C, $= t_1 \frac{1}{w_1} + t_2 \frac{1}{w_2} + \cdots + t_n \frac{1}{w_n}$. Tons per car for all commodities, the ICC figure we discuss,

$$= T \div C = (T \div T) \div (C \div T) = 1 \div (C \div T) = \frac{1}{\frac{t_1}{T} \cdot \frac{1}{w_1} + \frac{t_2}{T} \cdot \frac{1}{w_2} + \cdots + \frac{t_n}{T} \cdot \frac{1}{w_n}}.$$

Changes in the value of this expression can be produced by changes in either the t/T items or the w items.

have required the origination of 18,181,639 cars (Table 25), and the over-all average would have been 630,989,027 ÷ 18,181,639, or only 34.70 tons per car. Since this result would have occurred if all the 1929 individual loads per car had been maintained through 1932 but composition of tonnage had changed as it really did, the changes in composition were such as to reduce the over-all average. On the whole, the quantities of heavily loaded goods originated must have diminished by greater percentages than the quantities of lightly loaded goods. Indeed the changes in relative importance, by themselves, would have produced a somewhat greater fall than actually occurred; on the whole the individual average loads must have risen rather than fallen.

Table 25

Hypothetical Average Loads per Car, 1932: Illustrative Computations

Commodity	Tons originated 1932	Average load 1929[a]	Cars required in 1932 at 1929 av. load (1) ÷ (2)
Wheat	19,120,293	43.85	436,039
Coke	7,346,269	33.90	216,704
Automobiles	716,011	5.99	119,534
156 commodities	630,989,027		18,181,639[b]

[a] Tons originated, 1929 ÷ cars originated, 1929.

[b] Sum of figures for each of 156 commodities computed in the manner illustrated for wheat, coke, automobiles.

By similar procedures we calculate that changes in composition alone would have raised the 1932 actual over-all average of 34.92 tons to 35.90 tons in the peak year 1937. The actual average rose to 36.74, indicating that the changes in loads alone also tended to increase the average. From 1937 to 1938 the change in composition would have produced a decline from 36.74 to 35.85 tons, and therefore almost, but not quite, accounts for the actual decline to 35.78 tons. In this case the changes in individual average loads were such that they would have produced some decline in the over-all average by themselves, although not nearly as much as the changes in composition would have produced by themselves.

The foregoing computations pertain to three phases in which the cyclical variations in traffic were rather severe. Similar calculations could be made for the, in general, milder phases from 1920–21 to 1927–29.[4] But they would be less accurate. It would be

[4] We have an annual figure although no quarterly figures for 1920.

necessary to base them on a division of carload traffic into only 69 instead of 156 classes. If only data for rather broad groups of commodities can be used, changes in the relative importance of articles having widely different loads but included in the same groups may be disguised as changes in average loads. Without further computation, we conclude that changes in composition are probably more important than changes in loads for individual commodities, and that it is doubtful whether the latter, on the whole, rise and fall with traffic.

This conclusion accords with a consideration of the circumstances under which shippers decide how much they shall put in a car. In practice they do not have much discretion. To obtain the benefits of carload rates, a consignor must either load his shipment to a minimum weight specified in the railroad tariff or pay charges on that minimum. If he loads less, the rate he must pay per one hundred pounds is, in effect, higher; a fixed charge is spread over fewer pounds. He must incur a pecuniary penalty if he fails to load the specified quantity; and the penalty becomes progressively steeper the lighter the loading, at least until the higher L.C.L. rate is reached. If, in prosperous times, he has been accustomed to make heavier than minimum shipments, he can reduce the size of his loads to the tariff limit without loss when contraction reduces his aggregate volume of business. But he will probably not have much leeway, for in fixing carload minima, the amount of goods that can conveniently be placed in a car is given consideration. Conversely, when the volume of business begins to rise, shipments must already average close to the minimum and they cannot be enlarged very much without seriously increasing the cost and inconvenience of loading. What is true for an individual enterprise is more or less true for all shippers of a commodity, as minimum weights on any article are usually the same over a wide geographical area. Of course, shippers could bring pressure to have the minimums specified in railway tariffs reduced in contraction and railroads could endeavor to raise them in expansion. No comprehensive historical study of minimum weights has ever been made, but anyone familiar in detail with rate-making will doubt that widespread cyclical changes in these regulations occur. On the other hand, minimum weights vary a great deal from one commodity to another. Some are as low as 10,000 pounds, others as high as 100,000. Changes in composition can therefore easily affect the over-all average.

Other freight

As in the case of carload traffic, we must rely on something less appropriate than a ton-mile-per-car-mile figure to tell us what cyclical changes occur in the loading of L.C.L. cars. We do not even have an accurate figure for the average content at starting points. The nearest feasible approximation can be obtained by computing the ratio of the number of tons originated as reported by the ICC to the number of 'merchandise' (L.C.L.) cars loaded, as reported by the Association of American Railroads. But this figure understates the average load at the points from which the cars begin their runs. Many L.C.L. shipments are transferred en route from the cars in which they started their journey to other cars. Some are transferred twice, or even more often. In 1932 the number of tons transferred from one car to another slightly exceeded the number originated.[5] Consequently, the total tonnage loaded into cars at the points where they start their runs, including transferred freight, must greatly exceed the tonnage originated, and the average load at starting points must exceed the tonnage originated divided by the number of cars started. Furthermore, the load of an L.C.L. car, unlike that of one containing a carload shipment, often does not remain constant during the trip. Many L.C.L. cars distribute shipments to stations along the line. At each station some goods are taken out, others are put in. Even if we knew the true starting load it would not accurately represent the ton-miles per car-mile, for two reasons. As in the case of the L.C.L. figures, merchandise cars of heavy starting loads may have longer, or perhaps shorter, hauls than others and the load of one car is often different at different mile-posts. Nevertheless we shall assume that the available ratio changes in much the same way as the ideal ratio for our purpose, ton-miles of L.C.L. divided by car-miles of merchandise cars, would change.

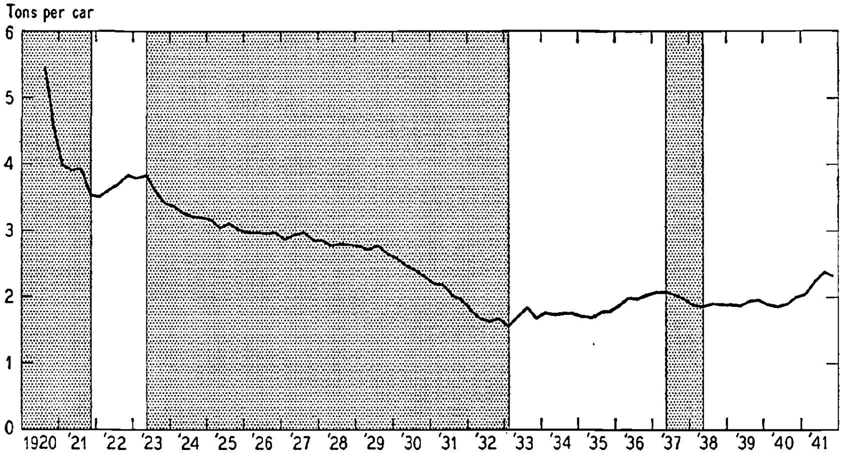
The average load of merchandise cars, indicated in this manner, reflected the major specific cycles in aggregate L.C.L. tonnage from 1920 to 1938 (Chart 33). Although we lack even the orig-

[5] Federal Coordinator of Transportation, *Merchandise Traffic Report* (Washington, D. C., 1934, mimeographed), p. 13.

inated-to-loaded ratio for the first two quarters of 1920, the average load apparently diminished sharply in the 1920–21 contraction. It responded to the 1921–23 recovery, fell during the long contraction of L.C.L. tonnage from 1923 to 1933, rose and fell in the 1933–38 cycle. The sharp reduction of traffic from 1923 to 1924, the more gradual shrinkage from 1924 to 1929, the accelerated fall from 1929 to 1932 (Chart 4) are all recognizably even if roughly paralleled in the history of the load per car.

CHART 33

Tons of Less-than-carload Freight Originated per Merchandise Car Loaded, Third Quarter 1920—Fourth Quarter 1941



Shaded periods are contractions in L.C.L. tons originated.

If railway officials in charge of loading attempted to keep their merchandise cars as full during a contraction in traffic as they were at the peak, their customers would suffer considerable inconvenience. This is true of both through and local business. L.C.L. is handled partly in cars that move from one metropolitan center to another without intermediate change of lading, and partly in way cars from which it is peddled to local stations along the line. When the aggregate volume in the country as a whole declines, the amount received per hour at various individual major centers, destined for other centers and therefore suitable for movement in through cars, must often decline. The loading officials could, of course, wait for so much to accumulate that they would send out cars as heavily burdened as before. But they would have to wait longer, and goods would be delayed. Where L.C.L. is handled in way freight trains, two cars devoted to it, or perhaps only one, may travel the line daily. If, when the tonnage to be distributed dwindles, the service is cut from two a day to one, or from one every day to one every other day, many consignments will have to wait longer to be forwarded. If the service is not cut, the average load will be reduced. Conversely, when traffic begins to expand, cars in both through and way service will have plenty of room in them, and loads can be increased without impairing the promptness of the service.

Table 26

Tons Originated per Car Originated, Carload Freight; and per Merchandise Car Loaded, Less-than-carload Freight

Change between Peaks and Troughs in Revenue Ton-miles, 1920–1938

Turn in ton-miles		Quarters from prec. date	Carload tons originated per car originated		Less than carload tons originated per car loaded			
					No.	Change from preceding date		
						Total	Per quarter	
Date	Level		No.	Direction of change			To peak from trough	To trough from peak
I 1920	Peak	...	...	...	...	...	...	...
III 1921	Trough	6	33.3	...	3.92	...	...	...
II 1923	Peak	7	35.2	+	3.83	−0.09	−.013	...
II 1924	Trough	4	34.2	−	3.25	−0.58	...	−.145
III 1926	Peak	9	35.1	+	2.96	−0.29	−.032	...
IV 1927	Trough	5	34.4	−	2.85	−0.11	...	−.022
IV 1928	Peak	4	35.0	+	2.79	−0.06	−.015	...
III 1932	Trough	15	34.6	−	1.63	−1.16	...	−.077
II 1937	Peak	19	37.2	+	2.07	0.44	.023	...
II 1938	Trough	4	35.4	−	1.86	−0.21	...	−.052

Although the cycles in L.C.L. traffic differed from those in revenue ton-miles, the merchandise load on the whole conformed positively to the latter also (Table 26). It showed no net rise in the first three of four expansions, however, but the decline was less rapid than in the adjacent contractions (with one exception: compare 1924–26 with 1926–27).

The load ratio has another defect: freight for use in the railroads' own operations is not included in the numerator although some noncommercial traffic must be carried in merchandise cars.

Supplies for the use of station agents and others along the line are often loaded in with revenue shipments. There is no information on the average load of company freight in solid carloads, but very likely its average also rises and falls with the aggregate volume of supplies currently needed, which in turn must vary with aggregate revenue traffic.

All freight

The preceding survey of changes in the average load of carload revenue freight and of other freight should lead us to expect that the average load for both kinds combined would conform to cycles in revenue ton-miles, since the average for each part conformed to them. To be sure, in examining the average load for C.L. freight we were obliged to study the average at starting point, and in considering L.C.L. we studied something analogous, while for total traffic we rely on an average of the mile-post type—net ton-miles per loaded car-mile. Such an average for the two components would not necessarily vary in the same way during a cycle as the averages of the starting-point type did. The two types can differ considerably in absolute level, as figures from the 1932 special study by the Federal Coordinator demonstrate. For all carload traffic, tons originated per car originated equaled 34.50,[6] while ton-miles per car-mile equaled only 28.16.

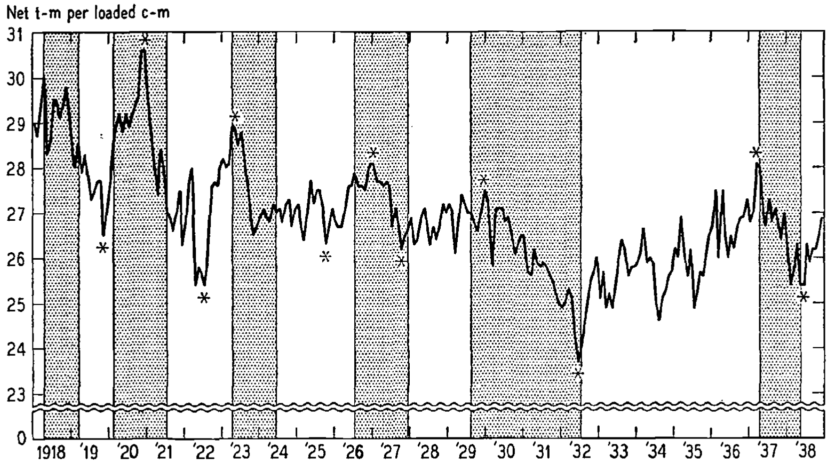
But in fact the ratio of all ton-miles to all loaded car-miles did rise and fall with cyclical variations in traffic (Chart 34). From 1918, when the monthly data begin, to 1938, each expansion or contraction in revenue ton-miles can be paired with an improvement or deterioration in performance per car-mile. In the earlier cycles, to be sure, the peaks and troughs in the average load did not correspond very closely in time to those in aggregate ton-miles; the 1919–20 expansion is a particularly glaring instance, for the rise in load did not begin until almost the end of the expansion in traffic. In the four or five more recent phases, however, the correspondence was much closer. And in every case, the average load at each traffic peak was higher than at the nearest troughs, and *vice versa*.

Annual data are available for six phases before 1918–19 (Chart 35). Although ton-miles per car-mile rose in the expansions, they

[6] This differs somewhat from the regular ICC figure for 1932, which was 34.92.

CHART 34

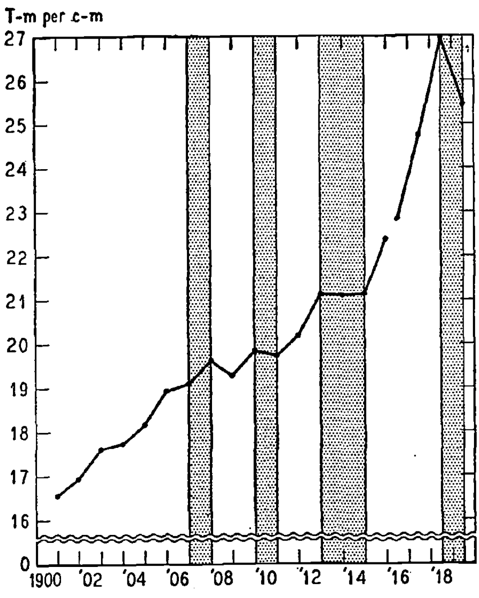
Load in a Car, All Freight, January 1918—December 1938 (net ton-miles per loaded car-mile)



Shaded periods are contractions in revenue ton-miles.

CHART 35

Load in a Car, All Freight, 1901–1919 (revenue ton-miles per loaded car-mile)



Shaded periods are contractions in revenue ton-miles.

rose also in two contractions, which is contrary to what the later monthly data would lead us to expect. Six comparisons of adjoining phases, however, including a comparison of 1918–19 with its predecessor, indicate that the average carload conformed positively to cycles in ton-miles, with one exception. The slight rise in the 1913–15 contraction was preceded and followed by a more vigorous rise. Only the comparison of 1907–08 with 1908–10 indicates a more vigorous rise in contraction. It is fair to say that even before 1918 the average carload tended to rise and fall with aggregate traffic.

We conclude that in any traffic cycle changes in the composition of carload traffic and efforts to preserve minimum standards of expedition in L.C.L. service are likely to result in lighter loads during contraction and heavier ones during expansion.

The average load increased with unprecedented rapidity in 1917 and 1918, in part at least because of the unusual efforts prompted by an emergency. Consignees at eastern ports were unable or at least failed to unload cars promptly; for this and perhaps other reasons, severe car shortages developed early in 1916 and persisted into early 1918 (Chart 71). It became especially desirable that when cars did become available they should be utilized intensively. Accordingly, the Railroads' War Board, in 1917, propagandized shippers to load more heavily. In 1918 the Railroad Administration continued this pressure. It recommended specific measures, such as using space-economizing containers, and piling in an extra layer or two of goods. In addition it concentrated the loading of L.C.L. for many runs on a few publicly advertised 'sailing' days per week.[7]

From cycle to cycle there was an upward trend in the average load for all freight until about 1920. In carload shipments the tendency persisted thereafter; at the trough in 1938, for example, more tons were originated per car than at any preceding trough for which we have data. One contributing factor was an increase in the size of freight cars; average capacity grew steadily from 29.4 tons in June 30, 1903 to 49.4 on December 31, 1938. Presumably the minimum weights specified in tariffs of C.L. rates were also gradually raised.

[7] Hines, *War History* . . . , pp. 15, 33, 34.

HEAVIER TRAINLOADS, TOO

Loaded cars in a train

Yard crews kept assembling longer and longer trains during each expansion from 1920 onward (Chart 36).[8] In three of the contractions, on the contrary, the number of loaded cars in a train declined sharply. In one of the remaining two, 1926–27, although fluctuating irregularly, it showed practically no net change. The three-month averages for the peak and trough of ton-miles indicate a slight fall, from 28.7 to 28.6 cars. In the other contraction, 1923–24, the number rose, but at an average rate of only 0.06 cars per month; in the preceding and following expansions the rates were 0.12 and 0.10 respectively. Loaded cars per train conformed positively without exception to cycles in traffic.

Annual figures for earlier cycles do not reveal such consistent conformity (Chart 37). The net rise during the war expansion was less rapid than during the neighboring contractions. The ratio did rise vigorously from 1915 to 1916 but fell thereafter. The 1918–19 increase was followed by a decline in the 1919–20 expansion. These exceptions were apparently caused by unusual circumstances which will be discussed presently. On the other hand, four pre-war comparisons of phases indicate positive conformity, and the 1919–20 was smaller than the 1920–21 reduction.

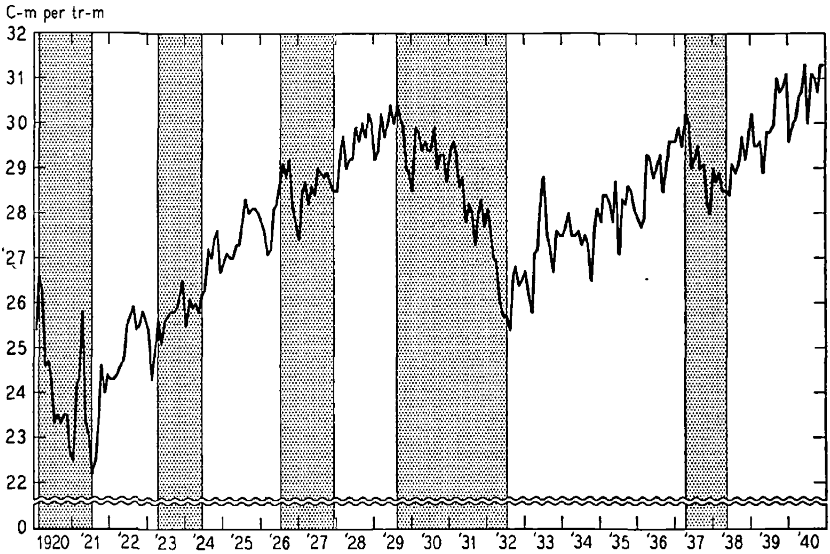
The reasons for the normally positive conformity to traffic are similar to those which account for the cyclical variation in the average load of L.C.L. traffic. When traffic diminishes the railroad companies are confronted with a dilemma. Even though average loads decline, cars awaiting movement do not accumulate as rapidly as before. It would take longer to build up trains of the size formerly dispatched, and traffic would be delayed. On the other hand, if shorter trains are forwarded, expenses per unit of traffic for train wages and perhaps other items are likely to increase. Yet the delay arising from a policy of vigorous economy

[8] The average is computed by dividing loaded car-miles by train-miles. Some trains go through from the yard in which they are originally made up to that in which they are finally broken up without change. Others pick up and drop cars en route; the number in such a train is variable. The ratio of car-miles to train-miles takes account of such variations. It is practically what we would get if we could count the loaded cars in each train passing each mile-post and average the results for all trains at all mile-posts.

could be quite substantial. On many lines of light traffic there is only one train a day even in good times, sometimes only one every other weekday, or even less often. Apparently the companies typically choose to sacrifice economy in some degree to expedition. When traffic revives, more cars can be coupled into a train without much if any impairment of service.

CHART 36

Loaded Cars in a Freight Train, January 1920—December 1940 (loaded car-miles per train-mile)

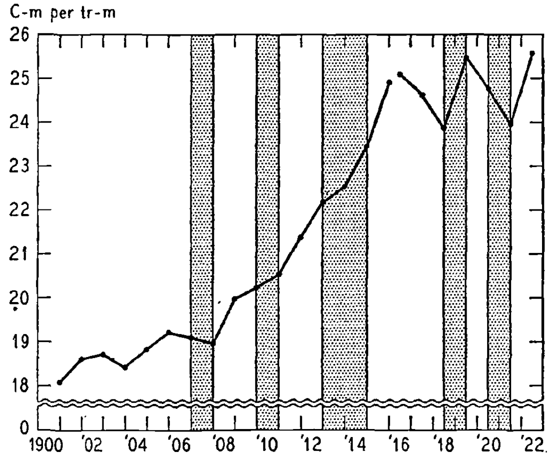


Shaded periods are contractions in revenue ton-miles.

The stability of the number of cars per train in 1926–27 and the small rise in 1923–24 invite special comment. In all the postwar contractions the speed of freight trains increased (Chart 40). If a decline in traffic, and the associated decline in the number of cars received at yards to be assembled into trains, is gradual, a very moderate increase in the time cars are detained permits the building up of trains as long as those made up at the peak of traffic. Because of the gradual improvement in speed between terminals, a mild increase in detention did not necessarily impair the over-all promptitude of service. If traffic declined rapidly, however, it became necessary, in spite of faster road movement, to sacrifice either train lengths or the quality of service. In 1923–24 and 1926–27 traffic declined at an average rate of 0.46 and 0.22 billion ton-miles per month respectively. In the other three contractions the rates were higher—0.64 billion in 1920–21, 0.59 in 1929–32, and 0.78 in 1937–38. When traffic diminished gradually train lengths were maintained or increased; when it shrank rapidly they were reduced.

CHART 37

Loaded Cars in a Freight Train, 1901–1922 (loaded car-miles per train-mile)



Shaded periods are contractions in revenue ton-miles.

The fluctuations in train length during the war phases, unlike that in 1923–24, cannot be described as showing modified positive conformity to traffic. The conformity was inverse: trains (or their loaded portion) became shorter in expansion (after 1916), longer in contraction. Two unusual factors may help to explain this exceptional situation. Government officials very commonly demanded transportation priority for war goods, especially in 1917.[9] The railroads may frequently have endeavored to meet these requests by forwarding cars in shorter and therefore more quickly completed trains. From 1917 to 1918, when there was an unusual rise in load per car, the number of car-miles diminished, even though ton-miles increased. Apparently there were fewer cars

[9] Hines, *War History . . .*, p. 13, 50.

to be assembled into trains in 1918 than in 1917. But if cars become scarcer either the number or the length of trains must be reduced; and considerations of expedition must often have led to the choice of the latter alternative, as they do when declining traffic rather than heavier loading reduces the number of cars. These circumstances may account for the fall in 1917 and 1918, and consequently for the smallness of the net rise from 1915 to 1918. The disappearance of demands for priority, and the relaxation of the 'sailing-day' restrictions on number of L.C.L. cars[9] may explain the rise from 1918 to 1919.

Tons in a train

The average quantity of freight in a train is the product of the average load per car and the average number of loaded cars. The ratio of the train-load at the end of a phase to the train-load at the beginning is the product of the corresponding ratios for the two factors.[10] Since both ratios tend to rise in expansions and fall in contractions of ton-miles, the train-load must likewise do so. And indeed monthly figures show that it increased in every expansion and diminished in every contraction after 1919 (Chart 38).

Before 1920 also, the average train-load invariably conformed positively to cycles in revenue ton-miles (Chart 39). In some contractions, to be sure, it did not fall (so far as annual figures disclose); but on each of these occasions it nevertheless rose less rapidly than in the neighboring expansions.

[10] As a measure of train-load we use net ton-miles divided by train-miles. When the measures previously used for the factors are recalled, it becomes obvious that

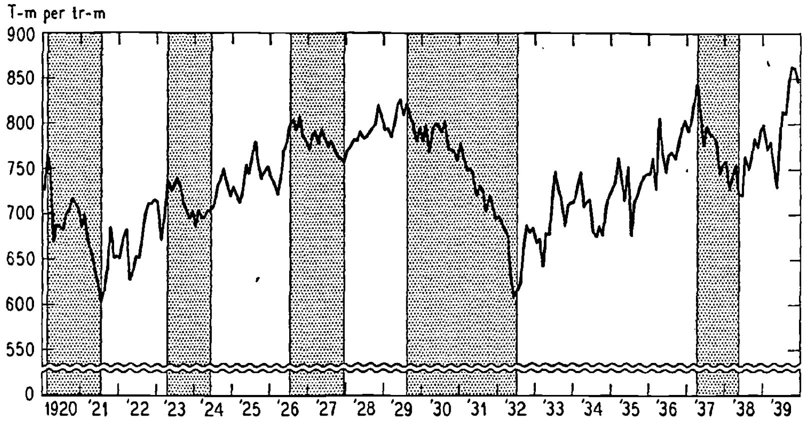
$$\frac{\text{Ton-miles}}{\text{Loaded car-miles}} \times \frac{\text{Loaded car-miles}}{\text{Train-miles}} = \frac{\text{Ton-miles}}{\text{Train-miles}}$$

Applying this general formula to the end (2) and beginning (1) of a phase we get

$$\frac{\dfrac{\text{Ton-miles}_2}{\text{Loaded car-miles}_2}}{\dfrac{\text{Ton-miles}_1}{\text{Loaded car-miles}_1}} \times \frac{\dfrac{\text{Loaded car-miles}_2}{\text{Train-miles}_2}}{\dfrac{\text{Loaded car-miles}_1}{\text{Train-miles}_1}} = \frac{\dfrac{\text{Ton-miles}_2}{\text{Train-miles}_2}}{\dfrac{\text{Ton-miles}_1}{\text{Train-miles}_1}}$$

CHART 38

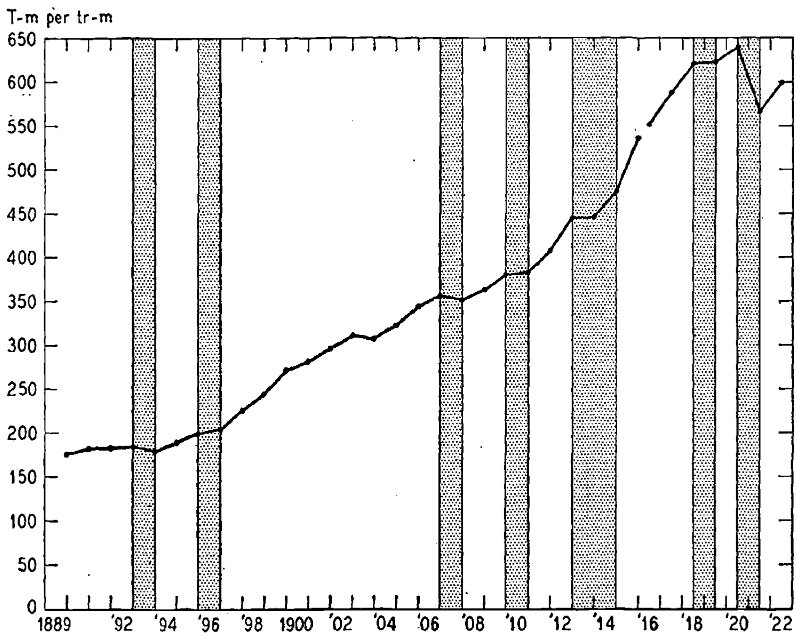
Tons in a Freight Train, January 1920—December 1939 (net ton-miles per train-mile)



Shaded periods are contractions in revenue ton-miles.

CHART 39

Tons in a Freight Train, 1890–1922 (revenue ton-miles per train-mile)



Shaded periods are contractions in revenue ton-miles.

Loads behind locomotives

A freight train is usually pulled by a single locomotive. Occasionally, however, one or more additional engines are used, especially on lines with steep grades. The number of miles run by locomotives in trains[11] therefore somewhat exceeds the number of train-miles. But the ratio of locomotive- to train-miles is extremely steady. Between January 1, 1920 and December 31, 1939 it was never higher than 1.08 in any month or lower than 1.05.[12] We can tell what cyclical variations occur in ton-miles per locomotive-mile without bothering to compute the actual figure month by month. Although it must at all times be somewhat lower than ton-miles per train-mile, it must also increase or decrease whenever the train-load does, and by practically the same percentage. We may conclude without further ado that the amount of freight behind an engine typically becomes larger in expansion and smaller in contraction.

In spite of cyclical variation there was a fairly steady upward trend in the size of train-loads from the early 1890's to 1929. The great cumulative increase was made possible by the installation of ever more powerful locomotives. Until the early years of the twentieth century the increase in power was achieved principally by building larger vehicles.[13] About that time designers turned their attention to the construction of engines with wider fireboxes. Hitherto the width had been restricted by the engine frames or the high driving wheels. The problem was solved by adding, at the rear, a low-wheeled 'trailing' truck, over which a wider box could be placed.[14] Another approach was to increase the rate at which coal might be fed. This was accomplished by automatic stokers, the first of which was applied in 1903. (A stoker supplied coal faster than a fireman could shovel it.) They were in general use by 1925.[15] Superheaters, beginning around

[11] I.e., excluding 'light' mileage—movement with no train attached.

[12] The basic data include the movement of 'light' *trains* (each consisting of a caboose only behind the engine) and their locomotives before 1935.

[13] George H. Houston, President, Baldwin Locomotive Works, *Official Proceedings*, Western Railway Club, March 1930, p. 13.

[14] A. W. Bruce, Designing Engineer, American Locomotive Co., Western Club, Nov. 1927, pp. 15–8.

[15] Association of American Railroads, Mechanical Division, *Locomotive Cyclopedia of American Practice* (Simmons-Boardman, 1944), p. 79; Houston, p. 13.

1910, and feedwater heaters, around 1918, increased the power obtained per ton of coal fired, and thus not only promoted fuel economy but increased the power of locomotives.[16] The use of the locomotive booster—an auxiliary engine at the rear of the locomotive or under the tender—also began around 1918. Boosters are helpful in starting heavy trains or overcoming short steep grades.[17] Apparently they are not commonly needed, for by 1930 only 7.1 percent and by 1938 only 9.1 percent of all locomotives were equipped with them. Around 1928 locomotive builders began to use steel alloys, which permitted higher steam pressures, in constructing boilers.[18]

To carry the more powerful locomotives with heavier and faster trains the railroads needed stronger road bed and tracks. The track structure has been continuously fortified with more thorough drainage, thicker ballast of broken rock and other firm materials, larger ties, better designed and heavier rail, and improved rail fastenings.[19] The average weight of rail in main tracks increased from 82.24 pounds per yard in 1920 to 94.15 pounds in 1938. Other changes increased the ability of locomotives to move traffic in another way. In numerous locations, the track was reconstructed to eliminate steep grades.

Because of the reduced average level of aggregate tonnage, Chart 38 does not show any clear upward trend after 1929. But when comparisons are made between periods of roughly equal traffic, it becomes evident that progress continued. The average load was heavier in 1930 than in 1927, and in 1938 than in 1931, although ton-miles were fewer in the later than in the earlier year of each comparison.

[16] These devices are discussed further in Chapter 8. Concerning their effect on power, see R. M. Ostermann, Vice President, The Superheater Co., Western Club, Nov. 1927, p. 45, Nov. 1936, p. 15.

[17] S. M. Vauclain, President, Baldwin Locomotive Works, *Locomotive Development* (1923), pp. 19–20.

[18] W. C. Dickerman, President, American Locomotive Co., Western Club, April 1938, p. 20.

[19] Robert Faries, Assistant Chief Engineer, Pennsylvania railroad, Western Club, March 1936, p. 22; H. R. Clarke, Engineer Maintenance of Way, Burlington railroad, Western Club, March 1939, pp. 19–20.

SPEED AND HOURLY PERFORMANCE

Speed of trains

Most of the technological changes just described permitted either heavier loads and higher speeds or some combination of the two. Others contributed primarily to the maintenance or increase of speed. Extra main tracks permitted trains to pass each other without stops or delays at sidings. The ratio of second, third, fourth, and other additional main track to miles of road operated rose steadily from 6.24 percent in 1890 to 16.11 percent in 1926, and then (more slowly) to 16.74 percent in 1938. Since 1905 the railroads have in many instances reduced the number of stops for coal and water by attaching larger tenders to the locomotives.[20] Automatic block signals expedited the movement of trains on 22 percent of all main tracks in 1920; the percentage rose steadily to 35 in 1938.[21] The first installation of centralized traffic control, which enables a single operator to observe the position of trains, manage the signals, and throw the switches on a complex of main and passing tracks, and thereby minimizes stops and permits faster movement, was made in 1927; about 1,600 miles had been equipped with this system by the end of 1938.[22] Around 1920 the roads began to use spring switches, previously confined to yards, at main-line junctions. The pressure of the wheels of a train approaching such a switch in the converging direction operates it; after the train has passed, spring and hydraulic pressure restore it to position. Formerly such a train had to stop while the switch was thrown.[23] Changes in maintenance practices also have expedited the movement of trains. New kinds of work equipment, which do not depend on locomotives for power and can move about on the roadside off the rails, free the track for revenue movements. Quicker performance of maintenance of way and bridge repair

[20] W. C. Dickerman, President, American Locomotive Co., *Official Proceedings*, New York Railway Club, April 1933, pp. 10, 297.

[21] Computed from data in *Tabulation of Statistics Pertaining to Block Signals . . .*, ICC Bureau of Safety, various issues, *Report* of the Director of the Bureau for 1933 and 1934, and *Statistics of Railways*.

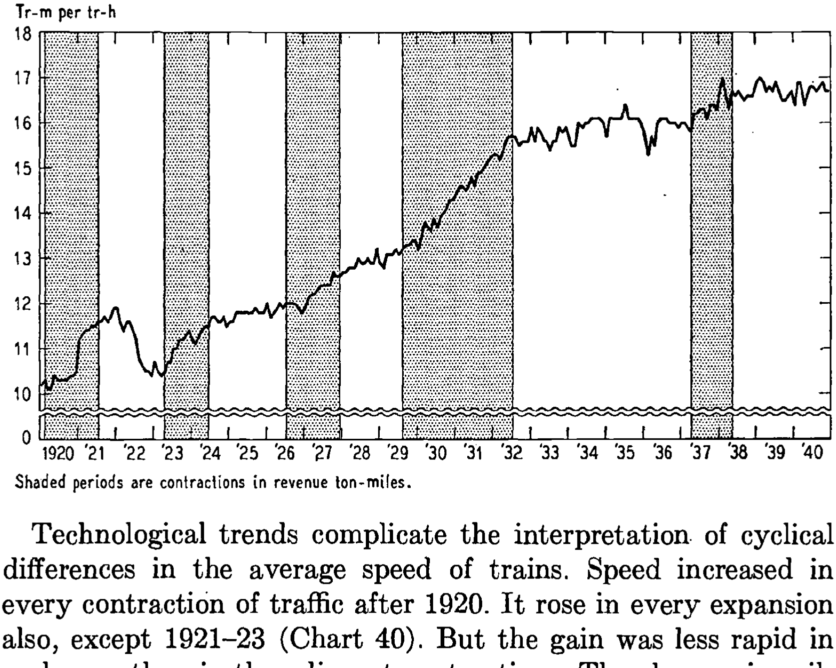
[22] Paul M. Gault, Signal Engineer, Missouri Pacific, Western Club, Feb. 1939, p. 20; Bureau of Safety, see preceding note.

[23] Gault, p. 17; *Railway Engineering and Maintenance Cyclopedia* (Elmer Thomas Howson, ed., Simmons-Boardman, 1945), pp. 1157–63.

work in general has had a similar effect. Chemical treatment of water for locomotives has reduced the number of delays caused by engine failures.[24]

CHART 40

Speed of a Freight Train, January 1920—December 1940 (train-miles per train-hour, freight service)



Shaded periods are contractions in revenue ton-miles.

Technological trends complicate the interpretation of cyclical differences in the average speed of trains. Speed increased in every contraction of traffic after 1920. It rose in every expansion also, except 1921–23 (Chart 40). But the gain was less rapid in each case than in the adjacent contractions. The changes in railway facilities and operating methods tended to make the trains faster both when traffic was declining and when it was increasing. From the smaller acceleration during expansions we infer that, if the technological changes had not occurred, speed would ac-

[24] On interference with traffic, and on water treatment, see the following (more fully cited in Ch. 8, section on maintenance labor): Armstrong, N. Y. Club, April 1929, p. 8875; the June 1941 article in *Railway Engineering and Maintenance*, pp. 403 ff. (repair of bridges); Powers, pp. 14 ff.

Our list of innovations that have favorably affected loads or speed or both is no doubt far from complete.

Almost every such innovation is introduced on some roads or parts of roads and spreads gradually to other parts and other roads. It therefore tends to raise the national average load or speed for a considerable period.

tually have fallen in all such phases, as it did in 1921–23. Anyhow, it conformed inversely to traffic without exception.

To understand the cyclical variations, one must note that the average speed is computed by dividing total train-miles by total train-hours, and that the latter are figured in the case of each train by counting all the time from the moment it leaves a terminal to the moment it arrives at the next terminal. Minutes in which it stands still at various points between terminals are therefore included as well as minutes in which it is literally in motion along the line.

Some trains run all the way through from terminal to terminal without pausing in between to drop or pick up traffic. But even they must halt in response to stop signals and slow down for cautionary ones. As traffic becomes denser and more trains occupy the line, an engineer is more often confronted with red or yellow lights. Trains spend more of their time waiting or crawling along behind other trains. And even if the right of way is clear, they probably travel more slowly when traffic is dense; for they are more heavily loaded, and presumably their greater burden often slows them down.

Other trains, 'local' and 'way' freights, make stops en route to receive or deliver traffic. Cars are switched into or out of such a train. L.C.L. freight is removed from or loaded into its merchandise car or cars. These trains, like through freights, no doubt encounter more adverse signals and are more heavily burdened when traffic is dense. But in addition they must spend more time in their wayside duties. Presumably the number of cars to be picked up or dropped on each run increases. More goods must be stowed into or carried out of the merchandise cars.

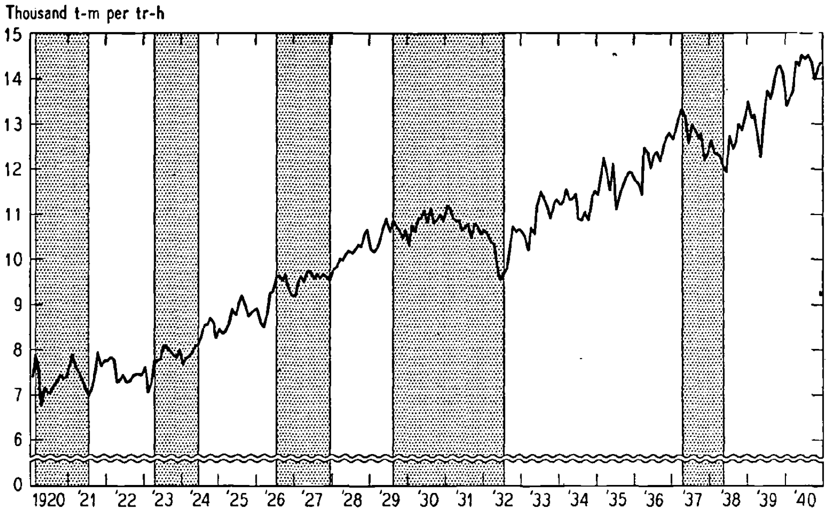
When aggregate traffic, and with it the number of trains, declines, a train encounters adverse signals less frequently. Its burden is lighter and it can travel faster when the road is clear. Way trains have fewer cars to pick up and drop, and it takes less time to load and unload a diminished volume of L.C.L. shipments.

Hourly train performance

The ton-miles of freight movement performed during an hour's movement of a train depend partly on its speed and partly on

CHART 41

Net Ton-miles per Train-hour, January 1920—December 1940



Shaded periods are contractions in revenue ton-miles

its load. If the story had not been complicated by changes in operating lay-outs and methods which tended to quicken the service at all times, the cyclical fluctuations in speed would have opposed those in train-load in their effect on hourly performance. Which would have proved more powerful? Apparently, in most cases, the train-load. For let us suppose that the change in speed had been more powerful. Then, in the absence of the more enduring influences, hourly performance would have fallen in expansion, risen in contraction. The addition of the influences making for greater speed at all times would have opposed the cyclical effect on the upswing, reenforced it on the downswing of traffic. We might have found a rapid rise in ton-miles per train-hour during contraction, a less rapid rise or even a fall during expansion—in other words, inverse conformity. But actually, with one exception, the conformity was positive (Chart 41). And this is what we should expect if, in the absence of the more permanent influences, train-load would have been more important than speed. For then hourly performance would have increased in expansion, fallen in contraction. The addition of those influences would have strengthened the former, weakened the latter tendency. We would be likely to find a rapid rise in expansion, perhaps a rise, but if so a less rapid one, in contraction. And that is about what happened. When hourly performance did not actually fall in contraction, its net rise per month was slower than in the adjoining expansions, except that in 1923–24 it was more rapid than in 1921–23. (From cycle to cycle, on the other hand, there was persistent improvement; hourly performance doubled in twenty years.)

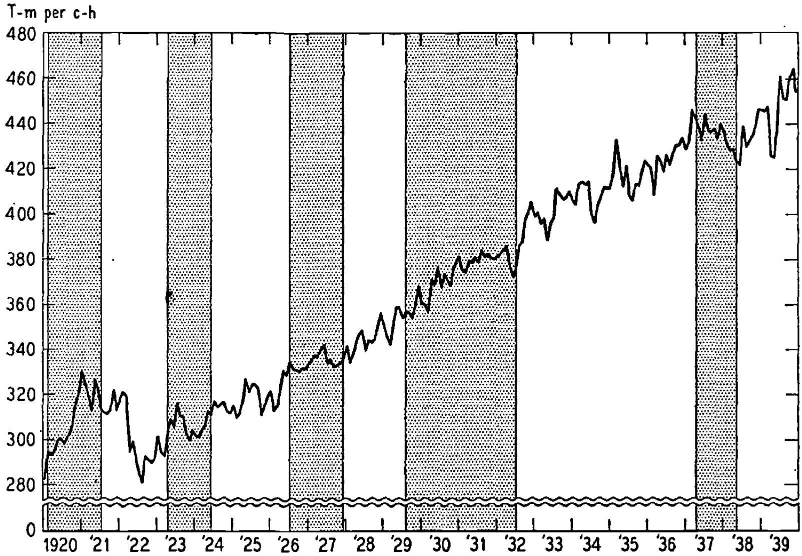
Hourly performance of equipment

No separate record of the hours locomotives work in pulling and pushing trains is compiled. The average speed of locomotives therefore cannot be computed. But it cannot differ greatly from that of trains. Because of the occasional use of helper engines, it is true, locomotive-miles are not identical with train-miles. Since helpers are used largely on steep grades where train movement is slow at best, their average rate of travel may be less than that of all other locomotives. But helper mileage is a small and pretty constant percentage of train-miles. The cyclical variations in average locomotive speed and average train speed must be very similar in direction and amplitude. We have already decided, for the same reason, that ton-miles per locomotive-mile must closely resemble ton-miles per train-mile. Since hourly performance is the product of load and speed, we conclude that it must, with one exception, have conformed positively to cycles in traffic in the case of engines as well as of trains. Furthermore, this conformity was probably of the modified type—differences in rates, not direction of change—in the pairs of phases 1923–24 and 1924–26, 1926–27 and 1927–29.

As with locomotives, so with freight cars: there is no direct measure of their average rate of travel when they are in trains. No doubt it differs a little from the average train or engine speed. Longer and heavier trains, for example, may run more slowly than shorter and lighter trains. If so, a greater proportion of total car-miles than of total train-miles is accounted for by slow movements, and the average speed of cars would be somewhat lower than that of trains. But the difference cannot be large, and cyclical variations in the average speed of freight cars must be about as great as those in train speed. We have therefore estimated the average hourly performance of freight cars while in trains by multiplying ton-miles per car-mile by train-miles per train-hour.

CHART 42

Net Ton-miles per Car-hour, January 1920—December 1939



Shaded periods are contractions in revenue ton-miles.

Table 27

Net Ton-miles per Car-hour
Change per Month between Peaks and Troughs in Revenue Ton-miles, 1920–1938

Turn in ton-miles		Months from prec. date	Net ton-miles per car-hour	Change from preceding date		
				Total	Per month	
Date	Level				To peak from trough	To trough from peak
Feb. 1920	Peak	...	290.0	...	...	...
July 1921	Trough	17	315.7	25.7	...	+1.51
Apr. 1923	Peak	21	301.6	−14.1	−0.67	...
June 1924	Trough	14	313.5	11.9	...	+0.85
July 1926	Peak	25	331.5	18.0	+0.72	...
Dec. 1927	Trough	17	336.9	5.4	...	+0.32
Aug. 1929	Peak	20	355.5	18.6	+0.93	...
July 1932	Trough	35	378.4	22.9	...	+0.65
Apr. 1937	Peak	57	442.7	64.3	+1.13	...
May 1938	Trough	13	424.8	−17.9	...	−1.38

It cannot be said that the hourly performance of cars, any more than that of trains, rose and fell with traffic (Chart 42). It did improve in all expansions except one; but it rose in all contractions, also, except one. Indeed it did not even conform as well as train performance; conformity was inverse in 3 of 8 comparisons (Table 27). The first 3 were inverse, the last 5 positive; perhaps there is a new regular tendency. In the last cycle the positive conformity was of the simplest type: hourly car performance rose in 1932–37, fell in 1937–38. Judging by the more recent experience one would expect variation in the average carload to be more important than variation in speed in the future, although the 1920–26 results cast doubt on that expectation.

MORE USEFUL HOURS WHEN TRAFFIC WAS HEAVY

How a freight car spends its time

Before we consider the effect of cycles in traffic on the number of hours a car is busy moving freight over the lines, it may be illuminating to note what happens during other hours. We are able to do this, illustratively, in unusual quantitative detail for one month, December 1933. Multiplying the average number of freight cars during that month by 744, the number of hours in the month, we can compute the total car-hours. The number of serviceable and unserviceable hours can be determined similarly. On the assumption that the average speed of cars equals the average speed of trains, we can estimate from the car-miles the number of loaded and of empty car-hours in trains. It turns out that freight cars spent only about 3 percent of their total hours in trains with loads inside them, about 2 percent in trains but empty, and about 15 percent in unserviceable condition (Table 30, last column, lines 7, 8, and 11).

It may seem a little absurd to inquire what a freight car does when it is not fit to do anything. We shall therefore confine the remaining discussion to percentages of total serviceable hours, excluding hours when cars are not in usable condition. Recomputing the two percentages for other time on this basis, we find that freight cars were loaded and in trains during 3.74 percent of their total serviceable hours, and empty but in trains during 2.44 percent.

We could develop corresponding figures for any period since 1919. What enables us to go further in this particular month is a special study by the Federal Coordinator of Transportation. He asked the railroads to trace the history of each car from which carload freight was unloaded on December 13 back to the moment at which it was placed for the receipt of that load. From his figures we can understand more completely what happened during the serviceable hours cars did not spend in trains.

Table 28

Car-days Spent by Freight Cars at Origin and Destination in Handling 49,104 Carloads terminated December 13, 1933

	Time included	Car-days		Days per carload
		Number	% of total	
	In care of shipper or consignee			
1	From placement for loading to release by shipper	69,655.64	49.82	1.42
2	From placement for unloading to release by consignee	70,156.09	50.18	1.43
3	Total	139,811.73	100.00	2.85
	In care of railroad company			
4	From release by shipper to departure in road train	23,378.96	43.24	0.48
5	From arrival at destination in road train to placement for unloading	30,690.85	56.76	0.63
6	Total	54,069.81	100.00	1.11

Federal Coordinator of Transportation, *Freight Traffic Report, Appendix I*, p. 94 ('Exhibit 220'). Percentages by NBER.

Before a car can move traffic, it must be placed for loading at a platform or on a siding. On the average, in the case of the cars in the Coordinator investigation, 34 hours elapsed between the minute a car was so placed and the minute when the shipper notified the railroad company it was full and ready to go (Table 29). Such loading intervals accounted for 5.54 percent of all serviceable hours (Table 30). After the shipper has released the loaded car to the company, the latter must switch it into a train for movement over the road. On the average, a car departed in a train about 11 hours after its release. Time between release and departure amounted to 1.85 percent of all serviceable hours. Many cars are transferred from one train to another train of the same railroad on their way to their final destinations. Between arrival in one train and departure in another the average car passed 18 hours in intermediate terminals. (Some cars included

Table 29

Car-days Spent by Freight Cars in Handling 49,104 Carloads terminated December 13, 1933

Kind of place at which days were spent	Time included	Car-days spent by all cars (1)	% of total car-days (1) ÷ line 8, col. (1) (2)	% of days in trains (1) ÷ line 7, col. (1) (3)	Hours per car (1) × 24 ÷ 49, 104 (4)
1 Origin terminal	From placement for loading to release by shipper[a]	69,673.63	23.54	148.14	34.05
2 Origin terminal	From release by shipper to departure in road train[b]	23,418.54	7.91	49.78	11.45
3 Intermediate terminals	From arrival in road train to departure in another road train of same company[c]	36,960.94	12.49	78.60	18.06
4 Interchange points	From arrival in road train to departure in road train of another company[c]	17,946.88	6.06	38.14	8.77
5 Destination terminal	From arrival in road train to placement for unloading[b]	30,740.89	10.39	65.39	15.02
6 Destination terminal	From placement for unloading to release by consignee[a]	70,177.10	23.72	149.28	34.30
7 On road	In road trains[c]	47,031.12	15.89	100.00	22.99
8 All places	From placement for loading to release by consignee	295,949.10	100.00	629.33	144.65

Same source as for Table 28, but from page 148 ('Exhibit 222'), except as noted. It is not clear that Exhibit 222 refers to exactly the same carloads as Exhibit 220. The number is not indicated in Exhibit 222 but must be about the same as in 220.

[a] Exhibit 220 reports 139,811.73 car-days for detention by shipper and consignee, slightly less than the 139,850.73 reported by Exhibit 222. We divided the Exhibit 222 figure in the proportions indicated by Exhibit 220. See Table 28.

[b] Exhibit 222 reports 54,159.43 hours of origin and destination carrier terminal time; Exhibit 220 reports 54,069.81. See preceding note.

[c] If a shipment was handled more than once at intermediate terminals, in interchange, or in road trains, the time elapsed in all such handlings was included.

in the average were no doubt handled through to destination in one train and hence spent no hours in this way; others were transferred more than once and spent considerably more than 18 hours.) In addition, some cars are transferred from a train of one railroad company to a train of another. Between arrival at interchange points in one train and departure in another an average car spent almost 9 hours. (Again, the figure would be zero for some and a multiple of 9 for others.) After a car arrived at its final terminal, 15 hours passed before its placement for unloading, and 34 elapsed between the time of placement and the time when the receiver notified the delivering railroad that the car was empty and could be taken away. In all, counting the time in trains, it took 145 hours, or a trifle more than 6 days, to get a car from placement for loading to release after unloading. Less than one of these days was spent in trains.

Table 30

Disposition of Car-hours, All Freight Cars, December 1933 (estimated)

	Disposition[a]	Car-hours		
		Number (thousands)	% of all serviceable	% of all
1	Loading	77,852[b]	5.54	4.72
2	Origin terminal	26,161[b]	1.86	1.59
3	Intermediate terminals	41,307[b]	2.94	2.51
4	Interchange	20,044[b]	1.43	1.22
5	Destination terminal	34,364[b]	2.44	2.09
6	Unloading	78,451[b]	5.58	4.76
7	In trains, loaded	52,553[c]	3.74	3.19
8	In trains, empty	34,238[d]	2.44	2.08
9	Other serviceable time, empty	1,040,713[e]	74.04	63.15
10	Total serviceable	1,405,683[f]	100.00	85.30
11	Unserviceable	242,246[g]	...	14.70
12	Total	1,647,929[h]	...	100.00

[a] For fuller description of disposition, lines 1–7, see corresponding lines of Table 29.

[b] Col. (3), Table 29, × line 7, this column.

[c] Loaded car-miles, 835,595,000, divided by train-miles per hour, 15.9. Dividend and divisor, like empty car-miles, number of cars on line and percentage unserviceable (below), from *Freight Service Operating Statistics*, Dec. 1934 (back figures for Dec. 1933 used).

[d] Empty car-miles, 544,387,000, divided by 15.9.

[e] Line 10 minus sum of lines 1 through 8.

[f] Line 12 minus line 11.

[g] Total cars on line, 2,214,958, × % unserviceable, 14.7, ÷ 100, × number of hours in December, 744.

[h] 2,214,958 × 744.

The six supplementary operations described account for 19.79 percent, or, with the loaded time in trains, for 23.53 percent of all serviceable hours. Inclusion of empty time in trains brings the ratio to 25.97 percent, leaving 74.03 percent of all serviceable hours unaccounted for. Switching of empty cars to loading points, away from unloading points, and from train to train, may have taken another 5 to 10 percent. Revenue switching movements from a shipper to a receiver in the same terminal area, without road train service, no doubt accounted for a small percentage. But cars must have stood idle and empty during more than half of their serviceable hours.[25]

Loaded car-hours in trains

Although the seven operations described in Table 29 are all directly connected with the movement of freight, we have consecutive monthly figures for the amount of car-time spent in the last one—loaded road movement—only (even these we had to estimate). From them we computed the ratio of loaded hours in trains to total serviceable hours (the estimate and computation are illustrated in Table 31). The results (Chart 43) are surprising on first acquaintance. From 1920 to 1938 loaded hours in trains were never more than 8.5 percent of serviceable hours. What is more important for our purpose, however, the ratio conformed clearly and positively to cycles in traffic. It rose in every expansion of ton-miles, fell in every contraction.

Since every car carrying freight must be loaded and unloaded and all except those picked up and delivered en route by the same way freight train must pass through terminals (initial, final, intermediate, or interchange), the aggregate time consumed in the other six processes must vary with the number of loaded hours

[25] Our whole calculation, Table 30, has several unavoidable but not fatal defects. Ignoring L.C.L. shipments, we assumed that the loaded car movement was in connection with carload shipments. The time of L.C.L. cars could be distributed, were data available, in the same way as in the table, although operations 1 and 6 would be performed by the railroads instead of by the shippers. The distribution of the time among lines 1 to 6 and between them and line 9 would be affected, although lines 7, 8, and 10-12 would not be changed. The figures on lines 1 and 6 would probably become greater, those on lines 3 and 4 smaller, and the unaccountable time (line 9) somewhat smaller.

Our figures include only the time privately owned cars spend on railroad lines. Omission of the idle and repair time they spend in the hands of owners tends to reduce the percentages on lines 9 and 11 somewhat.

Table 31

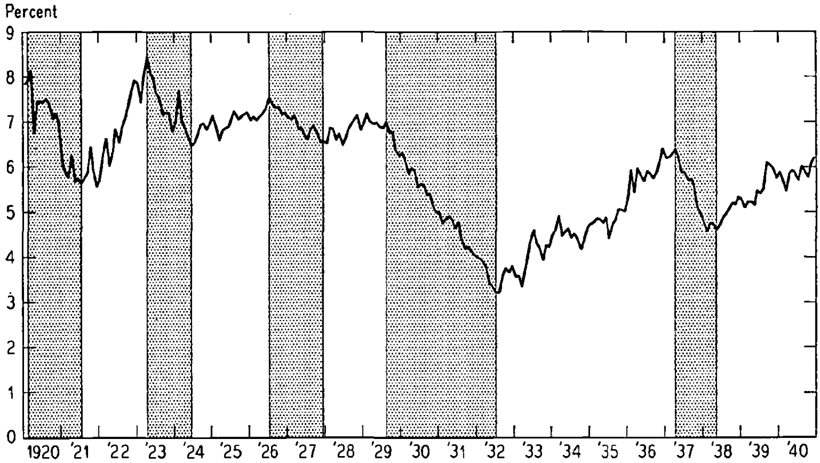
Time in Trains: Illustrative Computations, March 1929

(1)	Loaded car-miles (in road trains)	1,544,000,000
(2)	Av. miles per hour, trains in freight service	13.1
(3)	Loaded car-hours, in trains, (1) ÷ (2)	117,900,000
(4)	Av. number of serviceable freight cars on line	2,308,000
(5)	Loaded car-hours per serviceable car, (3) ÷ (4)	51.1
(6)	Serviceable hours per serviceable car, 24 × 365 ÷ 12	730†
(7)	% loaded car-hours in trains of serviceable car-hours, (5) ÷ (6) × 100	7.0
(8)	Road freight locomotive-miles (principal and helper)	54,900,000
(9)	Locomotive-hours in trains, (8) ÷ (2)	4,190,000
(10)	Av. number of serviceable locomotives assigned to road freight service	24,681
(11)	Locomotive-hours per serviceable locomotive, (9) ÷ (10)	169.8
(12)	% ratio of hours in trains to serviceable locomotive-hours, (11) ÷ (6) × 100	23.3

† In effect a seasonally adjusted figure, and, although the same for all months, comparable with the other seasonally adjusted data.

Chart 43

Loaded Freight Car-hours in Trains: Percentage of Total Serviceable Hours, January 1920—December 1940



Shaded periods are contractions in revenue ton-miles.

in trains, although doubtless not in strict proportion. Empty miles in trains increase and decline with loaded miles, although definitely not in proportion, as we shall demonstrate later. The ratio of time consumed in all such operations to total usable time must therefore vary with cycles in traffic, as the ratio of loaded hours in trains to serviceable hours does. Consequently, the ratio of idle to total time must fall in expansion and rise in contraction.

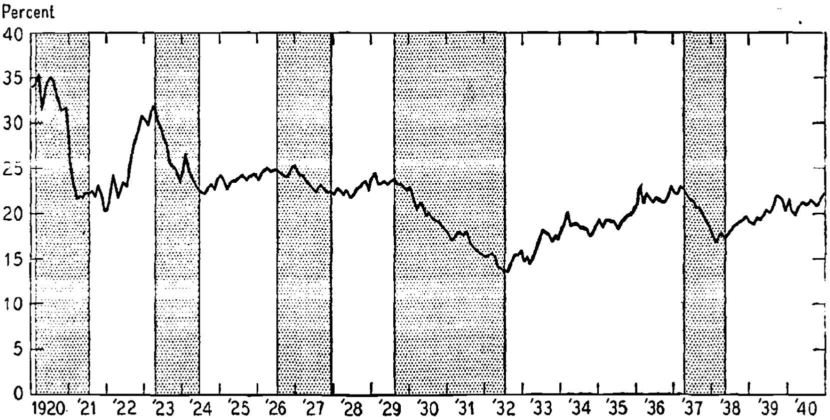
As one might expect, freight cars are actually in use during more of their usable hours in prosperity than in depression.

Locomotive-hours

An engine spends a much larger percentage of its time in trains than a car does (the calculation of the locomotive ratio too is illustrated in Table 31). But the ratio of engine hours in trains to total serviceable hours, like the ratio for cars, conforms to cycles in traffic (Chart 44). Every expansion and contraction in ton-miles was accompanied by a corresponding rise or fall in the percentage. Preparation for road movement requires some additional time. The crew looks over the engine, takes it from the roundhouse to the train, couples it on, tests the airbrakes. Other routines are necessary after the end of the road run. Locomotives make some road runs without even a caboose attached; but these 'light' locomotive-miles are only about 5 percent of miles with cars. Even if we could allow for time at initial and final terminals, as well as light miles, we would still find that usable motive power is standing idle, awaiting a call to duty, during most of the hours not occupied by train operation. The ratio of idle to total time must vary inversely with traffic. Employable locomotives are unemployed to a much greater extent during depression than during prosperity.

CHART 44

Freight Locomotive Hours in Trains: Percentage of Total Serviceable Hours, January 1920—December 1940



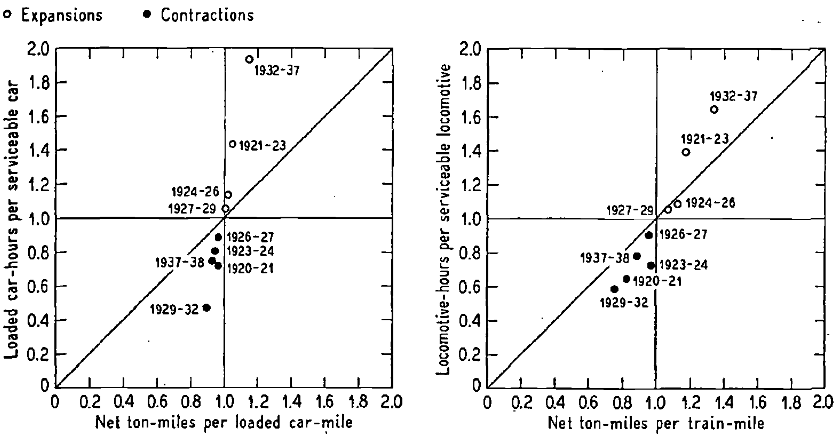
Shaded periods are contractions in revenue ton-miles.

Hours more important than loads

Cyclical fluctuations in the time equipment was in use usually exceeded those in average loads. The percentage rise in loaded hours per car per month was greater in every expansion, the percentage fall greater in every contraction, than the corresponding changes in the average carload (Chart 45; if the variations in the two had been equal, the dots would lie on the diagonal line). The number of hours engines were used in trains also fluctuated more, as a rule, than the size of train-loads, although in two expansions the latter increased by a larger percentage. In other phases, the difference between loads and hours was not as striking as in the case of cars.

CHART 45

Loads and Hours in Trains: Ratio of Average at End of Phase to Average at Beginning, 1920–1938

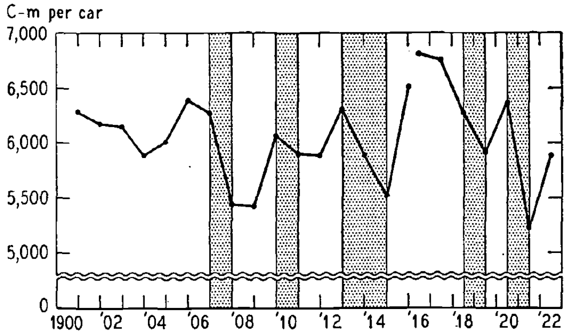


Useful hours before 1920

We have no data from which we could estimate hours in use in earlier cycles, and therefore cannot tell from direct evidence whether useful time per vehicle fluctuated cyclically in the same way as after 1920. However, we do have figures from which we can compute the average number of miles a car or locomotive traveled during a year. Since miles traveled are the product of

CHART 46

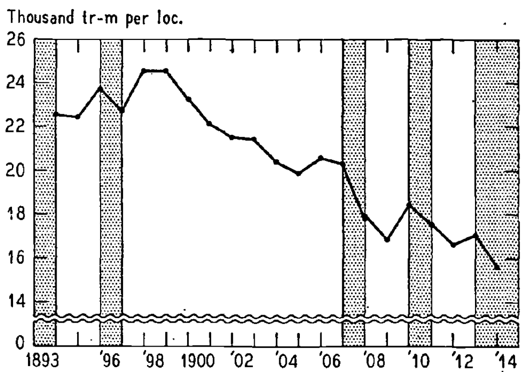
Loaded Car-miles per Freight-train Car, 1901–1922



Shaded periods are contractions in revenue ton-miles.

CHART 47

Train-miles per Freight Locomotive per year, 1894–1914



Shaded periods are contractions in revenue ton-miles.

hours in use and average speed, we can learn something concerning the combined effect of changes in the two factors. From 1907 to 1920 a typical freight car covered more distance in each peak than in the preceding or following trough year (Chart 46). Although the direction of change was not consistent from one year to the next in three of the expansions for which data are complete, there was a net rise in each. From 1893 to 1913 annual travel per locomotive diminished in every contraction. It diminished in two expansions also, but the decline per year was not as rapid as in the bordering contractions (Chart 47).[26] We hazard the guess that hours in use per vehicle conformed positively to cycles in traffic before as well as after 1920.

INTENSITY OF USE VARIED WITH TRAFFIC

Having examined fluctuations in each of the three components —load, speed, and time in use—we consider the combined effect of these fluctuations on the average freight service performed by a car or locomotive. For either kind of equipment, ton-miles per vehicle are the product of three ratios representing the components:

$$\frac{\text{Net ton-miles}}{\text{Loaded car-miles}} \times \frac{\text{Loaded car-miles}}{\text{Loaded car-hours (in trains)}} \times \frac{\text{Loaded car-hours (in trains)}}{\text{Serviceable cars}} = \frac{\text{Net ton-miles}}{\text{Serviceable cars}}$$

$$\frac{\text{Net ton-miles}}{\text{Locomotive-miles (in trains)}} \times \frac{\text{Locomotive-miles (in trains)}}{\text{Locomotive hours (in trains)}} \times \frac{\text{Locomotive hours (in trains)}}{\text{Serviceable locomotives}} = \frac{\text{Net ton-miles}}{\text{Serviceable locomotives}}$$

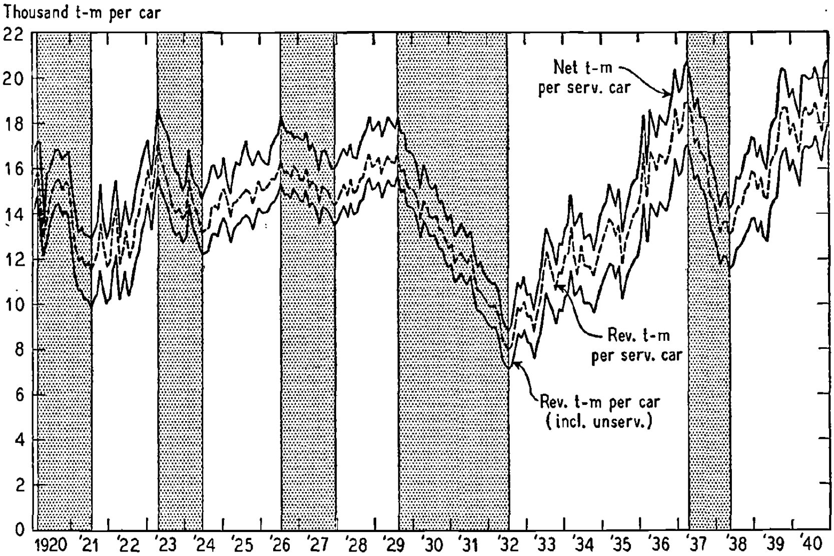
In the case of cars all three ratios on the left, and in that of locomotives, their close equivalents, were discussed in preceding sections. The first and third, in the period for which we have monthly data, invariably rose and fell with traffic. The second, on the contrary, tended to decline in expansion, although technical progress kept it from actually doing so except in 1921–23; and it always rose in contraction. Even in 1921–23, however, the influence of changes in load and useful time was more powerful than that of speed, as it was in all contractions. For ton-miles per serviceable car increased in every expansion, diminished in every contraction (Chart 48). And so did ton-miles per serviceable locomotive (Chart 49).

These conclusions pertain to 'net' ton-miles, that is, to work done by equipment in moving the companies' own materials and

[26] The data pertain to train-miles per locomotive; but locomotive-miles per locomotive (not available), although slightly higher, would vary in practically the same way. The downward trend may reflect imperfect statistical segregation of freight from passenger locomotives, a defect that led the ICC to abandon collection of the figures after 1914. The classification after 1920 is based on the service to which the vehicle was assigned, not on its design.

CHART 48

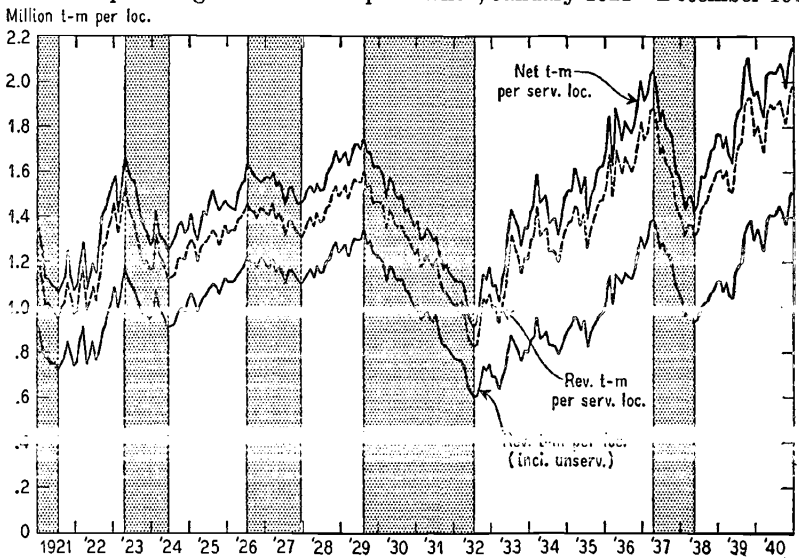
Ton-miles per Freight Car per Month, January 1920—December 1940



Shaded periods are contractions in revenue ton-miles.

CHART 49

Ton-miles per Freight Locomotive per Month, January 1921—December 1940

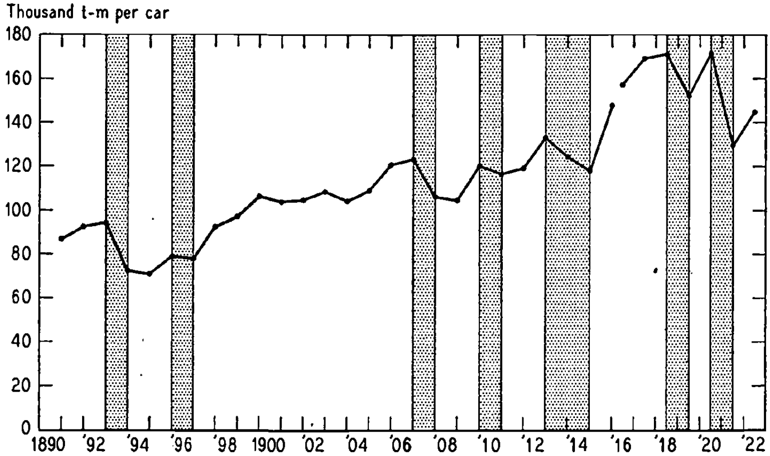


Shaded periods are contractions in revenue ton-miles.

supplies as well as hauling traffic for shippers. Although the transportation of company freight is a necessary incident in rendering service to the public, it does not of itself bring in revenue. But the same conclusion emerges when the paying traffic alone is divided by the number of serviceable vehicles: revenue ton-miles per car and per locomotive increased in every expansion, diminished in every contraction.

CHART 50

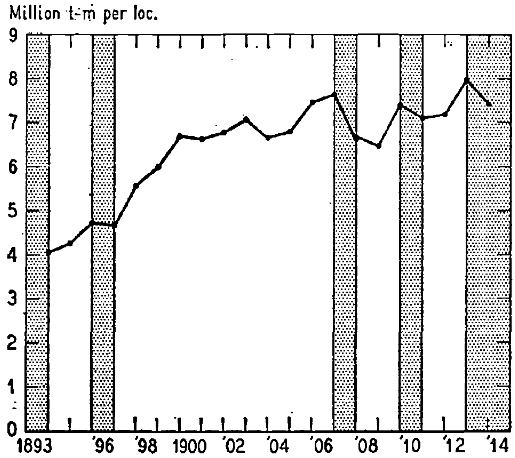
Revenue Ton-miles per Freight Car per Year, 1891–1922



Shaded periods are contractions in revenue ton-miles.

CHART 51

Revenue Ton-miles per Freight Locomotive per Year, 1894–1914



Shaded periods are contractions in revenue ton-miles.

So far we have discussed the relation between traffic and serviceable equipment only. The restriction appears sensible, for only serviceable vehicles are allowed to perform. But unusable cars and locomotives represent an investment, just as equipment in good order does. If one is interested in the utilization of investment, ton-miles per vehicle, including unserviceable units in the divisor, are of interest. This ratio too rose and fell with traffic.

Before 1920 the statistics permit a comparision of traffic only with total stock, including unserviceable equipment. Revenue ton-miles per freight car increased and decreased with traffic from 1893 to 1920 (Chart 50), just as afterward. Performance per freight locomotive improved in all expansions, deteriorated in all contractions, from 1893 to 1913 (Chart 51).

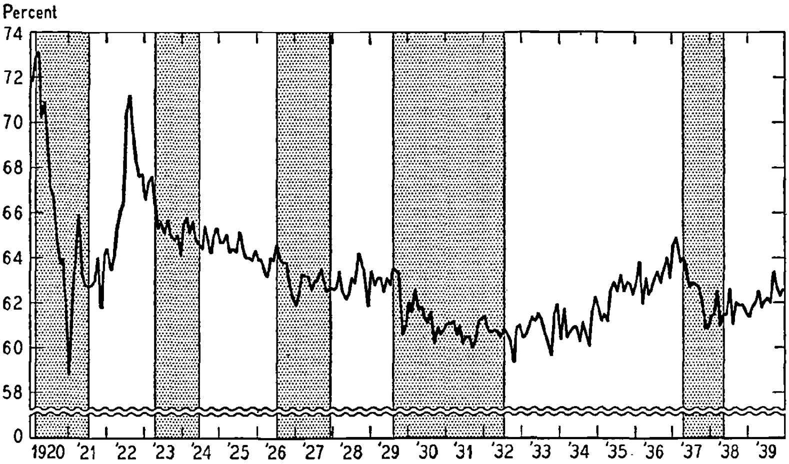
MORE EMPTY MOVEMENT, RELATIVELY, IN DEPRESSION

The number of cars arriving with loads to be removed in any terminal area seldom coincides with the number required for new shipments out of that area. Not all the incoming cars are of the types suitable for the outbound traffic. The railroad companies are compelled to move empty cars from points at which there is a surplus to points at which the vehicles unloaded may be inadequate to supply the needs of the traffic likely to be offered.

A cyclical increase in railroad traffic, and therefore in loaded car-miles, has usually been accompanied, in recent cycles, more or less closely by a growing movement of empty cars, and a decline in traffic and loaded mileage by diminishing empty mileage. But the changes in empty miles have been less than proportionate to those in loaded miles. Since 1920 the ratio of loaded to total movement has shown a net rise or net fall corresponding to the expansion and contraction of traffic, except in 1924–26, when it declined (Chart 52). Even then, the fall was less rapid than in the adjacent contractions. Annual data indicate that the ratio behaved similarly in the six phases from 1907 to 1918 (Chart 53). It declined in the last year of the 1915–18 expansion, to be sure, but there was a net increase for the phase as a whole. However, 1918–19 and 1919–20 were exceptional. The percentage rose in the contraction, fell in the expansion. The increase in 1918–19, furthermore, was more rapid than the (net) rise in 1915–18, although the fall in 1919–20 was less rapid than in the following phase.

CHART 52

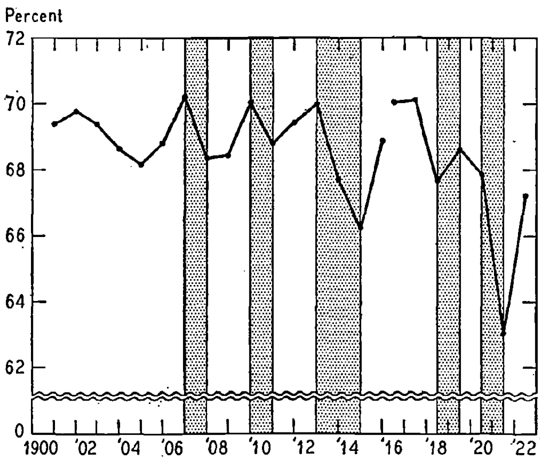
Percentage Ratio of Loaded to Total Freight Car-miles, January 1920—December 1939



Shaded periods are contractions in revenue ton-miles.

CHART 53

Percentage Ratio of Loaded to Total Freight Car-miles, 1901–1922



Shaded periods are contractions in revenue ton-miles.

A large part of the typical cyclical variation in the loaded percentage can be explained by changes in the composition of traffic. As shown in Chapter 1, the ratio of perishable foodstuffs and petroleum oils to aggregate traffic of all kinds conforms inversely to cycles in the latter. These commodities tend to become relatively less important in expansion, more important in contraction. They are shipped in refrigerator and tank cars most of which are privately owned and, according to scattered evidence, contain loads during a percentage of their movement smaller than a corresponding percentage for all cars. For privately owned refrigerators of all kinds (including packers' cars and those of railroad-controlled car companies) the ratio of loaded to total mileage was 57.8 percent in 1934.[27] Cars of the Magnolia Petroleum Company had a ratio of 54.3 in 1927. For those of the Sinclair Refining Company in 1928 it was 52.6. Loaded movement of tank cars on 35 railroads in December 1926 was 50.1 percent of their total movement.[28] The corresponding countrywide ratio for all kinds of cars was 60.9 in 1934, 62.9 in 1927, 62.8 in 1928, and 60.7 in December 1926. Since the ratio of the traffic in tank and refrigerator cars to all traffic conforms inversely to cycles in the latter, the ratio of miles traveled by these cars to those traveled by all cars must also conform inversely. Because they travel empty to an unusual degree, the ratio of empty to loaded movement conforms inversely, and the ratio of loaded to total movement therefore positively. It tends to rise when perishable and petroleum commodities become relatively less important, and to decline when they become more important.

Empty movement contributes to revenue only by making loaded movement possible; the companies are paid for the latter alone. The amount of unremunerative hauling they must do for each mile of paying movement becomes smaller in expansion and larger in contraction. The varying necessity for empty haulage, however, is considered, together with many other factors, in making the rates on the various commodities; the railroads may be compensated indirectly for the relative growth of such haulage in contraction.

[27] U. S. Senate, 75th Cong., 2d Sess., Committee on Interstate Commerce, *Investigation of Railroads, Holding Companies and Affiliated Companies. Hearings before a Subcommittee . . .*, data compiled by Association of American Railroads and printed opposite p. 10351.

[28] Computed from data in *Rates on Refined Petroleum Products from, to, and within the Southwest*, 171 ICC 381, pp. 395, 396.

A peculiarity of the curve for the loaded ratio invites comment. It climbs abruptly, then recedes in the latter half of 1922. The disturbance was not in the loaded, but in the empty miles: they declined, probably because of the shopmen's strike, which, as Chapter 6 will show, temporarily curtailed the supply of serviceable locomotives. Confronted with a shortage of motive power, railway operating officials apparently made unusual and successful efforts to reduce the empty movement of cars.