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CHAPTER 8

Fuel Economy

Not only labor but many commodities are needed in the performance of railway service. Fuel, lubricants, building materials, and numerous other articles are used up in the production of transportation. The ratio between the amount of movement performed and the quantity of any commodity consumed in the process may vary with cycles in traffic. We may think of each ingredient as having its specific, partial productivity. If we had figures we could divide the monthly movement of goods and persons by the monthly amount of any designated material used by the railroads. Because of lack of information, however, we can do this for only one commodity, or rather one group of commodities: fuel.[1] Separate data are available for consumption by locomotives in freight service and in passenger service. We can therefore relate the amount used in each to ton-miles and passenger-miles respectively, and are not driven to the perhaps somewhat artificial but elsewhere unavoidable procedure of employing composite traffic figures in our computations. Between 6 and 10 percent of all operating expenses are incurred to provide fuel for these two services (Table 88).

ECONOMY INCREASED AND DIMINISHED WITH TRAFFIC

Since 1920 at least, freight locomotives have burned an increasing quantity of fuel during each expansion of ton-miles, a diminishing amount during each contraction. Aggregate consumption by passenger locomotives has likewise invariably risen and fallen with travel; even the small and brief expansions of 1925 and 1928–29 were matched by rises in total fuel used.[2] But the fluctuations in

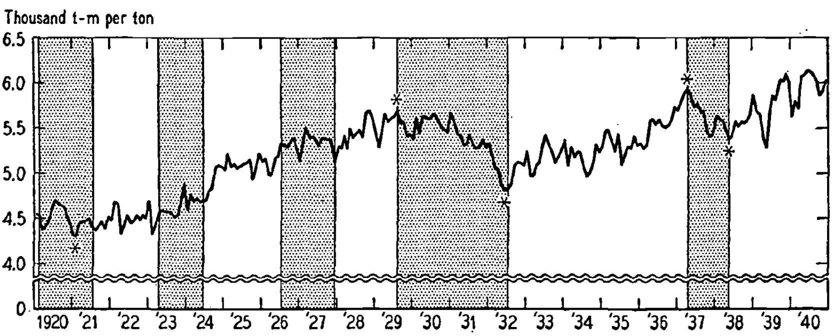
[1] Although coal burned in locomotives is still the principal source of power, other fuels and electricity are used in appreciable quantities. In the figures for consumption we use, they are included at their equivalent in tons of coal as variously estimated by the railroads in reporting to the ICC. The B.T.U. content and other characteristics of the coal used vary from one railroad line to another and the average quality on all lines may change from time to time. But it seems unlikely that such changes account for the cyclical variation we find in the ratio of traffic to fuel.

[2] Turning points for aggregate fuel in the respective services often differed somewhat from those in ton- and passenger-miles.

consumption were not proportionate to those in traffic. The ratio of revenue ton-miles to tons of fuel increased in every expansion, showed a net fall in every contraction except one (Chart 93). In that instance, 1923–24, the improvement in productivity was less rapid than in the following, although more rapid than in the preceding expansion. The net decline in 1920–21 and 1926–27 was slight, to be sure, and the movement within these phases irregular. Nevertheless, the ratio conformed positively, in 7 of 8 comparisons of adjoining phases, to the cycles in ton-miles. In the other service, the relation was even more regular. The number of passenger-miles to the performance of which the burning of a ton contributed rose in every expansion, fell in every contraction (Chart 94). In both services the economy of consumption was positively related to the volume of traffic.

CHART 93

Revenue Ton-miles per Ton of Coal or Equivalent Consumed in Freight Service, January 1920—December 1940



Shaded periods are contractions in revenue ton-miles.

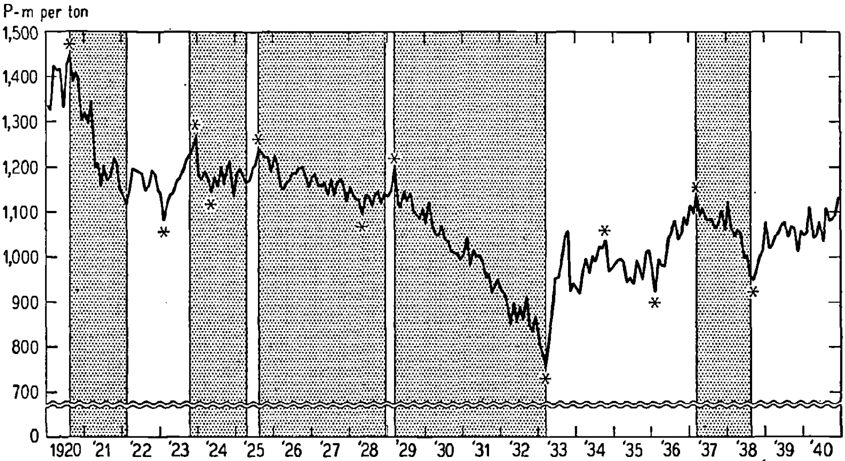
For the railroad companies, this means that, unless prices of fuel rise too much in expansion or fall too much in contraction, growth of business is accompanied by a decline in expense for energy per unit of traffic, shrinkage of business by increasing unit expense. For the coal, oil, and electric utility industries, it means that the railroad market does not expand in proportion to the increase or decline in proportion to the decline in traffic.[3] The

[3] Around 1937 or 1938 the railroads used about 20 percent of all bituminous coal and 15 percent or more of all fuel oil (including Diesel oil) consumed in the United States. The trend of the percentage taken by them had been downward. These

demand for coal is more stable than one might expect from fluctuations in the transportation for which it is needed.

CHART 94

Passenger-miles per Ton of Coal or Equivalent Consumed in Passenger Service, January 1920—December 1940



Shaded periods are contractions in passenger-miles.

From cycle to cycle, the ratio of traffic to consumption rose, or did not fall as much as the failure of aggregate traffic to regain former levels might lead one to expect. The technique of utilizing energy for transportation improved. Part of the heat formerly wasted, in the gases from the firebox, which pass through horizontal firetubes in the boiler to the smokestack, and in exhaust steam from the cylinders, vented with the gases, was conserved. Around 1919 the railroads began to install in the stack a feedwater heater, a device to which water from the tender is conducted and in which it is pre-heated by waste gases and steam before being led into the boiler. In the 'open' type, hot exhaust steam is trapped, condensed, mingled with the water from the tender,

figures include fuel used by switching locomotives, in stationary power plants, for [illegible] percentages for anthracite and commercially generated electricity were much lower, that for gasoline negligible. See Alexis P. Bukovsky, *Use and Cost of Railway Fuel and Problems in Fuel Statistics*, ICC Bureau of Transport Economics and Statistics, Statement 4428 (mimeographed, 1944), pp. 14–22, and *Electric Light and Power Industry* (Bureau of the Census, 1937), p. 20.

and thus returned to the boiler. At the end of 1928 three manufacturers had sold 5,854 feedwater heaters, all except 3 since 1919. By 1936 heaters were in use on perhaps a fourth of all steam locomotives in service, and were built into all new steam locomotives.[4]

Another device, the superheater, salvages waste energy in a quite different way. On leaving the boiler, where it has the same temperature as the water, steam is led to a distributor in the smokebox. From the latter, narrow U-shaped tubes extend back into the flues carrying the waste gases and return to a collector. The steam circulates through the U-tubes, acquiring 'superheat' from the surrounding gases. More powerful because of the higher temperature, it can do more work when it finally travels from the collector into the cyclinders. The earliest firetube superheaters were installed about 1910. By the end of 1932, 76.9 percent of all steam locomotives in use had them; the percentage rose continuously to 87.3 at the end of 1938.[5]

Conservation of fuel was further promoted in many instances by rearranging operations in such a way that a train would move over two or more divisions without changing engines. Locomotives spent a larger percentage of their time on the road, a smaller percentage at terminals between assignments. After a steam engine is detached from a train the fire is either maintained, to keep the engine ready for a new mission, or dumped and eventually replaced by a new fire. The fuel burned or dropped does not move any traffic. Longer runs therefore resulted in greater economy.[6]

[4] On feedwater heaters we consulted: Association of American Railroads, Mechanical Division, *Locomotive Cyclopedia*, 1944 ed., pp. 44, 359 and *Proceedings* of annual convention, 1929, p. 898 (Report of Committee on Locomotive Design and Construction); Western Club, *Official Proceedings*, Nov. 1936, remarks of R. M. Ostermann, Vice-President, The Superheater Co., pp. 11 ff., T. C. McBride, Worthington Pump and Machinery Corp., p. 27, and C. T. Ripley, Chief Mechanical Engineer, Santa Fe railroad, p. 31.

[5] On the nature and date of the introduction of superheaters, see *Locomotive Cyclopedia*, pp. 80, 333. Percentages calculated from *Statistics of Railways*.

[6] For descriptions of progress in lengthening runs during the 1920's see the remarks, in Mechanical Division, *Proceedings*, of O. S. Jackson, Superintendent, Motive Power and Equipment, Union Pacific, 1925, pp. 190–2, 1930, p. 968; George McCormick, Superintendent, Motive Power, Southern Pacific, 1926, p. 695; S. Zwight, General Mechanical Superintendent, Northern Pacific, 1927, p. 822. For the effect on fuel consumption, McCormick, p. 696; Joint Committee on Utilization of Locomotives, 1926, p. 662; J. E. Bjorkholm, Assistant Superintendent of Motive Power, Milwaukee railroad, 1930, p. 977.

Longer runs had other advantages. On some lines mixing of boiler waters from

NO GROWING WASTE IN HIGH PROSPERITY

Although productivity shows a net rise and a net fall with the corresponding changes in traffic, it does not therefore necessarily rise throughout expansion or fall throughout contraction. The theory that efficiency tends to degenerate in late prosperity and improve toward the end of deepening depression might be applicable to fuel consumption. Perhaps the management of energy sources tends to become lax when railway officials become relatively busy; perhaps the skill with which engineers and firemen utilize coal becomes diluted as less experienced men are taken on; perhaps the railroads must resort to inferior grades of fuel as more and more is needed. These tendencies, if they exist, should be reversed in contraction. Let us see whether there is any indication of them in the figures.

The location of turning points in productivity gives little evidence of a degeneration in late expansion or an improvement in late contraction. We feel unable to locate any turns in productivity in freight service corresponding to the traffic peak of 1923 and 1926 or the trough of 1924 and 1927. This leaves us with only 5 turns (Chart 93). We place 3 exactly at the turn in ton-miles. Another we spot in June 1932, one month before the traffic turn. But the difference in productivity between the two months is negligible—4,802 ton-miles per ton of fuel in June and 4,810 in July. Only in the one remaining instance was there any significant interval: in 1921 productivity reached bottom five months before the trough in traffic. In passenger service we have less difficulty in recognizing turns in productivity. We think we find one for each turn in aggregate passenger-miles, or 10 altogether (ignoring the turns in the middle of 1933–37). But there seems to be no consistent or preponderant tendency to lead or lag. In 5 instances the peak or trough in passenger-miles per ton of fuel coincided with that in traffic. Economy began to improve before the trough in

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sources on different divisions minimized the formation of boiler scale and hence the need for repairing damage from bad water (C. E. Brooks, Chief of Motive Power, Canadian National, [illegible], p. 697; Jackson, p. 701). Avoiding the extreme change of temperature that occurs in heating up before and cooling down after a run reduced the number of leaks and other boiler troubles calling for maintenance expense (John Purcell, Assistant to President, Santa Fe railroad, pp. 691–2).

Our description of three salient innovations does not profess to tell the full story of progress in economizing fuel.

traffic in 2 instances and after it in 2. Once it continued to improve after travel began to diminish (Chart 94). One cannot fairly say that in either service changes in productivity commonly preceded or commonly followed those in traffic.

Table 69
Revenue Ton-miles per Ton of Fuel Consumed in Road Freight Service
Averages for Stages of Cycles in Revenue Ton-miles

Cycle†	I	II	III	IV	V	VI	VII	VIII	IX
1919–21	No data on fuel				4,480	4,507	4,530	4,435	4,428
1921–24	4,428	4,474	4,480	4,501	4,532	4,576	4,647	4,718	4,692
1924–27	4,692	4,978	5,076	5,118	5,279	5,323	5,359	5,371	5,266
1927–32	5,266	5,357	5,533	5,541	5,624	5,536	5,486	5,166	4,837
1932–38	4,837	5,163	5,236	5,519	5,899	5,763	5,501	5,577	5,425

† The beginning and ending months are those indicated by asterisks in Chart 7.

Table 70
Passenger-miles per Ton of Fuel Consumed in Road Passenger Service
Averages for Stages of Cycles in Passenger-miles

Cycle†	I	II	III	IV	V	VI	VII	VIII	IX
1918–22	No data on fuel				1,420	1,352	1,223	1,177	1,134
1922–25	1,134	1,177	1,146	1,173	1,229	1,205	1,168	1,185	1,173
1925–28	Expansion too short for				1,225	1,194	1,168	1,132	1,131
1928–33	division into stages				1,158	1,095	996	878	790
1933–38	790	960	983	1,032	1,107	1,089	1,082	1,032	970

† The beginning and ending months are those indicated by asterisks in Chart 19.

This negative conclusion is not shaken if one compares the average level of productivity at the end of a phase with its level in earlier stages.[7] In all of 4 freight traffic expansions, productivity was highest—economy of fuel greatest—in the very last stage (Table 69). In 4 of 5 contractions, it was lowest at the very end. Even in the fifth (1923–24) the last segment was the only one in which productivity declined; in the other segments it rose; the most unfavorable showing came at the end, although the decline was not great enough to wipe out all the progress made earlier in the contraction. In passenger service the story is similar (Table 70). Two of the expansions, 1925 and 1928–29, contain so few months altogether that we cannot very well make five groups and strike averages. But in both, the highest productivity was achieved

[7] The method of dividing a phase into stages and segments is explained in Chapter 7.

in the last month; and except from December 1928 to January 1929, it improved from each month to the next. In the other 2 expansions, the average for the last stage was higher than that for any of the preceding stages. In 4 of 5 contractions, the average for the last stage was the lowest of all, although by a negligible margin in 1925–28 (1,131 passenger-miles per ton in stage IX, 1,132 in stage VIII). In the fifth (1923–25) the average at the end, 1,173 passenger-miles per ton, was only slightly higher than the lowest average for any stage, 1,168 for VII.

It cannot even be said that declines in productivity were more common in the late stages than elsewhere in expansion, or in the early stages than elsewhere in contraction. In freight service productivity did not fall in any segment of any expansion. In the diminishing phases of ton-miles it fell in 2 of the first, the second, and the third segments, but in all 5 of the last segments. In passenger service it rose in every segment of the two expansions except the second of 1922–24. It fell in all 5 of the first and second segments, rose, to be sure, in one of the third, but again fell in all 5 of the final segments. The theory that efficiency tends to fall before expansion ends and to rise before it begins is not applicable to fuel consumption.

NO REGULAR TAPERING OFF

Changes compared with time elapsed

Although there was progress toward greater economy in almost every segment of expansion, conceivably it could be more rapid in the earlier than in the later segments. And although declines in productivity occurred even at the end of contractions, one can imagine the loss being gradually brought under tighter control, in which case we would expect a fall in one segment to be followed by a less rapid fall, if not a rise, in a later segment. But the data give doubtful support, if any, even to these modified expectations (Tables 71 and 72, summarized from this point of view in Table 73). In the first segment of expansions, to be sure, the productivity does seem to have improved faster than in most later stretches. But in freight contractions it did not deteriorate at all in 3 of 5 first segments, and in the other two the initial rate of decline was later exceeded. In passenger contractions, the initial fall was more

Table 71

Revenue Ton-miles per Ton of Fuel Consumed in Road Freight Service
Change per Month during Segments of Phases in Revenue Ton-miles

Phase of ton-miles	First segment	Second segment	Third segment	Fourth segment
Expansions				
1921–23	11.5	0.9	3.2	7.8
1924–26	63.6	12.2	5.2	35.8
1927–29	26.0	27.1	1.2	23.7
1932–37	32.6	3.9	15.3	38.0
Contractions				
1920–21	9.0	4.2	−17.3	−2.3
1923–24	17.6	15.8	15.8	−10.4
1926–27	14.7	47.3	2.2	−35.0
1929–32	−14.7	−4.3	−27.8	−54.8
1937–38	−54.4	−65.5	19.0	−60.8

Computed from data in Table 69 and number of months between midpoints of stages, e.g.; (4,474 − 4,428) ÷ 4 = 11.5.

Table 72

Passenger-miles per Ton of Fuel Consumed in Road Passenger Service
Change per Month during Segments of Phases in Passenger-miles

Phase of passenger-miles	First segment	Second segment	Third segment	Fourth segment
Expansions				
1922–25	12.3	−4.8	4.2	16.0
1933–37	20.0	1.5	3.2	8.8
Contractions				
1920–22	−19.4	−23.5	−8.4	−12.3
1923–25	−6.9	−6.7	3.1	−3.4
1925–28	−4.4	−2.0	−2.8	−0.1
1929–33	−7.4	−6.4	−7.6	−10.4
1937–38	−6.0	−1.3	−9.1	−20.7

Computed from data in Table 70 and number of months between midpoints of stages, e.g.; (1,177 − 1,134) ÷ 3.5 = 12.3.

Table 73

Productivity of Fuel: Change per Month
Summary of Comparisons among Segments

	Segments to be compared in each phase					
	First & second	First & third	First & fourth	Second & third	Second & fourth	Third & fourth
	Number of expansions in which productivity rose during earlier, fell or rose less rapidly during later segment					
Ton-miles	3 of 4	4 of 4	3 of 4	2 of 4	1 of 4	0 of 4
Passenger-miles	2 of 2	2 of 2	1 of 2	0 of 2	0 of 2	0 of 2
	Number of contractions in which productivity fell during earlier, rose or fell less rapidly during later segment					
Ton-miles	1 of 5	1 of 5	0 of 5	1 of 5	1 of 5	1 of 5
Passenger-miles	4 of 5	3 of 5	3 of 5	2 of 5	3 of 5	1 of 5

Derived from Tables 71 and 72.

Table 74

Revenue Ton-miles per Ton of Fuel Consumed in Road Freight Service
Change per Billion-mile Change in Revenue Ton-miles

Phase of ton-miles	First segment	Second segment	Third segment	Fourth segment
Expansions				
1921–23	31	12	3	7
1924–26	137	67	24	87
1927–29	89	94	13	395
1932–37	92	34	55	74
Contractions				
1920–21	12	†	−12	7
1923–24	29	21	†	−11
1926–27	126	30	7	−110
1929–32	−25	−9	−45	−73
1937–38	−60	−76	20	−200

† Ton-miles increased.

Table 75

Passenger-miles per Ton of Fuel Consumed in Road Passenger Service
Change per Billion-mile Change in Passenger-miles

Phase of passenger-miles	First segment	Second segment	Third segment	Fourth segment
Expansions				
1922–23	406	−221	252	747
1933–37	601	261	146	321
Contractions				
1920–22	−216	−222	−250	−321
1923–25	−207	−239	486	−200
1925–28	−463	−194	−180	−13
1929–33	−342	−186	−226	−338
1937–38	−450	−146	−265	−539

Table 76

Productivity of Fuel: Change per Billion-unit Change in Traffic
Summary of Comparisons among Segments

	Segments to be compared in each phase					
	First & second	First & third	First & fourth	Second & third	Second & Fourth	Third & Fourth
	Number of expansions in which productivity rose during earlier, fell or rose less per billion-unit increase of traffic, during later segment					
Ton-miles	3 of 4	4 of 4	3 of 4	3 of 4	1 of 4	0 of 4
Passenger-miles	2 of 2	2 of 2	1 of 2	1 of 2	0 of 2	0 of 2
	Number of contractions in which productivity fell during earlier, rose or [illegible]					
Ton-miles	1 of 4	1 of 4	0 of 5	1 of 3	0 of 4	1 of 4
Passenger-miles	3 of 5	4 of 5	3 of 5	2 of 5	2 of 5	1 of 5

Derived from Tables 74 and 75.

rapid than later falls in a not very impressive majority of cases. Whatever the situation as to the first, comparison of the second with still later segments certainly does not consistently indicate any further tapering of the rate of change in either service or either kind of phase.

Changes compared with those in traffic

The variations in productivity, however, may have been influenced by inequalities in the rate of growth of traffic during the several parts of a phase. To deal with this possibility we may ask: were the gains in economy smaller in proportion to the growth of traffic in later segments of expansion, and the losses smaller in proportion to the shrinkage of traffic in later segments of contraction. Once more the answer seems to be 'yes' (with one exception) if one compares the first with later stretches of expansion, a very qualified yes for the first segment of contractions in travel, and a definite no for the first segment of contractions in ton-miles (Table 76; data in 74 and 75). Again there was no consistent further tapering off after the second segment.