

important effect upon the provisioning of those cities, which, by their railways, command the interior country.

Amer. Railroad Journal.

FOR THE JOURNAL OF THE FRANKLIN INSTITUTE.

Cost of Transportation on Railroads. By CHARLES ELLET, JR., C. E.

(Continued from Vol. IV, page 367.)

The importance of ascertaining the expense of transportation on railroads, to a large portion of the population of this country, has led to many discussions, and many inquiries, with a view to its determination. No general method has, however, yet been produced; by which it can be ascertained with any tolerable degree of accuracy. The difficulty appears to have arisen, in a great measure, from the fact, that these expenses consist in a variety of elements, which increase and diminish in value by different laws, and at rates which depend on the combinations of these elements in each particular case. It has, also, to some extent, grown out of the fact, that during the progress of this system, every year has produced some new work of improvement, which has supplied new data to calculators—and, unfortunately, data which have preceded the effect of the two greatest causes of expenditure—the destruction consequent on use, and natural decay. Without referring to another difficulty—the extravagant estimates of the friends of particular projects, and, sometimes, the gross misrepresentations of the enemies of others—we see that the subject is much too complicated to be unraveled without close study, and mature reflection. To make a general solution, we have, obviously, to allow for differences of grade, differences of tonnage, differences between the amounts of travel, and have due regard to the length, and even the age of the improvement.

Now, to attempt to go through this whole subject, and produce and analyze the data on which are founded all my conclusions, would require much more labor, than I have a disposition, at this time, to appropriate to the question. What I now propose to do, is again to point out the LAW which governs railroad expenditures, and to fix, with greater accuracy, the values of the constant coefficients than was practicable when I first offered the formula which are here repeated.

It is my intention to submit, in the first place, the law which governs the expenditures on a *new road*, and attempt to offer a reasonable explanation, and a just estimate, of the difference between the expenses incident to a new road, and an old one. If my method be true, the reasons, and the values which I assign for this difference, must be obviously just. The general law must first satisfy the mind, and the rate of increase, in passing from a new to an old road, must likewise be rational and convincing. If, after this preparatory evidence, I bring forward a certain new road of great length, and show that the calculated cost corresponds well with the actual result, it will certainly be a strong confirmation of the general correctness of the method. But still, for a prudent man proposing to risk his fortune, this alone ought not to be sufficient. This particular example might be selected be-

cause it was accidentally found to suit the object; he would have a right, therefore, to call on me to produce a *short* road, and show that the results still correspond with my calculation. His intellect might not yet be fully satisfied; it would be fair for him to call for another example, in which the trade and travel were both unusually great, in order to be assured that the method is applicable to works of that character also; and, even after finding this result to be confirmatory of the method, extreme prudence would dictate an additional application to another road with very small trade.

All this appearing satisfactory, he could not well retain a doubt; but, when men stake their fortunes, and the comfort and indulgence of their families on the issue, they have a right—they are bound—to exercise great circumspection. Such a party might, therefore, well call for an application of the method to an *old road*—or to one that has arrived at maturity, at least,—in order to see whether his investment is likely to be permanently good.

If this doubt be also satisfied; if he finds that the application may be safely made to a road of this description; if, in addition, it is made to one of this sort with a great trade—next, to one with a small trade—then to one with great travel and no tonnage; afterward to a long one, and, finally, to a short one; to some roads with light, and to others with heavy grades—and, if he find that it gives consistent results in all these varied applications—as a reasonable, and as an intelligent man, he will be compelled to admit, that the method is in accordance with THE LAW, and that its results are the TRUTH.

It is such testimony that I propose to offer the reader, and I solicit his attention in order that he may judge fairly of my consistency—for consistency is a test of truth.

The following propositions are what I designate as Laws:—

I. The cost of motive power, with engines of the same class, is proportional to the distance which the engines run. The cost per mile is nearly the same on roads of all grades—the difference in expense on roads with different grades, consists not essentially in variations of the cost *per mile run*, but in variations of the number of miles which must be performed to do the same duty.

II. The repairs of the road, with equal trade, are proportional to its length; that is to say, *cæteris paribus*, it costs twice as much to keep up a road 200 miles long, as it does to maintain one in the same condition, of which the length is 100 miles; just as it costs twice as much to run engines 200,000 miles, as it would to run the same class of engines 100,000 miles.

III. The repairs of cars are proportional to the number of tons conveyed, and to the distance to which they are conveyed. It costs twice as much to repair cars which run two millions, as it does those which run one million of miles per annum. Again, it costs twice as much to repair cars which convey 20,000 tons a given distance, as it does those which convey 10,000 tons the same distance. The same principle applies equally to the conveyance of passengers; it applies also to accidents, incidentals, and contingencies—for these things increase with, and are proportional to, the increase of business.

These may appear like self-evident truths, and they are, in fact, so glaring that they scarcely appear to have been looked on at all. The custom now is to regard the expense of cars as proportional to the distance the *engine* runs. It is here made proportional to the distance the *cars* run. It is customary also to consider the repairs of the road as proportional to the distance traveled by the engine—whereas it is only proportional to the length of the road.

These are simple principles, and such as cannot well be doubted, or denied. It remains to state the values of the constants.

Repairs of Roads.

The repairs of a railroad, I have stated, must be divided into two classes—those which are dependent on, and those which are independent of, the amount of the tonnage. Of the first division, the wear of iron depends entirely on the use, and the wear of the wood, but partially on the use. The rotting of timber, the cleaning out of ditches, the repairs of culverts, embankments, &c., are independent of the trade. But these items are not independent of *time*; the expenses of repairs increase but little until the wood in the sills, ties and rails, begins to decay, and require removal, when they usually soon attain their maximum, and afterward diminish, until they reach a second minimum.

The following table exhibits the cost of repairs on six of the most successful roads in this country, which I have purposely selected from different sections. The table embraces three roads of each of the two great classes—three wooden superstructures with plate rails, and three iron roads with T or H patterns.

By casting the eye down the columns, the progressive increase of expenses will be easily recognized. It must be borne in mind, however, that these numbers do not include the renewal of the iron—an item always charged to “extraordinary repairs,” or “permanent improvements”—as though iron rails were ever permanent, or their destruction extraordinary. Eventually, the cost of the new iron passes into capital stock, or funded debt.

TABLE showing the Increase of the Cost of Repairs of Railroads.

Year.	Permanent Roads—T Rail.			Wooden Roads—Flat Bars.		
	Boston & Lowell.	Boston & Provid'ce.	Boston & Worcester.	Utica & Schenec'y.	Petersburg Road.	S. Carolina Road.
1836					251	870*
1837	546	285	206	354	664	880
1838	611	411	281	330	542	1040
1839	731	209	405	450	539	982
1840	816	334	830	613	794	592
1841	1200	597	784	837	857	547
1842	1350	514	903	935		503
1843						375

I may add the following notes of the cost of motive power per mile traveled by the engines, which are extracted from documents that were not in my possession when I first stated the cost per mile for passenger engines at 25 cents, and of freight engines at 30 cents.

* Finished in 1833, when the expenses were very low.

TABLE showing the Cost of Locomotive Power for 1842.

Name of Road.	Miles run.	Expense.	Cost per mile.	Year	Remarks.
Boston and Providence.	35,031	\$ 11,399	32½	1842	Freight engines.
Boston and Providence.	77,774	23,352	30	1842	Passenger engines.
Western Road.	397,295	84,165	21½	1842	Exclusive of wages.
Western Road.	397,295	115,000	30	1842	Wages included.
Utica and Schenectady.	155,828	33,454	21½	1841	Exclusive of new engines.
Utica and Schenectady.	155,828	52,268	33- ⁶ / ₁₀	1841	Including new engines.
Reading Road.	83,717	17,443	20- ⁸ / ₁₀	1841	With new engines.
Reading Road.	198,055	49,800	25½	1842	New, but heavier, engines.

This table entirely confirms the previous estimate (vol. iv, p. 307.) Another table in my possession (derived from reports of 1842) gives for the average value of repairs of locomotives, 7 cents per mile run; my impression is, however, that this item is worth not less than 8 cents, and that future observation will maintain it, for engines that are not fresh from the factory, at about that average.

We may now pass to the method and the rule which I propose for computing the aggregate annual expenses of a road. In the first number of this investigation, I proposed a formula which was published in this journal, for determining the value of these expenses—stating, however, that there was no line in the country which had yet exhibited results as favorable as those expressed by that formula. The present paper is intended to show these expenses *as they are*; the same formula is used though the constants are modified to suit the actual condition of the system.

For new Roads.

The aggregate annual charges on *new roads** are made up of the following items, viz:—

For every mile traveled by the engines, 24 cents; for every ton conveyed one mile, 9 mills; for every passenger conveyed one mile, 7 mills; and for every mile in length of the road, 300 dollars, a fact which is expressed by the formula,

$$\frac{24}{100} N + \frac{9}{1000} T + \frac{7}{1000} P + 300h.$$

Now, new engines consume as much, or nearly as much, fuel and oil as those which have been used; and they require the same number of enginemen and firemen. The only reduction in the cost of their maintenance, consists in the item of repairs. The bill for repairs for the first year or two, is only about one-half its mean value; and as the average cost of repairs is about 7 cents per mile run, the aggregate cost per mile run on a road which has passed its fourth year, should be 27½ cents, instead of 24 cents.

The *timber* in the superstructure is worth, on the average, from 1000 to 1500 dollars per mile, and lasts from 5 to 7 years. The decay of timber in roads of mature age, is, therefore, about \$200 per mile—so that ordinary repairs on such roads will be about \$500 per mile.

The wear of cars after the road has been a few years in operation, is equivalent to about 4½ mills per ton per mile; and on a new road

* I designate as *new*, roads less than five years old.

it is scarcely appreciable. The difference between the perceptible injury to the road and cars, on a new and old road, is about 5 mills per ton per mile. The rule then is,—

For old Roads.

For every mile traveled by the engines, (passenger engines 25 and freight engines 30 cents,) an average of $27\frac{1}{2}$ cents; for every ton conveyed one mile, 14 mills; for every passenger conveyed one mile, 7 mills; and for every mile of road, \$ 500.

If the principles and the values here offered be correct, they will stand the test of trial, and in order to make the test the strongest possible, I will add, in a subsequent paper, an estimate of the probable results on a road in active operation, and the subject of much speculation at the present time, the correctness of which estimate can be verified at the end of the year.

This rule, if applied to the business of a line in activity, will give only those expenses which are usually denominated "ordinary expenses." In order to arrive at the *true cost* of maintenance we have to add, of course, the extraordinary expenses, which we can likewise estimate with some, though not very great, accuracy, by data now supplied by the improvements of the country.

Application of the formula to Active Works.

I shall apply this method of computation, in the first place, to a railroad in Georgia, 147½ miles long, with easy grades and little business; next, to one in Massachusetts, 156 miles long, with grades of more than 80 feet to the mile, on which the engines travel nearly four hundred thousand miles per annum, and where the trade and travel are both great; I will then apply it to a short road in the State of New York, which carries no tonnage at all, but which derives its revenue entirely from passengers, and which has moderate grades, and a moderate business; next, I will make the application to a road in Maryland 70 miles long, with grades of 84 feet, and which derives two-thirds of its revenue from tonnage. Finally, I will apply it to a road in Pennsylvania 56 miles long, with favorable grades and moderate business—and again to the same road the next year, when extended 38 miles further, and having an increase of business.

The following table gives the length, grades and business of these roads; and, in the two last columns, are placed, side by side, the actual and calculated expenses.

TABLE exhibiting the actual and computed cost of maintaining
New Roads, calculated from the formula,

$$\frac{24}{100} N + \frac{9}{1000} T + \frac{7}{1000} P + 500h.$$

Name of Road.	Length, miles.	G'de, in ft.	M. trav- eled by engines.	Thro' tonn'e.	Thro' travel.	Expenses.	Calculat'd expenses.	Year.
Georgia Road,	147½	37	152,873	10,000	12,000	\$109,819	\$106,605	1842
Western Road,	156	83	397,295	40,000	53,000	256,619	256,187	1842
Syracuse and Utica,	53		84,000		70,769	62,325	62,315	1842
Baltim'e & Susqueh'a.	70	84	128,349	23,000	16,500	75,224	74,379	1842
Reading Road,	56	19	83,717	24,000	31,453	62,635	61,318	1841
Reading Road,	94		198,055	65,000	33,720	138,900	152,911	1842

The roads named in this table are all those which have been completed less than four years, of which I have been able to procure the trade and travel, aggregate expenses, and distance run by the locomotive engines for the year 1842. In some of these I have been compelled to deduce the through tonnage from the receipts and prices—the reports giving only the aggregate tonnage ;—in general the through travel is given with precision.

The agreement between the actual and calculated results in this table, is most remarkable, and exhibits a degree of uniformity in the administration of the lines, which could not have been anticipated. Indeed it is most probably because the roads are so new that the agreement is so perfect. When they begin to feel the effects of time and use, they will give way unequally, and exhibit much wider deviations from the rule. This fact is exemplified in the following table, which exhibits the results of experience on ten important railroads, selected from different sections of the country. The roads in this table vary in length from 14 miles to 136 miles; in grades from 10 ft. per mile, to 83 ft. per mile; in freight from nothing to 94,000 tons; in travel from 7,000 to 180,000 passengers; and in expenses from 30,000 to 225,000 dollars per annum.

TABLE exhibiting the actual and computed cost of maintaining roads which have been completed more than four years, calculated by the formula,

$$\frac{27.5}{100}N + \frac{14}{1000}T + \frac{7}{1000}P + 500h.$$

Name of Roads.	Year.	L'gth in miles.	Gr'de. in feet.	Miles run.	Thr'gh tonna'e	Thr'gh travel.	Actual expenses.	Calculat'd expenses.
Boston and Providence,	1842	42	38	120,000	21,200	117,129	\$101,596	\$100,897
Baltim'e and Washing'n,	1841-2	30½		91,428	27,369	114,260	73,684	76,166
Petersburg Road,	1842	61	30	131,160	22,000	16,000	96,398	92,489
Nashua and Lowell,	1841	14	10	44,040	28,663	85,737	30,708	33,131
Baltimore and Ohio,	1842	82	82½	299,617	44,477	34,380	220,135	192,925
Portsmouth & Roanoke,	1842	79		96,900	5,975	7,662	73,345	76,703
Boston and Lowell,	1842	26	10	143,607	93,927	179,819	131,012	119,409
Philadelp'a & Columb a,	1842	82	45	261,844			116,000	112,979
S. Carolina Road,	1842	136	35	260,324	27,000	24,000	225,743	213,945
Boston and Worcester,	1842	44½	42	241,319	61,911	165,720	168,509	176,815
Utica and Schenectady,	1841-2	78		152,764		114,527	154,436	143,542

[NOTE.—The miles run on the *Petersburg Road* are assumed to be the same as in 1841; the tonnage is estimated from the tonnage of 1841, with an allowance for the increased receipts. The results on the *Baltimore and Ohio Road* for 1841 are preferred, because those of 1842 are complicated by the extension of the line to Cumberland. The report of the *Philadelphia and Columbia Road* contains only the expenses of motive power and repairs; the freight and passengers are conveyed by other parties; we have, therefore, in the formula to make $P=0$ and $T=0$, for this case. The tonnage and travel on the *South Carolina Road* are deduced from the printed reports. The actual charges on some of the lines will be seen to differ from other published statements; this will be found to arise from the fact that

these statements contain charges for interest, ferries, cars, and motive power on branch roads, which are rejected in this comparison.]

Here is presented a list of eleven roads, situated in different sections of the country, and offering every variety of length, grade and business that could be desired, in order to put the formula to the severest test. The greatest difference which is exhibited in the whole list between the actual annual cost of maintenance, and the estimated cost, is *12 per cent.*; certainly no closer agreement could be expected, since the actual expenditures fluctuate to that extent—and, perhaps, through wider limits—from year to year; the removals of decayed timber, and various contingencies, being found much more extensive some years than others. In looking over the list I am able to account, in almost every instance, for these departures from the formula, by my personal knowledge of the situation of the line. It will probably be seen on some future occasion, that those roads which now exhibit expenses above the formula, will fall below it for other years—a remark which is applicable to the Boston and Lowell, Baltimore and Ohio, and South Carolina Roads.

It is no part of my object to flatter the expectations of railroad companies, but to exhibit to them and the public the truth; to those companies whose works are now new, and who *seem* to be making money, I would suggest the timely formation of a contingent fund, to prepare them for a contingency which will as surely reach them as the next new year. It is bad policy to divide the *annual expenses* as if they were real profits; the money that is earned at the expense of the rails, cars, and machinery, should be hoarded to replace those things, and not distributed, as if they were to last forever. It can be shown that every company should annually store away, in times of prosperity, while their work is new, at least 6 cents for every mile travelled by their engines, 1 cent for every ton conveyed one mile, and 200 dollars for every mile of road, to replace decayed materials, and injured iron and machinery. If their profits will not permit that reservation, then the prudent man will avoid their stock; and the company should cut down their expenses to the limit assigned by the trade. Where these expenses do not consist of interest on debt, this retrenchment is almost always possible.

In the first of these tables the Reading Railroad appears to escape the application of the rule; the calculated expenses exceeding the actual charges, as stated by the company, some \$14,000, or about 10 per cent. There has probably been a division made between the current and contingent expenses on this line; indeed, on inspecting the published exhibit, I find that the whole sum set down for *timber* used in repairing 94 miles of road, including rails, sills, &c., is just \$2,431. Now, I know personally, that twice that sum would not pay for the timber required for repairing the bridges alone; the bridge account last year must have amounted to more than \$12,000, and seems not to be included in the published statement. This sum being added to the published total, brings the year's expenses up to \$151,000, or within $1\frac{1}{4}$ per ct. of the formula. Perhaps the company regard the loss of a bridge as so extraordinary an occurrence, that it can never take place again; but

their report already points to another which is found to be "less permanent than the rest;" and time will show that no part of railway superstructures will long remain permanent under the action of heavy engines and their trains. Besides there will be freshets, and tornadoes, and fires; and on a road which has a great many bridges constructed of perishable materials, and which is travelled by 25 or 30 locomotives every day, or about 10,000 trains a year—with engines using pine wood for fuel—many accidents must be expected. One bridge per annum is a small allowance for the average loss; and if the bridges happen to be fortunate, there will be rotten sills, or crushed iron, enough to compensate for the difference.

We perceive then that the formula applies also to this road; and I will now insert a table exhibiting its application to all the roads of which I have been able to obtain the amount of trade, and annex a column showing the percentage of error for each; not having the number of miles run by passenger and freight engines separately in every instance, I make use of the mean value 27½ cents per mile run.

TABLE.

Name of Road.	Year.	Lth.	G's.	Miles run.	Through tonnage.	Through travel.	Actual expenses.	Calculated expenses.	Error per cent.
Georgia Road,	1842	147½	37	152,873	10,000	12,000	\$ 169,819	\$ 106,665	-38
Western Road,	1842	156	83	397,295	40,000	53,000	236,619	256,187	0
Syracuse and Utica,	1842	53		84,000		70,769	62,325	62,315	0
Baltimore and Susque'a.,	1842	70	84	128,349	23,000	16,500	75,231	74,379	-1
Reading Road,	1841	56	19	83,717	24,000	31,453	62,635	61,318	-2
Reading Road,	1842	94	35	198,055	65,000	33,720	151,000	152,911	+14
Boston and Providence,	1842	42	33	120,000	21,200	117,129	101,596	100,972	-3
Baltim. and Washington,	1841-2	30½	91	428	27,569	114,260	73,684	76,193	+34
Petersburg Road,	1842	61	30	131,160	22,000	16,000	96,398	92,410	-4
Nashua and Lowell,	1842	14	10	44,040	23,663	85,737	39,708	33,131	+8
Baltimore and Ohio,	1841	82	82½	299,617	44,477	31,380	220,135	192,935	-12
Portsmouth and R. anoke,	1842	79		96,000	5,975	7,682	73,345	76,703	+5
Boston and Lowell,	1842	26	10	143,607	93,927	179,819	131,612	119,409	-9
South Carolina Road,	1842	136	35	260,324	27,000	24,000	235,743	213,945	-5
Boston and Worcester,	1842	44½	42	241,319	61,911	165,720	168,509	176,831	+8
Utica and Schenectady,	1841-2	78		152,746		114,527	154,456	142,542	-8
Philada. and Columbia,	1842	82	45	261,744			116,005	112,979	-24
Aggregate,		1251		2,886,292	Tons 1 mile, 33,360,560	Pas. 1 mile, 57,726,906	\$ 2,109,183	\$ 2,068,163	

One word more in reference to this table. I offer here a list of 17 railroads, presenting almost every conceivable variety of length, grade, and character. It is not a *selected* table, but contains the results of one year's operations on *every* road, without exception, concerning which I have been able to obtain the necessary data—materials which have only been procured by dint of great exertion. It will be seen that the management upon these various lines is very nearly uniform, and that they are *all* obedient to the *law*. The greatest departure from the formula is 12 per cent.

Now, this list embraces roads which are situated in every one of the sea-board States from Maine to Georgia; the aggregate length of line exhibited is 1251 miles; the engines traverse annually a space of 2,886,300 miles, and they carry no less than 33,360,560 tons, and 57,726,906 passengers one mile. The aggregate ordinary expense of maintaining this length of line, and accommodating this amount of tonnage, is actually \$2,109,188 annually, and the calculated expense \$2,068,165. The difference between the calculation and the fact is \$41,023, or less than two per cent.

I conceive, therefore, that I have authority sufficient for announcing this formula as expressing the law of railroad expenses—a law to which all the roads in the country are obedient. If stronger evidence of its correctness could be offered, I know not in what it would consist. It is in vain to urge here that a certain road has peculiarly steep, or peculiarly light, grades, which should exempt it from the application of the rule. The formula which I announce, accounts for these differences. When the grades are easy, the engines make fewer miles, and the rule looks only to the miles.

There is yet another point of great importance connected with this subject, which ought not to be overlooked, viz., the “extraordinary expenses.” It is the custom among too many of the parties interested in the railroads of this country, to look upon the suggestion that iron may be worn out, as a thing so chimerical and visionary, as to be entirely unworthy of their sober thoughts. In the course of a few years they are surprised by the fact—the certainty—that money must be raised, and that their iron *must be* renewed. Instead of being warned by experience, and commencing immediately the work of retrenchment, and the provision of a surplus fund to meet the recurrence of the contingency, they look upon it as extraordinary in the extreme—a sheer accident, which cannot occur again, or which can be warded off by a heavier iron. Experience and common sense teach that heavier iron will be attended with heavier expense; but they have *not yet* taught that the wear will be less. A heavier rail will longer resist a given trade; but will each dollar put into the heavy rail go farther? This, however, is a subject which must be reserved for a future number of the Journal.

To be Continued.