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Appendix A

The Nature and Limitations of the Data

The details underlying the construction of the data presented in this report will be given in full in a monograph which is now in progress.[17] Some brief remarks are presented here on the general nature and limitations of these series.

For the period after 1911 the U.S. Interstate Commerce Commission has compiled data on gross capital expenditures by the bulk of American railroads. Only relatively minor adjustments were necessary in these figures to approximate complete coverage.

For the years prior to 1912 it was necessary to resort to the annual reports of state railroad commisisons, which in some cases carried capital expenditures as well as other financial items for individual roads. Samples obtained for selected years were used to derive estimates of gross capital expenditures for all railroads. The samples ranged in size from 20 to nearly 70 per cent of the total and were designed, insofar as possible, to provide representative geographical coverage. Primarily because the cost of transcribing was high, such samples were taken, on the average, for every third year. The greatest span between any two samples was four years. Estimates of gross capital expenditures for intersample years were interpolated, after adjustment for the price factor, by means of a series on miles of track operated.

Changes in miles of track operated provide an admittedly poor indicator of capital expenditures, primarily because they represent only one facet of investment and because of an indeterminate lag between expenditures and the completion of lines of track.[18] For this reason for

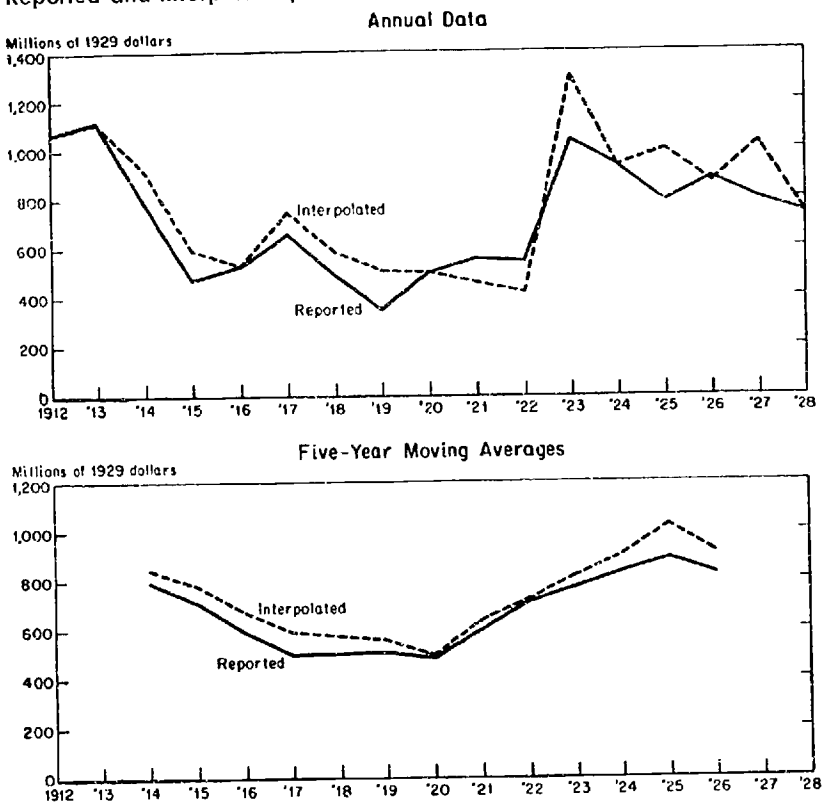
[17] The monograph will embrace capital formation and financing not only by the railroads but by other utilities and transportation industries as well.

[18] For completeness it may also be noted that a change in miles of track operated is not strictly a *gross* change. However, the relative importance of abandoned lines — and all other retirements — in the period before 1910 was negligible.

all years prior to 1910[19] the year-to-year changes in gross capital expenditures — or in any other series derived from these — must be viewed as rough approximations. Accordingly, five-year moving averages were computed for all the series presented in the report. They eliminate much of the error stemming from the crude interpolation

CHART A-1

Comparison of Gross Capital Expenditures in Constant Dollars Reported and Interpolated, 1912-1928



Source: Reported expenditures from Tables A-1 and A-2. Interpolation based on data from *Statistics of Railways*, Interstate Commerce Commission, various years.

employed and, by excluding much of the "minor" cyclical movements permit a greater degree of attention to be focused on the long cycles and other long-term phenomena which are of prime interest here.

[19] The Interstate Commerce Commission figures begin in 1912, but samples from the state railroad commission reports were taken in 1910 and 1911.

Unfortunately, there is no *direct* test of the accuracy of the method of interpolation employed for this series, or of the extent to which results are improved by use of the five-year moving average. Changes in miles of track operated were almost certainly a much more accurate indicator of capital expenditures in the earlier years, when construction of road and new lines were a more important segment of total investment, than later. Nevertheless, it was deemed instructive — experimentally — to apply this method of interpolation to the later years and compare results with the actually reported data.

The results of this experiment are shown in Chart A-1. As already indicated, in the actual use of this method for the period before 1912, sample data were available every third year on the average, though samples were not evenly spaced throughout. In the experiment it was assumed that every fourth year was known. As in the earlier period, changes in miles of track operated were used to interpolate for the intervening years. It was possible to work this experiment from 1912 only through 1928, since after this date — unlike the earlier period — negative changes in track miles occur, and these are of course inadmissible for interpolating gross capital expenditures.

In the first panel of Chart A-1, estimates derived from track mileage (between benchmark years) are compared on an annual basis with actually reported figures, after appropriate adjustment and deflation. The average absolute error for the entire period is 13 per cent, and the largest error in any year is 46 per cent in 1919. As noted above, one would expect these errors to be substantially larger than those actually incurred in the earlier period for which this method of estimation was employed, though there is no direct proof of this. Of particular interest here, however, is the extent to which these errors are reduced by use of five-year moving averages.

A comparison of the five-year moving averages of the actual and interpolated series is shown in the second panel of Chart A-1. The average absolute error incurred is 7 per cent and the maximum error is 18 per cent in 1917 — about half the size of the errors in the annual series. Of perhaps as much importance as this is the improvement obtained in the direction of movement. In the annual series the interpolated values move in the wrong direction seven out of sixteen times. In the five-year moving average, disagreements occur only in 1918 and

1919, and in both cases the opposing movements of actual and interpolated series are very small. Moreover, peaks and troughs of the two series are in perfect agreement.

It may be concluded, therefore, that the five-year moving averages materially reduce the errors resulting from the interpolation method employed in estimating gross capital expenditures prior to 1910. There is a further presumption that the errors remaining in the five-year moving averages are small[20] and that their direction of movement and turning points are generally reliable.

The qualifications of the accuracy of the series on gross capital expenditures apply equally to net capital expenditures, except that in the latter case an additional problem arises--that involved in the estimation of capital consumption. The estimates made here of capital consumption (and in virtually all other places to the writer's knowledge) are to be viewed as rough approximations of the extent to which physical capital was used up, on the average, from year to year over the period. No attempt is made to measure the very short period (and usually small) changes which result from fluctuations in the intensity of capital utilization. The series does purport to measure the changes over time related to alterations in the stock and composition of capital. They are based, ultimately, on estimates of the average length of life of railroad property, provided by the Interstate Commerce Commission. It may be noted that capital consumption of the railroads is *relatively* small in the early years, when information on length of life of property is least reliable. Furthermore, since capital consumption is progressive rather than sporadic, any errors made are not likely to be erratic in nature. In general a substantial error in the estimates in the early period (say in the years prior to 1915) would have the effect of providing only a small error in the secular trend of the net capital

[20] The average error of 7 per cent found in the five-year moving average of the interpolated series during 1914-1926 is probably much greater than the actual error encountered when this method was used in the earlier period, for two reasons: (1) as suggested above, track mileage was probably a more accurate indicator of capital formation in the earlier period, and (2) samples were actually available, on the average, more frequently than every four years, the assumption employed in the illustration. On the other hand, there are of course sampling errors in the benchmark estimates of gross capital expenditures in the years prior to 1912, not reflected in the experiment. The size of these samples, given above, suggests that the errors involved are not likely to be great; they are discussed in detail in the forthcoming monograph already mentioned.

expenditures series and virtually no perceptible error in the short or intermediate term changes.

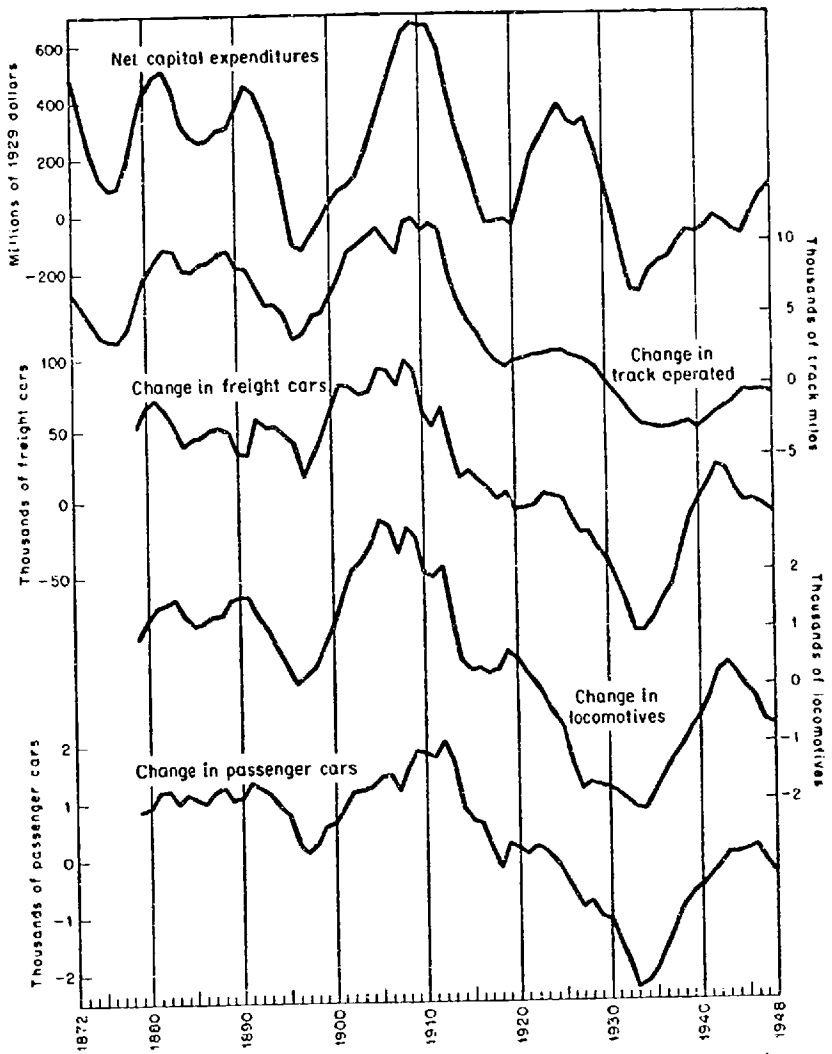
The series on value of road and equipment is built up from the net capital formation series plus a benchmark estimate of the value of the stock of capital on a particular date supplied by the Interstate Commerce Commission. The benchmark, of course, determines the over-all level. The accuracy of the change in this series over time is a reflection only of the accuracy of estimated net capital expenditures.

Principal emphasis in the body of this report is placed upon the deflated series, for interest is most often centered upon the flow and stock of *real* capital. For the years 1915 to 1950 the index of railroad construction costs prepared by the Interstate Commerce Commission is employed for purposes of deflation. For earlier years it was necessary to construct a special index from data on construction material prices, equipment material prices, and wage rates. For no period were indexes available which precisely fulfilled the variety of tasks for which they were required, such as deflating capital consumption or the stock of capital, and a number of assumptions as well as adjustments of the original data were found necessary. These assumptions and adjustments, however, were subjected to independent checks wherever possible. It should be noted that the price indexes employed here share a deficiency common to almost all measures of price change. They do not reflect alterations in the quality of goods over time. Were account taken of improvements in quality, estimates of the physical volume of railroad capital in the more recent years would be larger than those here recorded.

Finally, a rough check on the accuracy of our investment series may be provided by comparison with data available on changes in the physical volume of railroad investment goods. Perfect agreement cannot be expected for a number of reasons, entirely apart from the inevitability of statistical error. In the first place, data are not available on the physical volume of *all* types of investment goods. Second, changes in the stocks of these goods are gross differences; they include the effects of retirements, as well as additions, but make no allowance for depreciation on existing stock. Third, no effort was made to combine the different types of investment goods into an over-all index, for the problems involved in weighting are considerable and would in

CHART A-2

Net Capital Expenditures, Constant Dollars, and Changes in Track and Equipment, U. S. Railroads Five-Year Moving Averages, 1872-1948



Source: Net capital expenditures, Table A-1. Track and equipment changes based on data from *Statistics of Railways*, Interstate Commerce Commission for 1890 and subsequent years and on *Poor's Manual of the Railroads in the United States* for earlier years. The ICC data, which refer to Classes I, II, and III railroads, were adjusted for each year to cover all roads.

themselves give rise to an indeterminate error of undoubtedly substantial size.

For all these reasons, attention must be focused upon the broader characteristics of the series depicted in Chart A-2. If this is done, it will be seen that there is nearly perfect agreement between our own capital formation series and the data on physical volume considered together. In the one important exception, described below, the difference is attributable to the limitations of the physical volume series.

Initially, it should be noted that all series reach their all-time peaks at or near the end of the first decade of the twentieth century — in 1909 in our own series of net capital expenditures, in 1909 in track, in 1908 in freight cars, 1905 in locomotives, and 1912 in passenger cars. Prior to the 1897-1920 cycle, which culminated in this peak, the series in all cases remain at a level about one-half to three-fourths of the way from the 1897 trough to the 1909 peak. The two long cycles preceding this giant rise appear in track and in locomotives, are less distinctly marked in freight cars, but are absent from passenger cars, which is the least important of the physical volume series in this period. All series show a trough in the early thirties and a subsequent rise. In all cases investment after World War I appears substantially lower in general than in the earlier years.

The outstanding difference between our own and the physical volume series occurs in the 1920's. It is in this period, however, that retirements reached record levels, far exceeding the rate of capital consumption, and for this reason, especially, changes in physical volume tend to understate the actual flow of investment. The tremendous volume of traffic in World War I, coupled with supply and labor shortages, precluded the maintenance of track, buildings, and rolling stock at accustomed standards and, at the same time, necessitated the general deferral of replacements. At the end of the war, extensive rebuilding and re-equipping were required. The flood of investment that occurred is not mirrored in the physical volume series because of the simultaneous retirement of obsolete equipment. It should be emphasized that in the twenties, investment was directed toward improvements of many kinds rather than to extensions of line. Thus signal systems were improved and in many cases installed for the first time in this period. This and other similar activities are not reflected in the physical volume

series in Chart A-2. Average annual retirements in the twenties, compared with other periods, are as follows:

Decade	*1929 Dollars (millions)*
1870-1879	5
1880-1889	10
1890-1899	10
1900-1909	14
1910-1919	171
1920-1929	1,204
1930-1939	222
1940-1946	360
1947-1949	620

A smaller but somewhat similar difference between our series on net capital expenditures and the physical volume series appears in the late 1940's. Again retirements rose sharply after World War II, exceeding the actual rate of capital consumption. This rise in retirements served to reduce the physical volume series, though there can be little doubt that the real rate of capital formation rose after World War II as indicated in our series.

TABLE A-1

Value of Road and Equipment, Capital Formation, and Capital Consumption U.S. Railroads,* Five-Year Moving Averages, 1872-1949
(millions of dollars)

YEAR	VALUE OF ROAD AND EQUIPMENT JAN. 1		GROSS CAPITAL EXPENDITURES		CAPITAL CONSUMPTION		NET CAPITAL EXPENDITURES	
	Current Dollars (1)	*1929 Dollars* (2)	*Current Dollars* (3)	*1929 Dollars* (4)	*Current Dollars* (5)	*1929 Dollars* (6)	*Current Dollars* (7)	*1929 Dollars* (8)
1872	$4,333	$8,108	$318	$604	$70	$133	$247	$472
1873	4,544	8,580	263	497	75	142	188	355
1874	4,704	8,935	200	376	77	150	122	226
1875	4,746	9,161	147	292	77	156	70	136
1876	4,598	9,297	118	254	74	161	43	94
1877	4,354	9,391	113	261	72	164	41	97
1878	4,155	9,487	148	347	72	168	77	179
1879	4,128	9,666	216	499	74	174	142	325
1880	4,236	9,991	272	616	78	181	194	435
1881	4,504	10,426	306	683	84	191	221	493
1882	4,830	10,919	320	711	90	201	230	510
1883	5,138	11,429	294	652	95	212	199	441
1884	5,310	11,869	247	551	99	222	149	329
1885	5,424	12,198	223	507	101	230	122	276
1886	5,469	12,475	216	498	103	238	113	260
1887	5,526	12,735	222	514	106	246	115	267
1888	5,613	13,002	238	552	110	254	128	298
1889	5,734	13,299	244	570	112	263	132	307
1890	5,822	13,607	271	642	115	271	156	370
1891	5,916	13,977	307	738	117	281	190	457
1892	6,036	14,434	300	729	120	292	180	437
1893	6,109	14,872	267	657	122	303	145	354
1894	6,139	15,226	229	568	125	313	105	255
1895	6,172	15,481	158	395	126	321	31	73
1896	6,126	15,554	87	223	128	327	−41	−104
1897	6,053	15,450	84	207	132	330	−48	−123
1898	6,126	15,327	112	262	138	333	−26	−71
1899	6,294	15,255	139	321	143	337	−4	−16
1900	6,454	15,239	170	382	150	341	19	40
1901	6,716	15,279	197	431	158	347	38	84
1902	7,007	15,362	212	454	165	354	47	101
1903	7,192	15,463	236	496	171	360	66	136
1904	7,391	15,599	294	590	181	367	113	223
1905	7,781	15,822	368	709	192	376	176	333
1906	8,251	16,155	440	827	203	386	237	441
1907	8,718	16,596	515	942	216	397	299	545
1908	9,313	17,141	592	1,053	230	410	362	643
1909	9,978	17,784	628	1,099	243	425	385	674

TABLE A-1 (cont.)

YEAR	VALUE OF ROAD AND EQUIPMENT JAN. 1		GROSS CAPITAL EXPENDITURES		CAPITAL CONSUMPTION		NET CAPITAL EXPENDITURES	
	Current Dollars (1)	*1929 Dollars* (2)	*Current Dollars* (3)	*1929 Dollars* (4)	*Current Dollars* (5)	*1929 Dollars* (6)	*Current Dollars* (7)	*1929 Dollars* (8)
1910	$10,534	$18,458	$641	$1,108	$255	$441	$386	$668
1911	11,066	19,126	662	1,123	269	455	393	668
1912	11,683	19,794	630	1,059	280	470	350	589
1913	12,129	20,383	543	909	290	484	254	425
1914	12,442	20,808	485	791	308	496	178	295
1915	13,071	21,103	471	709	341	507	129	202
1916	14,303	21,305	435	583	392	516	43	67
1917	16,189	21,372	422	495	457	523	—35	—28
1918	18,588	21,344	501	501	539	526	—38	—25
1919	21,790	21,319	547	507	578	526	—31	—19
1920	23,360	21,301	538	484	586	523	—47	—39
1921	23,765	21,262	658	595	584	519	74	75
1922	23,948	21,337	772	711	566	514	206	197
1923	23,666	21,534	795	768	525	509	270	258
1924	22,448	21,792	854	832	516	506	338	326
1925	22,549	22,118	911	882	519	503	392	379
1926	23,190	22,497	836	822	507	499	329	323
1927	23,169	22,820	814	809	498	495	316	314
1928	23,270	23,134	822	825	492	493	331	332
1929	23,374	23,466	715	728	480	494	234	234
1930	23,063	23,700	587	611	462	496	125	115
1931	22,236	23,815	464	491	446	498	18	—7
1932	21,355	23,808	328	362	434	502	—106	—140
1933	20,491	23,669	196	229	425	504	—229	—275
1934	19,730	23,394	191	228	423	506	—231	—278
1935	19,312	23,116	271	310	436	509	—164	—199
1936	19,617	22,916	303	342	448	512	—145	—170
1937	19,918	22,746	321	359	457	516	—137	—157
1938	20,031	22,590	379	419	467	519	—88	—100
1939	20,244	22,490	427	457	483	522	—57	—65
1940	20,782	22,425	450	455	507	523	—57	—68
1941	21,664	22,357	492	474	541	525	—49	—50
1942	22,986	22,306	555	511	575	526	—20	—15
1943	24,363	22,291	577	501	613	528	—36	—27
1944	25,830	22,264	580	471	660	532	—80	—61
1945	27,548	22,203	617	463	709	535	—92	—73
1946	29,294	22,131	785	539	767	539	19	0
1947	31,467	22,131	940	602	827	544	113	58
1948	33,735	22,189	1,052	642	887	549	166	93
1949	36,004	22,282						

* All data exclude investment in land and land rights.

Source: Forthcoming monograph on capital formation and financing by public utilities.

TABLE A-2

Value of Road and Equipment, Capital Formation, and Capital Consumption U.S. Railroads,* Annual Data, 1910-1950
(millions of dollars)

YEAR	VALUE OF ROAD AND EQUIPMENT JAN. 1		GROSS CAPITAL EXPENDITURES		CAPITAL CONSUMPTION		NET CAPITAL EXPENDITURES	
	Current Dollars (1)	*1929 Dollars* (2)	*Current Dollars* (3)	*1929 Dollars* (4)	*Current Dollars* (5)	*1929 Dollars* (6)	*Current Dollars* (7)	*1929 Dollars* (8)
1910	$10,459	$18,413	$714	$1,216	$258	$440	$456	$777
1911	11,265	19,190	653	1,114	268	457	385	657
1912	11,630	19,847	636	1,067	281	471	355	596
1913	12,184	20,443	682	1,116	296	486	386	632
1914	12,877	21,075	465	783	297	500	168	283
1915	12,687	21,358	281	467	307	510	−26	−43
1916	12,832	21,315	363	524	358	517	5	7
1917	14,776	21,322	562	657	449	525	113	132
1918	18,343	21,454	503	483	549	527	−46	−44
1919	22,309	21,410	401	345	622	535	−221	−190
1920	24,679	21,220	678	498	718	527	−40	−29
1921	28,841	21,191	591	554	552	517	39	37
1922	22,629	21,228	518	541	487	509	31	32
1923	20,367	21,260	1,103	1,035	543	509	560	525
1924	23,223	21,785	972	927	532	508	439	419
1925	23,270	22,204	791	782	510	504	281	278
1926	22,752	22,482	887	876	506	500	381	376
1927	23,132	22,858	804	790	503	494	301	296
1928	23,571	23,154	727	736	483	489	244	247
1929	23,120	23,401	860	860	487	487	373	373
1930	23,774	23,774	834	865	479	497	355	368
1931	23,273	24,142	349	389	450	501	−101	−112
1932	21,579	24,030	166	203	413	504	−247	−301
1933	19,434	23,729	112	140	403	503	−299	−363
1934	18,716	23,366	180	214	424	503	−244	−290
1935	19,453	23,076	171	200	433	507	−262	−307
1936	19,467	22,769	328	381	441	512	−113	−131
1937	19,491	22,638	565	613	477	518	88	95
1938	20,960	22,733	273	304	467	520	−194	−216
1939	20,220	22,517	267	297	469	522	−202	−225
1940	20,018	22,292	462	501	482	523	−20	−22
1941	20,533	22,270	566	569	522	525	44	44
1942	22,180	22,314	684	604	597	527	87	77
1943	25,369	22,391	483	401	635	527	−152	−126
1944	26,829	22,265	581	480	639	528	−58	−48
1945	26,905	22,217	569	452	672	534	−103	−82
1946	27,868	22,135	581	416	757	542	−176	−126
1947	30,769	22,009	873	564	844	545	29	19
1948	34,099	22,028	1,322	781	921	544	401	237
1949	37,695	22,265	1,357	799	942	555	415	244
1950	38,243	22,509	1,129	651	970	559	159	92
1951	39,213	22,601						

* All data exclude investment in land and land rights.

Source: Forthcoming monograph on capital formation and financing by public utilities.