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## **Cost of transportation on railroads**

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**COST**

**OF TRANSPORTATION**

**ON**

**RAILROADS.**

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**BY CHARLES ELLET, JR.,**  
**CIVIL ENGINEER.**



**PHILADELPHIA:**

1844

1850

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## P R E F A C E .

The following pages were written at intervals, during the years 1842-3 and 4, and printed in a series of numbers in the Journal of the Franklin Institute.

The reader will find some slight changes in the values of the coefficients, which are to be attributed to the influence of facts and experience, which were obtained during the progress of investigations always aiming at, and gradually approaching, the truth.

PREFACE.

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ON THE  
COST OF TRANSPORTATION  
ON  
RAILROADS.

BY C. ELLET, Jr., C. E.

1842.

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OF THE

COST OF TRANSPORTATION

OR

RAILROADS

BY G. ELLET, A. C. E.

1842

ON THE  
COST OF TRANSPORTATION, &c.

FROM THE JOURNAL OF THE FRANKLIN INSTITUTE.

I have never yet seen any formula, derived from the experience of active lines, by which the cost of transportation on railroads may be determined with an approach to accuracy. The expenses of maintaining a line of railroad are not *all* proportional to the distance traveled by the locomotive engine, nor to the tonnage conveyed; neither are they all independent of either of these considerations. But the aggregate annual cost is made up of certain items, which are, in fact, nearly proportional to the distance run by all the engines; of others which are strictly proportional to the tonnage conveyed; and of some which are nearly, or quite, independent, both of the trade and of the distance traveled.

I offer the following rule for the determination of this aggregate, in the belief that every well managed railroad, of ordinary construction, carrying engines of ordinary power, where the transportation is effected at the usual speed, and which accommodates a respectable amount of business, will exhibit results in close agreement with its indications. This formula is derived from the considerations which follow, and the constant quantities are supplied from the best experience I have been able to obtain from the past management of the public works of this country. In course of time, when the velocity of burthen trains is reduced to three or four miles per hour, and companies learn to know where and how to economize, it is probable that some of the items may be reduced; but time and experience have yet to decide how much.

I. *Repairs of Road.*—The repairs of a railroad consists of two distinct divisions; the first of which is nearly independent of the amount of the trade, and may be estimated, on the average, at about \$500 per mile. The second division is dependent on the amount of the tonnage, and represents the injury done to the road by the passage of one ton of freight. I estimate this wear and tear at  $\frac{3.5}{100}$  of a cent per ton per mile.

II. *Expense of Cars.*—The expense of repairing and renewing the burthen cars is proportional to the distance which they run, or to the tonnage of the line; and may be estimated at  $\frac{4.5}{100}$  of a cent per ton per mile.

III. *The expense of agents, conductors, the force at depots, breakmen, and contingencies of all sorts*, is likewise nearly proportional to the business of the road, and cannot be assumed at less than *six mills per ton per mile*.

IV. *Locomotive Power*.—The expense of repairs and renewals of locomotive engines and tenders, the cost of fuel, and the pay of enginemen and firemen, are nearly proportional to the distance run, and may be estimated at *thirty cents per mile traveled by the engine*.

Now, to express the cost of maintaining a line of road, under good management, for one year, let us represent by

N the number of miles run by all the engines;

T the whole number of tons net conveyed one mile; and

h the length of the road in miles.

Then, according to the foregoing data,

$$\frac{3 N}{10} + \frac{14}{1000} T + 500 h.$$

will be the aggregate annual cost in dollars, (where the business consists exclusively of tonnage,) of maintaining the line and its equipage.

If the road accommodates a mixed business, of trade and passengers, to obtain the aggregate expense, we must add  $\frac{1}{100} P$ —where P represents the whole number of passengers carried one mile.

This formula takes proper account of the difference of grades, but is not applicable to very short roads—to roads doing a very inadequate business—by which I mean less business than can be accommodated by one engine—nor to the first four years' operation, while the road, cars, and locomotives, are yet all new.

By applying this rule to the active lines of the country, it will be found that the larger establishments—those which possess a valuable trade—give very similar results.

There are none on which the expenses fall within the limit assigned by the formula, excepting, perhaps, one or two which have been recently completed, and on which the cost of renewing the iron, timber, bridges, cars, and locomotives, is not yet very sensibly felt. It will be found to suit those cases better a few years hence.

*On the Value of Gradients.* In the preceding remarks I proposed a formula for the determination of the cost of transportation on railroads. I am aware that that expression is not in accordance with the opinion which now prevails in regard to the economy of railroad conveyance; and that there are many gentlemen of experience and reputation who are prepared to adopt a much lower estimate than mine. But, until some road can be adduced on which the experiment has been tried long enough to exhibit a result which can be received as a fair average, and which authorizes lower constants, I cannot consent

to the reduction of the formula. In its present state it gives a measure below the actual performance on any road in the United States.

I am also aware that, in not presenting the average cost of freight in any particular number of cents per ton per mile; or in any particular sum per mile traveled by the locomotive engines, I have deviated from the popular and most approved methods of treating the subject. But I regard the aggregate cost per mile run as no guide whatever to the economy which characterizes the management of a railroad; and deem it an unauthorized assumption that because this sum is, in any instance, unusually low, the work is conducted with more than ordinary success. The fact, where it exists, can only be used to prove, if other circumstances remain the same, that the engines have taken smaller loads, and made a greater number of trips, and run more miles, than was absolutely necessary. In fact, if we admit, what cannot well be denied—that under similar circumstances, and with engines of the same class, the cost of locomotive power is proportional to the distance run—or that the cost of running one mile is not *diminished* by *increasing* the load, it follows as a consequence that, *cæteris paribus*, *the more economical the administration of a road, the greater will be the aggregate cost per mile run by the locomotive engines.*

Neither is the circumstance that the aggregate expenses of a line for one year divided by the number of tons conveyed, exhibits a low average per ton per mile, any test of good management. The fact, by itself, is more likely to prove that the tonnage was great than that the administration was judicious.

I shall now proceed to deduce from this general expression of the cost of freight, certain consequences of the utmost importance in the location and establishment of railroad lines, which I believe have hitherto been little, if at all, regarded.

*What is the Value of Gradients?* I mean by this question, how much more is a railroad having gradients of thirty feet per mile worth than the same road with grades of forty feet per mile? Or, how much money would good economy authorize an engineer to expend, in the construction of his road, in order to reduce the limiting gradient any given amount?

I have seen various intricate and laborious solutions of questions which involve the loss of *time* and the consumption of *steam* in the ascent of gradients; but I have never yet met with any examination of this interesting and all important problem. The loss of *time*, in this country, is usually a matter of little consequence in the transportation of merchandize; and experience teaches that the cost of motive power is very nearly proportional to the distance traveled by the engine, and very little affected, within the limits which ordinarily

occur in practice, by irregularities in the tractile power. It is no doubt true that if we were to make observations under extreme circumstances—as where the engines move on a perfect level, and where they frequently mount the steepest grades they can possibly ascend without loads—the cost of motive power per mile run, would be found to exhibit very considerable variations. The charges for fuel, as well as for repairs, would be materially increased by the increase of the acclivity of the grades. But we have no such extreme cases in practice; and the following investigation is based on the authorized assumption that the cost of running the locomotive engine and its tender, without other load, is proportional to the distance run, and independent of variations of the tractile force consequent on the ordinary irregularities of grade.

In the preceding remarks, the aggregate annual expenses of a line of railroad under good management were represented by this formula,

$$\frac{3N}{10} + \frac{14T}{1000} + 500h, \quad (A)$$

In which  $N$  is put for the number of miles traveled, during the year, by the locomotive engines,  $T$  the number of tons net carried one mile, and  $h$  for the length of the line.

This formula, it will be observed, expresses the cost of transportation without any express computation of the effect of the grades over which the tonnage is carried. Nevertheless, the result which it yields is not independent of the grades; for they enter into the value of  $N$ , and control the number of miles traveled by the engines. The variation of the maximum gradient will not cause a sensible variation of any item of the aggregate cost of transportation excepting that of the locomotive power.

Now, in deducing the changes in the cost of locomotive power consequent on changes of grade, I shall assume that the circumstances of the trade are such as will permit that the machine be always started with a full train—that is to say, with the largest train which it is certain to control on the limiting grade. In many instances this assumption is not strictly in accordance with the facts; since it is frequently advisable—particularly where the grades are light, and the trade inconsiderable—to effect a portion of the transportation with imperfect loads. In such cases greater ascents might obviously be encountered without increasing the cost of carrying every train; and the effect of assuming that the trains are all full, when a portion of them is not full, will evidently be, to render the estimated increase of cost consequent on the gradient somewhat higher than it really is.

The formula is intended to fix a *limit* within which the actual value of the grade must always be found; and as it should be the object of every company to do their transportation with the least possi-

ble labour, and at the least possible cost, the number of miles actually traveled ought to approach very nearly the number corresponding with the assumption of full trains; and consequently, except in extreme cases, the estimate should not be much in excess. But if the situation and circumstances of the line be such as will preclude the probability of loading all the tonnage trains to the proper limit, some allowance may be made, in the application of the formula, for that portion of the trade which it does not embrace.

Now, if the limiting gradient of the road be changed, the number of miles traveled by the locomotive engines will also be changed. If the load be reduced one half by the introduction of any plane, the number of trips, and, consequently, the cost of locomotive power, will be very nearly doubled by the admission of that plane.

But the number of miles traveled by the engines in the course of a year, supposing them to convey full loads, and the transportation, accordingly, to be effected with the greatest possible economy of power, will be expressed by

$$\frac{2 T'}{n} = N,$$

Where  $n$  is put for the average gross load in tons, up the limiting grade, and  $T'$  for the gross weight in tons carried in full trains one mile in the direction to which that gradient is opposed.

We know, from satisfactory experiments, that an inclination of twenty feet per mile, on a road in good adjustment, requires for its ascent a power nearly double; and one forty feet per mile a power treble, and one of sixty feet a power quadruple (or, for grades under eighty feet, very nearly in this proportion) that which is required to draw the same weight on a level. In other words, if  $W$  be the gross load an engine is capable of drawing with safety and certainty on a level road, and  $x$  the inclination, in feet per mile, of the gradient which limits the load, then

$$\frac{20}{20+x} W = n$$

will be the load, near enough for our object, with which it can mount the plane ascending  $x$  feet in a mile.

If we now designate by  $C$  the cost of running the engine with its tender only, one mile; by  $c$  the additional cost of motive power per mile, due to each ton gross added to the load—then  $C + cn$  will be the whole cost of motive power per mile run. This sum may be written

$$C + c \frac{20 W}{20+x},$$

by substituting for  $n$  its value expressed in terms of the grade and the power of the engine.

If we now multiply this sum by  $2 T' \frac{20+x}{20 W}$ , the number of miles that ought to be traveled by all the engines in the course of a year, we shall obtain for the whole annual expense of motive power

$$2 T' \left( C \frac{20+x}{20 W} + c \right),$$

and for the whole annual cost of maintaining the line and transmitting the trade which it receives

$$2 T' \left( C \frac{20+x}{20 W} + c \right) + \frac{14 T'}{1000} + 500 h; \quad (B)$$

in which we have the aggregate cost of transportation, with the greatest attainable economy of power, cleared of the number of miles traveled by the engine, and expressed in terms of the particular grade which controls the cost of power.

In order to determine the sum which we might expend for the reduction of this limiting gradient, which is the problem under consideration, we must ascertain the value of this formula for different values of  $x$ , and take the difference between those values.

If we now suppose  $x$  to assume the new value  $x'$ , the corresponding difference produced in the aggregate annual expenses by the change of gradient, supposing still that the trains are full, will be

$$2 C \frac{x'-x}{20 W} T'. \quad (C)$$

*The increase of expenses is proportional to the increase of the sine of the angle of inclination of the gradient; and directly proportional to the gross tonnage which ascends the limiting grade, in full trains, and reciprocally as the power of the engine capable of running one mile at the assumed cost of locomotive power.*

The value of gradients, or the expenses which they produce on railroad lines, will diminish, therefore, proportionally to the improvement in the power of the engines.

Let us now substitute for  $C$  its value—three-tenths of a dollar—and put  $x'-x=1$ ; and we shall obtain

$$\frac{3 T'}{100 W} \quad (D)$$

for the increase of the annual expenses of a road consequent on the addition of one foot per mile to the acclivity of the limiting slope.

It is not easy to assign the proper measure of the average power of the freight engines now in use; but if we assume 300 tons gross for the maximum load on a level at all seasons of the year, of engines of the medium class—from ten to twelve tons weight—we shall not be too low for the present condition of the machine, and the average power of all good engines of that class.

With this addition to the *data* of the problem, we shall have

$$\frac{T'}{10000} \quad (E)$$

for the annual value, in dollars, of one foot in the acclivity of the maximum, or limiting, gradient.

If we now capitalize this quantity, or determine from it the original outlay of capital which would be justifiable in order to avoid an increase in the ascent of *one foot per mile*, we shall find it to be

$$\frac{1}{600} \text{ of a dollar,} \quad (F)$$

or  $1\frac{2}{3}$  mills for each gross ton carried one mile—the value of money being taken at 6 per cent.

In other words, to find the value of any reduction of the acclivity of the limiting grade, on ordinary railroads,

*We multiply the number of tons gross carried up that grade in full trains by the length of the line* (or by the distance run by the engines which cross the grade in question,) *and by the number of feet per mile in the ascent which it is proposed to save, and divide by 600.* The result will be the value of the reduction of the grade, in dollars.

There is one point in this annunciation, worthy of remark, and which I believe is never regarded in the consideration of such subjects—if indeed this question itself has ever received any consideration. The amount which may be paid, or ought to be expended, for the reduction of the maximum grade, *is proportional to the length of the road*, if the engines run “through;” or proportional to the length of the “stage” on which the gradient is found, if the line be very long and divided into stages. And this law will continue to apply until it becomes more economical to employ one or more assistant engine to aid in the ascent of such grades; in which case the value of these auxiliary engines, or the expenses which they involve, limits the sum which may be expended in the reduction of the acclivity.

For the purpose of an application of the rule which I have announced, let us suppose that the road is thirty miles in length; that the duty to be exacted of the engines is equivalent to 20,000 tons gross conveyed “through” in the direction to which the limiting gradient is opposed; and that the cheapest admissable line would present a gradient of fifty feet per mile. How much could we afford to expend, in the construction of the road, in order to reduce this limit to forty feet? By the formula (F) we have

$$\frac{20,000 \times 30 \times 10}{600} = \$10,000.$$

The comparison of this result with the cost which would be actually required, under the circumstances, controls the location. But if the trade in this case had been assumed at 200,000 gross tons, and the length of the line sixty miles, the value of ten feet per mile in the limiting gradient would have been

$$\frac{200,000 \times 60 \times 10}{600} = \$200,000.$$

The magnitude of this last result would, of course, bring up the question of the relative economy of auxiliary power, which would be wholly inadmissible in the former case. Should the comparison determine in favour of assistant engines for the limiting gradient, our equation would then become applicable again to the determination of the value of the next highest gradient, or the sum which might be expended in its reduction.

In the preceding numbers I have offered convenient and appropriate formulas for computing the cost of transportation on railroads, and determining the effect produced on that cost by variations in the acclivity of the limiting gradients. I propose now to ascertain the value of any increase or diminution of the length of the line in terms of that grade; that is to say, to determine how many feet per mile the steepness of the limiting gradient may be increased for the purpose of saving one mile of distance; or what increase of distance will be justifiable in the development of a road for the purpose of reducing the line to a level, or of saving any given amount in the rate of ascent of the limiting gradient.

For this purpose we will recur to our formula (B), which expresses the annual charges of the company, and write it thus—

$$\left( 2 C \frac{20 + x'}{20 W} t' + c t'' + \frac{14 t}{1000} + 500 \right) h;$$

in which  $x'$  is put for the empirical, or accidental grade, in feet per mile, which it is desirable to relieve;  $t'$  the number of tons gross which annually ascend that grade in full trains;  $t$  the number of tons net annually transported through the line, in both directions and in full trains;  $t''$  the number of tons gross carried through the line;  $C$  the cost of running a freight engine with its tender one mile;  $c$  the additional cost of locomotive power for each gross ton carried one mile, and  $h$  the length of the road in miles.

It will, of course, be observed that this formula is applicable only to roads which are used exclusively for the conveyance of freight, and is obtained in the supposition that all the engines are loaded to their maximum capacity on the limiting gradient. But in all lines used for general travel, the passenger trains, at least, and sometimes a portion

of the freight trains, are much lighter than the engine is capable of conveying on this grade.

In order, therefore, to express correctly the aggregate annual expenses, *on such lines*, and to render the equation, which it is proposed to deduce, as general as possible, we must add to the above formula the cost of motive power for the number of miles traveled by the engines which are not fully loaded, and the expenses incident to the conveyance of the whole number of through passengers, which are not covered by the cost of power. These expenses have already been stated to be  $\frac{p h}{100}$ , where  $p$  represents the number of passengers carried "through;" and if we represent by  $N'$  the number of trips made by engines carrying passengers and less than their full complement of freight, and by  $C'$  the cost of running such engines with their tenders one mile, the expression of the aggregate annual expenses, in its most general form, will become

$$\left( C' N' + 2C \frac{20 + x'}{20 W} t' + c t'' + \frac{14 t}{1000} + \frac{p}{100} + 500 \right) h; \quad (G)$$

in which only one of the terms is affected by the value of the grade.

This is a modification of the approximate formula (A), given in a previous number, and is expressed in different terms, though it yields very similar results.

By means of this expression we may readily compare the merits of two lines, of different lengths and grades, and accommodating the same, or different amounts of tonnage, and determine the difference between their values. For this purpose we have only to substitute for the notation the actual values of the gradients, and the lengths of the two lines, and calculate by the equation the annual charges which they respectively involve.

It was from this expression in the simpler state in which it may be presented for application to a road on which the business is restricted exclusively to the transportation of freight, that we determined, in the preceding number, the sum which might, with propriety, be expended for the reduction of the limiting gradient. But we are not to regard that expression as authorizing a diminution of the acclivity of the gradient, at the expense of any augmentation of distance, unless the value of the increase of the distance be taken into the account. Any increase of the length of the line of the improvement necessarily involves an increase of expense for its maintenance; for the locomotive power which traverses it, and for the cars which pass over the additional distance. The value of this increase of the annual charges consequent on any augmentation  $h' - h$  is obviously

$$\left( C' N' + 2 C \frac{20 + x'}{20 W} t' + c t'' + \frac{14 t}{1000} + \frac{p}{100} + 500 \right) (h' - h); \quad (H)$$

an expression from which we are able to calculate immediately the annual value of any augmentation or reduction of the length of the road, and consequently the sum which it would be expedient to expend for the purpose of effecting any given reduction.

But we have already seen that if we diminish the inclination of the maximum gradient any quantity  $x' - x$  feet per mile, we simultaneously reduce the aggregate annual expenses the amount represented by the expression

$$2 C \frac{x' - x}{20 W} t' h.$$

In order, then, to determine the change in the length of the line which will have the same effect on the cost of transportation as any given reduction of the limiting gradient, we must equate these two quantities, and deduce from the equation the value of distance, or  $h' - h$  in terms of the change of gradient. This operation produces for the expression of the quantity which we will be authorized to increase the length of a road for the purpose of reducing the limiting gradient, of which the ascent is  $x'$  feet per mile, down to any other rate  $x$  feet per mile,

$$\frac{C}{10 W} \frac{h t' (x' - x)}{C' N' + 2 C \frac{20 + x'}{20 W} t' + c t'' + \frac{14 t}{1000} + \frac{p}{100} + 500} = h' - h. \quad (I)$$

The augmentation of the length of the road adequate to compensate for any given reduction of the limiting grade, is therefore directly proportional to the original length, and reciprocally, or very nearly so, as the power of the engines used in the conveyance of the freight. The greater the tonnage which ascends the limiting gradient, the greater is the distance that the length of the line may be increased in order to reduce that gradient any given amount per mile; and the greater the power of the engine kept in operation at a given expense per mile run, the less would be the increase of the length of the road for the same purpose. The greater the number of passengers that are carried in light trains, and the greater the proportion of the tonnage which is conveyed by engines loaded below the maximum due to the limiting grade, the shorter must be the line and the steeper the grades. The measure of all these influences is deducible from the formula, which I regard as the true equation of distance. It is expressed in as accurate terms as it is practicable to obtain with our present experience. In course of time the co-efficients may, perhaps, be advan-

tageously modified, to suit the more precise determination of the value of railway constants, which we may anticipate from the increasing facilities which are offered, and the more accurate observations which such facilities will permit.

In order to apply the formulas, we must determine the values of  $C$ ,  $C'$  and  $c$ . Of the two first,  $C$  may be estimated, in ordinary cases, at three-tenths of a dollar, and  $C'$  at a quarter of a dollar; and experiment will justify the assumption of a half mill per mile for the average increase of the cost of motive power, due to each gross ton added to the load of the engine—a fact which is expressed by the equation  $c = \frac{1}{2000}$  of a dollar. In the formula  $t''$  is put for the gross tonnage of the line, consisting of passengers and freight and the cars which contain both, whether attached to engines conveying full or partial loads.

Let us take the following case for an example. The length of the road, by the preliminary survey, is 30 miles; the limit grade which the eye and judgment have established on the profile, is 40 feet per mile; the anticipated freight is 60,000 tons net, and is likely to be so divided in direction that there will be found an annual gross weight of 40,000 tons ascending this limit grade. The tonnage trains are supposed to be full, and the gross weight of cars, freight and passengers is 130,000 tons. The number of through passengers is 20,000, and the power of the engines intended to be used is adequate to the command of 300 tons gross on a level road. Now,

I. How much would it be good policy to expend in the construction of this road in order to reduce the grade which limits the load from 40 feet down to 30 feet per mile?

II. How much could we afford to pay for the reduction of the length of the road one mile?

III. How much would we be authorized to increase the length of the road in order to reduce the rate of ascent of the limit grade ten feet per mile?

IV. How much would we be authorized to increase the length of the same road in order to reduce the limit grade ten feet per mile, in the supposition that no passengers are to be conveyed, and that the gross tonnage is all conveyed in full trains, and amounts, exclusive of passengers and their baggage, to 120,000 tons?

Now we have  $C' = \frac{1}{4}$ ;  $C = \frac{3}{10}$ ;  $c = \frac{1}{2000}$ ;  $t = 60,000$ ;  $t' = 40,000$ ;  $t'' = 130,000$ , and for the fourth problem 120,000;  $p = 20,000$ ;  $h = 30$ ;  $x' = 40$ ;  $x = 30$ , and  $W = 300$ .

The appropriate quantities being substituted in equation (F) will give, in answer to the first problem,

$$\frac{40,000 \times 30 \times (40 - 30)}{600} = \$20,000:$$

or, it would be worth while to expend 20,000 dollars in grading the road to reduce the ascent of this limiting slope ten feet per mile, providing we do not thereby incur any increase of the cost of maintenance, or any augmentation of distance.

Again, by inserting the values provided by our data in equation (H) we obtain, for the solution of the second problem, in the supposition that the passenger trains make two trips a day, or that  $N' = 730$

$$\frac{730}{4} + \frac{3}{5} \cdot \frac{20+40}{20 \times 300} \times 40,000 + \frac{130,000}{2,000} + \frac{14 \times 60,000}{1,000} + \frac{20,000}{100} + 500 =$$

2,027 dollars, for the annual charge incident to each mile of the length of this particular road. We multiply this quantity by  $\frac{100}{6}$  to obtain the equivalent capital, which we find to be \$33,783.

It would be worth about \$34,000 to reduce the length of this road one mile.

Again, by inserting these values in equation (I) we will obtain in solution of the third problem

$$\frac{\frac{3}{10} \times 30 \times 40,000 (40 - 30)}{3000 \left( \frac{730}{4} + \frac{3}{5} \cdot \frac{20+40}{20 \times 300} \times 40,000 + \frac{130,000}{2,000} + \frac{14 \times 60,000}{1,000} + \frac{20,000}{100} + 500 \right)} = \frac{1200}{2027}$$

or about *four-sevenths of a mile*. On such a road, the value of ten feet in the limiting grade is only equal to four-sevenths of a mile in distance, although that grade is not opposed to the heavy trade—a fact which should prompt us to be on our guard when we attempt to reduce the grades of a road by an increase of distance before we have examined well into the character and amount of the trade which is to be accommodated.

Finally, we shall have, for the solution of the fourth problem,

$$\frac{\frac{3}{10} \times 30 \times 40,000 (40 - 30)}{3000 \left( \frac{3}{5} \cdot \frac{20+40}{20 \times 300} \times 40,000 + \frac{120,000}{2,000} + \frac{14 \times 60,000}{1,000} + 500 \right)} = \frac{40}{55}$$

or about *five-sevenths of a mile*:—showing that we can increase the length of this road 25 per cent. more, for the purpose of reducing the grade any given amount when we carry no passengers, although the amount of freight is the same, than when the road is destined, in part, for the accommodation of travel. This is simply to say that the value of distance increases with the increase of every part of the business of the line; while the value of a gradient increases only with that portion of the business which ascends it in full trains.

It may be objected to the method which is here pursued that the

calculations are predicated on data which are exceedingly difficult, if not impossible, to procure, in anticipation of the experimental result. It is certainly true that such inquiries are not free from some difficulty and uncertainty; and it is also true that the engineer must overcome this difficulty or proceed to his work entirely at random. The values of grades and distances turn upon these facts, and they must either be regulated without regard to any principle, or by these, or some similar equations. The application of the equations will, of course, be somewhat inconvenient, since they compel us to know something about the thing we are doing; they compel us, when we propose to cut down a hill or fill up a hollow, to know what it is to be done for, and to judge how much we shall cut, and when we shall stop. But, however inconvenient it may be to answer such inquiries, it is not the less important to study the subject, and learn how to answer them by some better mode than mere conjecture.

It is unnecessary to make additional application of the formulæ. They are remarkably simple and obvious, and by supplying a ready and convenient mode of comparing different lines, or different locations of the same line, they remove many of the difficulties with which every engineer must have felt himself embarrassed in the exploration or establishment of important improvements. They indicate the proper and only convenient general mode of estimating the aggregate cost of transportation under different assumed quantities of tonnage; and teach us, in the location of a line, the correct value of distance—in the calculation of which the cost of freight is the essential element—and at the same time enable us so to regulate the grades that the transportation may not be improperly embarrassed, and that the company may not be induced to pay more for the reduction of the cost of freight than the reduction is worth. These are all matters of great interest, and questions which can never be overlooked by an engineer who faithfully performs his duty. Indeed, they must all be met, and maturely considered, at every step of his progress, or the work which is placed under his professional charge will be found to be a failure, and in all probability soon pass into the hands of assignees, or come under the hammer of the Sheriff. They are always objects of immense consequence in the decision of the great questions of general location, which arise in determining the proper routes for railroads of great extent, passing through districts where different lines, having various pretensions, are presented, and where the comparisons of distances, grades, and elevations are of constant occurrence. They are also important where no such general choice is presented, in determining on the details of the location of every line. A road is scarcely ever surveyed on which there is not found some one gradient which controls the average load of the engine, and which it is desirable to reduce.

The first point to be determined, in all such cases, is the probable amount of trade to be transported. This is the leading fact which should govern all the arrangements which are to be made with a view to its accommodation; and the one which has probably elicited the least attention of all in the construction of the railroads, great or small, of this country. There are some lines which were apparently intended for the accommodation of immense quantities of freight, in the design for which no computation was ever instituted for the purpose of ascertaining the probable amount of the trade, or the sum which that quantity would authorize the company to expend for the purpose of removing given obstructions; and there are others on which the actual tonnage is so small that the directors have yet been ashamed to name it to the public, although, in the construction of their road, they permitted arrangements to be made for its accommodation, on a scale of magnificence which could hardly have been justified in anticipation of the trade of India. More labour has been expended in the transportation of materials for the construction of many roads than would have been required to effect the transportation without them of all the tonnage which they are destined to transmit, for all time to come.

There is, accordingly, no return received for the absorbed capital; these works are failures, and they have failed in consequence of the disrespect of the parties by whom they were destroyed, of the first principles which should control every application of machinery to economical purposes—viz. *to make the power proportional to the duty to be performed—and to expend no more money for any object than the value of the object will warrant.* Had this simple maxim been kept constantly in view in the prosecution of the enterprises which, in this country, have characterized the last twelve years—and been made the test of every plan and every arrangement—there would have been no ruined companies, no railroad auctions, and probably no failures.

In discussing the important questions incident to this subject, the object has been to obtain fair average values of the points at issue, and to deliver the results of the investigation as free from algebraical expressions as is consistent with the necessary accuracy. In this view several quantities, of subordinate consequence, have been overlooked, and the investigation is made to turn upon the essential considerations which rule the result. And this is sufficient; for it is in vain to hope for the attainment of perfect accuracy in questions of this nature, where much uncertainty always prevails in the determination of the value of the data; and the solution which comes within 10 or 15 per cent. of the truth possesses all the accuracy that is necessary to insure the requisite confidence. It is not to *such* errors that companies may

trace their destruction; but to the utter and entire disregard of all the essential quantities, circumstances, and considerations, on which success was dependent.

The ruling fact, which ought to control every movement and every plan, is the number of tons to be conveyed one mile. This quantity is made up of the absolute tonnage and the length of the line. If a locomotive engine of 50 horses power be capable of conveying the daily trade on a road 50 miles long, it follows that an engine of five horses power will be adequate to the conveyance of the same tonnage on a road five miles long. And if an engine of 50, or any other number of horses power is able to accomplish the whole labour required on the first road, the same engine will be occupied but *one hour out of ten* in doing the work of the second road. The shorter road, therefore, requires less power—engines of less weight—rails consequently of less strength—and admits, as we have seen, of steeper grades.

In short, *the number of tons to be carried, and the distance which it is to be carried, control the grades, establish the location, and determine the power; the power required fixes the weight of the engine which supplies it; the weight of the engine rules the strength of the rail by which it is supported, and the strength of the rail limits the weight of the car and its load.*

There are certain obvious relations between the duty to be performed by the road and the capacity of the improvement, and the power of the machinery to be applied on it; and if these relations be not respected, both in the general design, and in all the detail, it can only be by sheer accident that the enterprise is successful.

#### *On the Value of Time.*

In estimating the cost of transportation on railroads I have taken no account, in the preceding numbers, of an item which is generally considered of great consequence in determining the result; viz. *the value of time*. Speed is the peculiar advantage of railroads, and one which is certainly sometimes deserving of much consideration in the administration of the work. I propose to estimate its real value, as nearly as it can be done, in the transportation of passengers and merchandize.

First, then, what are we to regard as the measure of the value of time on any article of merchandize? Is it not the interest on the capital invested in the commodity, at the rate at which the proprietor estimates his profits for the time, added to the rate at which his goods depreciate in value in consequence of detention on the route?

If this be true—and I cannot well perceive what other value than this the *time* lost in their conveyance can possess—let us endeavour

to ascertain to what it will amount under different circumstances; and for this purpose we will represent by

$r$  the rate of interest, and depreciation of the value of the goods, per cent. per annum;

$P$  the value in dollars of one ton of the commodity; and

$V$  any velocity of transportation in miles per hour.

There are 8760 hours in a year; and if we represent this number by  $m$ , the interest and depreciation of the value of a ton of goods, in the space of one hour, will be expressed by

$$\frac{P r}{100 m};$$

and during the time the goods are carried one mile at the velocity  $V$ , it will amount to the sum

$$\frac{P r}{100 m V}.$$

This interest and depreciation, for any other greater velocity  $V'$ , will be for the time consumed in traversing one mile

$$\frac{P r}{100 m V'}.$$

and, consequently, the difference between the values of the two velocities  $V$  and  $V'$  (supposing that the time and speed be well employed, and that the engine drivers do not waste at the stations and depots what he gains on the route,) for each ton and for one mile, will be

$$\frac{P r}{100 m} \left( \frac{V' - V}{V' V} \right). \quad (K)$$

This expression represents the amount which the goods would depreciate while passing over one mile, at the velocity  $V$ , over and above their interest and depreciation while traversing the same distance at the velocity  $V'$ ; or the additional sum which the owner of the goods would be willing to pay to have them carried at the speed  $V'$  instead of the slower rate  $V$ .

Now let us apply this equation to the transportation of coal, and assume for the velocity  $V'$  that which would be likely to have place on a railroad, or ten miles per hour; and for that of  $V$  the ordinary speed of a canal boat, or two and a half miles per hour; for the value of the commodity, *three dollars* per ton, and for the value of the capital employed in the trade, 20 per cent. per annum.

How much per ton per mile would the value of a speed of ten miles

per hour exceed that of two and a half miles? By the equation we have here

$$\frac{3 \times 20}{8760 \times 100} \left( \frac{10 - 2.5}{10 \times 2.5} \right) = \frac{1}{48666} \text{ of a dollar,}$$

or a fraction more than the fiftieth part of one mill per ton per mile. It would appear, then, if this process be correct, that there is but little encouragement to tear the road, and cars, and engines to pieces—augment the risk of accident, and increase the actual cost of transportation 100 per cent.—for the purpose of delivering coal a few hours sooner than it might be effected on a canal at a speed of two and a half miles per hour. If the value of the coal be not more than three dollars per ton at the mine, and the value of the capital engaged in the trade not more than 20 per cent. per annum, the difference to the proprietor could not amount to more than the *fifth part of one cent per ton for the whole time consumed in traversing a space of 100 miles.*

Again, let us suppose that the article is flour, of which the value is six dollars per barrel; and let us, at the same time, assume that the depreciation would be 100 per cent. per annum; which is equivalent to the supposition that it would be entirely destroyed if it were detained one year on the passage, and that the depreciation is uniform during the whole period. We will also suppose that the speed on the railroad is infinitely great, or that a mile might be passed by a locomotive engine in a space of time so short as to be wholly inappreciable; while the speed with which the same article would be transported on a canal is, as usual, two and a half miles per hour.

What is the value of the time lost on the canal in this case? Here we have  $r = 100$ ,  $P = 6$ ,  $V' = \text{infinite}$ , and  $V = 2\frac{1}{2}$ ; which quantities being substituted in the equation yield

$$\frac{100 \times 6}{8760 \times 100} \cdot \frac{1}{2\frac{1}{2}} = \frac{1}{3650} \text{ of a dollar,}$$

or about the *fourth part of one mill per mile per barrel.*

This will be recognized as rather an extreme case; but still it does not justify a high speed,—for three mills per ton per mile is generally not very perceptible among the quantities which enter into the aggregate expenses of a railroad line.

Let us next suppose the commodity to be groceries—such, for instance, as sugar and coffee—of which the value may be assumed at two hundred dollars per ton; and that the interest and depreciation are equal to 20 per cent. per annum. In this case we will find for the difference between the value of a speed of ten miles per hour, and

one of two and a half miles per hour—between the speed of a locomotive and that of a canal boat,

$$\frac{200 \times 20}{8760 \times 100} \left( \frac{10 - 2\frac{1}{2}}{10 \times 2\frac{1}{2}} \right) = \frac{1}{730} \text{ of a dollar,}$$

or about *one and a third mills per ton per mile*. The difference between the value of a speed of five and one of ten miles per hour, would not in this case have exceeded a half mill per ton per mile.

A high speed, then, is not justifiable in the transportation of groceries for the purpose of saving time in the delivery of the freight. If it be adopted at all it must be because the condition of the road, or some other part of the business which it accommodates, renders it imperative, or because the injury which the work sustains in consequence of the greater velocity is not properly appreciated by the parties in control of the line.

We will next take the case of dry goods, of which the average value may, perhaps, be assumed at 2,000 dollars per ton; the interest and depreciation will again be put at 20 per cent., and the respective velocities at two and a half and fifteen miles per hour.

By the formula we have, in this case,

$$\frac{2000 \times 20}{8760 \times 100} \left( \frac{15 - 2\frac{1}{2}}{15 \times 2\frac{1}{2}} \right) = \frac{1}{66} \text{ of a dollar,}$$

*or one cent and a half per ton per mile.*

This sum is nearly equal to the actual cost of transportation on a road in good condition; and it is therefore apparent that in the conveyance of trains composed exclusively of the most valuable goods, a greater velocity than two and a half miles per hour is always proper; but when it is recollected that there is never more than a very small proportion of the merchandize passing over a line, which possesses anything like the value here assumed—2,000 dollars per ton—the adoption of a higher velocity must still be regarded as of very doubtful utility. Even in the case before us—where the value of the goods is assumed at 2,000 dollars per ton—the difference between the value of a speed of fifteen miles per hour and one of six miles per hour, would not amount to a half cent per ton per mile—a sum which would by no means justify a high speed even if the train were loaded entirely with such goods.

If we apply the same method of computation to the conveyance of passengers, and estimate the average value of the time of all the individuals in the trains, at twelve cents per hour, we shall have for the difference between the value of a speed of fifteen miles per hour

and the usual speed of freight boats on canals, or two and a half miles per hour,

$$12 \left( \frac{15 - 2\frac{1}{2}}{15 \times 2\frac{1}{2}} \right) = 4 \text{ cents per passenger per mile.}$$

If the average time of all the individuals traveling be worth twelve cents per hour, the charges on a road where a speed of fifteen miles per hour is adopted, *may be four cents per mile higher than could be demanded on one where a velocity of only two and a half miles per hour is maintained.* Of course there is a great difference between the values put on their time by different individuals, and, of course, too, there must be much uncertainty in fixing upon a general average. But twelve cents per hour, including the expenses incident to the trip, is, by no means, a high estimate for the time of all the individuals traveling in the public conveyances; but yet, low as it is, it shows for the value of the time of one person—exclusive of what mere impatience would prompt him to pay—a sum nearly two thousand times greater than that of a ton of coal, thirty times greater than that of a hogshead of sugar, and nearly three times that of a ton of ordinary dry goods, transported at the same rate.

We may perceive, then, why the superiority of railroads is so much greater in the transportation of passengers than of heavy freight; and how it may happen that a velocity, which is, in the highest degree, economical when adopted for the convenience of travelers, may be ruinous when applied to the transportation of minerals and produce. Indeed, it is difficult to over-estimate the injury which is inflicted on the interests of stockholders, from the continuance of this evil in the management of railroads, although it has been materially abated within the last four years. The value of the additional time which is consumed at the slower rate, is absolutely unworthy of consideration in the conveyance of merchandize; and the only question which ought to occupy the attention of the directory, is the reduction of the actual expenses of the line, and the selection of that velocity which corresponds with the greatest possible economy. The great and constant effort should be to reduce the cost of transportation to the lowest limit. It is not railroads nor canals that increase the trade of a country, or add wealth to the districts which they traverse. It is the reduction of the charges for conveyance which these improvements permit, from which these great advantages are derived: and high speed on such commodities offers no compensation for the high charges which it exacts.

These considerations are applicable only to the value of time on the goods transported. But the loss of interest, and depreciation of the

value of the freight, are not the only losses involved in the adoption of an insufficient speed. The value of the time of the *train, and of the train hands*, is also to be considered, and enters into the complete expression of the actual cost of transportation. If the engines and cars, and the men who conduct them, do less duty than they might accomplish by the adoption of a higher velocity, the value of the time of the increase of stock and force which will be required to effect the same duty at the slower rate, must obviously be charged against that velocity.

It is true that there are cases in which the speed to be adopted is governed by the necessity of accommodating a certain amount of trade, or making room for a large passenger conveyance, which could not be adequately provided for on a single track, without maintaining a speed determined by the circumstances. Of course the company must submit to this necessity; they must adopt a high velocity where these or other imperative conditions exact it. But the question now is, what is the value of velocity or time, where they have the power to exercise their own discretion in the selection of the speed?

In all such cases, the slower the motion of the train the less will be the expenses of the company, unless it be reduced so low that the interest on the cars and engines which convey the freight, and the loss of the time of the engine and train hands, more than compensates for the reduced charges for repairs of the road and machinery.

We will designate by  $F$  the value of the locomotive engine in dollars; by  $f$  the value of the stock in cars for each ton of freight; by  $m'$  the value of the time of all the hands in the train for one hour; and by  $q$  the number of tons of merchandize in the train.

The value of one hour for the whole train will be, at 6 per cent.,

$$\frac{6}{100m}(F + fq) + m'; \quad (L)$$

and if we represent this quantity by  $H$ , the difference between the values of the velocity  $V'$  and that of  $V$ , will be for each ton, and for one mile,

$$\frac{H}{q} \left( \frac{V' - V}{V'V} \right). \quad (M)$$

This is the difference per ton per mile to the company between the values of these velocities, where no imperative conditions obtain.

Now let us see what value this expression exhibits under different circumstances; and for this purpose we will put  $F=5000$ ;  $f=100$ ;  $q=50$ ;  $m=8760$ ;  $m'=\frac{1}{5}$ , all of which are very common values, and suppose, in the first instance, that the business of the line may be transacted by an adequate supply of engines, men and cars, at some

exceedingly slow rate—as half a mile per hour—how much more would it cost the company, in the value of time, to carry the trade at this rate, than at a speed of ten miles per hour?

Equation (L) gives us

$$H = \frac{11}{40} \text{ of a dollar,}$$

for the value of one hour of the time of the train. This value of  $H$  being substituted in equation (M) will yield,

$$\frac{11}{40 \times 50} \cdot \frac{10 - \frac{1}{2}}{10 \times \frac{1}{2}} = \frac{209}{20000} \text{ of a dollar,}$$

*or more than one cent per ton per mile.*

Now, in this case, the value of the time of the train, exclusive of the goods, is equal to half the actual cost of transportation on a well managed road with ample trade; and it is perfectly apparent that, even overlooking the loss of time and depreciation of the price of the goods, such a rate is wholly inadmissible. But let us apply the equation to the determination of the difference of value of a speed of five miles and one of ten miles per hour, under the same circumstances. In this case equation (M) gives us

$$\frac{11}{40 \times 50} \cdot \frac{10 - 5}{10 \times 5} = \frac{11}{20000} \text{ of a dollar.}$$

*or only one half mill per ton per mile—*or less than the tithe of the actual difference of cost—consequent on the destruction of cars, engines and track—risk of accident and damage to goods, incident to the adoption of the greater velocity.

The whole difference between the value of a speed of five miles per hour and one of ten miles per hour, will rarely exceed one mill per ton per mile, in its effect on the interest of the value of the train, together with the depreciation of the value of the goods conveyed. However great, then, may be the inducement to carry passengers at a more rapid rate, there is no sufficient cause for transporting freight at a speed of more than five miles per hour, unless, as already premised, a higher rate is absolutely essential for the accommodation of all the trade which is commanded by the line—a condition which, on ordinary roads in this country, very rarely prevails.

We are not likely to overrate the injurious effect, or too strongly to deprecate the continuance, of the mischievous practice which still prevails in this country in the transportation of heavy commodities. The iron rails are rapidly destroyed by it; the wear and tear of the cars and engines are greatly augmented, and the useful effect of the power applied is materially reduced. There is no corresponding advantage obtained. The value of the time which is saved is almost too small to

be estimated for the freight, and the value of the time lost by the train bears no perceptible proportion to the injury which is done to the road and its furniture.

## COST OF TRANSPORTATION ON RAILROADS.

BY CHARLES ELLET, JR., C. E.

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	618	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	33½	1841	Including new engines.
Reading Road.	83,717	17,443	20½	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,*

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

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	61,218	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.	G'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	30 $\frac{1}{2}$		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	82 $\frac{1}{2}$	299,617	44,477	34,380	220,135	192,925
Portsmouth & Roanoke,	1842	79		96,000	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	44 $\frac{1}{2}$	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 cent. 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 per centage 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  $27\frac{1}{2}$  cents per mile run.

TABLE.

Name of Road.	Year.	L. h.	G. ds.	Miles run.	Through tonnage.	Through travel.	Actual expenses.	Calculated expenses.	Err'r pr.ct.
Georgia Road,	1842	147½	37	152,873	10,000	12,000	\$ 109,819	\$ 106,605	-2½
Western Road,	1842	156	83	397,295	40,000	53,000	256,619	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	75,224	74,379	-1
Reading Road,	1841	56	19	83,717	24,000	31,453	62,635	61,318	-2
Boston and Providence,	1842	94	35	198,055	65,000	33,730	151,000	152,911	+1½
Baltim. and Washington,	1841-2	42	38	120,000	21,200	117,129	101,596	100,902	-¾
Petersburg Road,	1842	61	30	91,428	27,369	114,260	73,684	76,193	+3½
Nashua and Lowell,	1842	14	10	44,040	23,663	85,737	30,708	33,131	+8
Baltimore and Ohio,	1841	82	82½	299,617	44,477	34,380	220,135	192,923	-12
Portsmo'th and Roanoke,	1842	79		96,000	5,975	7,662	73,345	76,703	+5
Boston and Lowell,	1842	26	10	143,607	93,927	179,819	131,012	119,409	-9
South Carolina Road,	1842	136	35	260,324	27,000	24,000	225,743	213,943	-5
Boston and Worcester,	1842	44½	42	241,319	61,911	165,720	168,509	176,831	+6
Utica and Schenectady,	1841-2	78		152,746		114,527	154,436	142,542	-8
Pallada. and Columbia,	1842	82	45	261,744			116,000	112,979	-2½
Aggregate,		1251		2,886,292	Tons 1 mile, 3 3,360,560	Pas. 1 mile, 57,726,906	\$ 2,109,188	\$ 2,068,165	

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.

#### *Repairs of Engines and Cars.*

It is the custom of many companies to publish the cost of repairs of their cars and engines in a single item, so as to make it impossible for the reader to determine, from their accounts, what portion of the bill

was created by the engines, or the difference between the repairs due to different sorts of cars; but still an industrious investigation of the subject gives us facts enough to estimate these separate items for ordinary cases, with all desirable accuracy. I have stated in a former paper that the repairs of burthen cars are worth, on the average,  $4\frac{1}{2}$  mills per ton per mile; and that the repairs of the engines averaged, during the year 1842, *seven cents per mile run*. I have also observed that the repairs of passenger cars vary from three-fourths of a mill to a mill and a half, and sometimes exceed 2 mills per passenger per mile. If these facts—all of which enter into the formula which I have offered for the determination of the aggregate annual expenses of a railroad company—be well established, they will not only stand the test of trial for the aggregate, but they will apply in detail. Not only should the formula for determining the aggregate expenses be correct, and correspond with actual results—as we have seen—but the separate items of which it is composed, must, likewise, bear the test, and give results in agreement with the average results of experience.

It is not pretended that a formula could be offered which would show the exact cost of every item of every company for every year—because the actual expenditures due to each item fluctuate from year to year; but it is maintained that these fluctuations are above and below a certain average line, from which they may depart towards either side for a certain time, but to which, and beyond which, on the opposite side, they are as sure to come as the pendulum is sure to approach the vertical in its vibrations. Although it was not my intention to enter so minutely into these details, probably more confidence will be yielded to my statements when the data on which they are founded are presented. These data, for the repairs of engines, are exhibited in the following

TABLE.

Name of Roads.	Year	Miles run by engines.	Cost of repairs of engines.	Repairs pr mile run.	Remarks.
Philada. Wilm. & Balt.	1842	177,859	\$ 17,071	9.6Cts.	Old Road.
Western Road,	1842	397,295	21,177	6.1	New road.
Georgia Road,	1842	152,873	10,155*	6.7	{ Ordinary & extraord'y repairs & improvem's.
Balt. & Susquehanna,	1842	128,349	7,193	5.6	New road
Utica and Schenectady,	1842	150,000	10,346	6.9	Passenger business.
Baltimore and Ohio,	1841	299,617	20,640	7.0	{ Old roads in good condition.
Baltim'e and Washing'n,	1842	95,817	7,973	7.2	{
Philada. & Columbia,	1842	261,744	21,915	8.4	Generally freit business.
Boston and Providence,	1842	112,805	7,257	6.5	{
Baltimore and Ohio,	1843	509,765	35,941	7.0	{ Old roads in good condition.
Wash. and Baltimore,	1843	96,716	6,714	7.0	{
		2,382,840	\$ 169,380	Avr. 7.1	

This table exhibits the cost of repairs of engines which have traversed a space of 2,382,840 miles; and shows that the average is

\* This Company have added to the usual division of their expenses into ordinary and extraordinary repairs, the new classification of "improvements to engines;" not being able to conceive that a small stock of engines could run 153,000 miles, and be materially improved by it, I regard these "improvements" as *expenses*.

within one-tenth of a cent, per mile run, of the mean value at which I had stated it. It is my impression, however, that the average on these same roads will be greater for the year 1843.

Now, if we call *N* the number of miles traveled by the locomotive engines; *T* the number of tons of freight carried one mile; and *P* the number of passengers carried one mile, the average aggregate cost of repairs of passenger and burthen cars, and locomotive engines, will be shown, very nearly, by the formula,

$$\frac{7N}{100} + \frac{4.5T}{1000} + \frac{P}{1000}$$

By expressing the cost of repairs in this way, we are able to determine, at once, the expenses of repairs for an entire train composed of either description of cars, or of both sorts, and in any proportions.

Although this, and all my other, estimates might be much strengthened, by bringing forward facts resulting from former experience, I prefer, with one or two exceptions, to limit my examples, on this occasion, to those works of which I have obtained authentic information for the year 1842. Of course, I exclude those lines which have been so recently completed, as to require no repairs at all for cars.

The following table presents the number of miles run by locomotive engines, and the number of tons and passengers carried one mile on eight railroads for the year 1842, and two for 1843—which have been recently published;—and in the two last columns will be seen the actual expenses of repairs of cars and engines, and the expenses of the same computed by the formula.

TABLE.

Name of Road.	Year	Miles run by eng'rs.	Tons carried one mile.	Passengers carried one mile.	Actual cost of repairs.	Comput'd cost of repairs.
Petersburg Road,	1842	131,160	1,342,000	976,000	\$ 16,513	\$ 16,196
Boston and Providence,	1842	129,000	890,400	4,919,418	13,506	17,326
Baltimore and Ohio,	1841	299,617	3,647,093	2,495,911	45,534	39,881
Baltimore and Ohio,	1842	334,519	3,985,425	2,738,779	44,568	44,189
Baltimore and Ohio,	1843	509,765	7,109,310	6,062,455	62,862	73,738
Baltim. and Washington,	1843	96,716	803,429	2,646,719	17,453	14,801
Baltimore and Susque'a.,	1842	128,349	1,610,000	1,165,000	13,370	17,390
Balt. and Washington.	1842	95,817	877,138	3,188,943	17,053	13,864
Utica and Schenectady,	1842	150,000		8,413,704	13,842	18,914
Boston and Lowell,	1842	143,607	2,442,102	4,675,294	28,316	25,716
Georgia Road,	1842	152,873	1,475,000	1,370,000	19,899	19,107

On inspecting this list we will observe that the actual charges on some of the roads are a little above, and on others a little below, the indications of the formula—but that the deviations are in no instance too wide to render the rule, as far as it goes, a safe test of the value of an investment. The actual cost on the Baltimore and Ohio Railroad falls considerably below the computed cost for the year 1843. In 1842 the agreement was very close, and in 1841 the result was nearly as much above as that of 1843 is below the rule. Indeed, in 1841 the sum of \$ 9,766 was expended for *new* burthen and passenger cars, in addition to the \$ 45,534 charged to repairs of cars and engines. The aggregate expenses for repairs of cars and engines, on that work, for

the three years amounted to \$152,964—and the expenses calculated by the formula to \$157,808. If we add the sum paid for *new cars*, to the actual cost of repairs, the actual expenses, for the three years, will be \$162,730, or 3 per cent. above the computed expenses.

The formula simply exhibits what it is intended to show—the average for a succession of years. I do not include the Boston and Worcester road in this table, because the result on that work is entirely anomalous. For previous years the agreement between the calculation and expenses was sufficiently close; but in 1842 there was a material increase of business, an extraordinary reduction in the expense of repairing the cars and engines, and a simultaneous augmentation of the capital—or charge for construction—of \$390,000. I am obliged to suppose that new cars and engines were added to the line, and that a portion of the business was performed by new stock.\*

We may now pass to another very important division of railroad expenses, which are usually, though very improperly, denominated “extraordinary expenses.” I refer chiefly to the

*Wear of Iron Rails.*—There is, perhaps, no subject of interest to the engineer which has attracted less serious attention, or has been more vaguely and indefinitely considered, than the wear of railroad iron. Instead of attempting to find some correct and rational measure of this wear, the public, and in a great measure, the profession also, have persisted in regarding the visible destruction of the iron on roads which have been some years in operation, as a consequence of the inferior quality of the particular specimen, or of the inadequate strength of the particular pattern. It is the custom to say that the mashed and splintered iron of the Camden and Amboy, and Columbia roads was bad; but no argument has ever been adduced to show that good iron, in the same situation, and subjected to the same sort of treatment, would do better.

So long as railroads happened to occupy positions where they would be used for the mere conveyance of the travel, and a few thousand tons of goods, between adjacent cities, the durability of iron was a question of subordinate interest. An engineer could be satisfied that his rail would last 10 or 20, or 30, years, and could generally count on a sufficient increase of business consequent on the increase of population, to compensate for its destruction in that space of time. But railroads are now projected to take the place of important canals, and to furnish the means of transport for the heavy products of the earth at exceeding low rates. The question assumes, therefore, another aspect. The trade of the Erie canal in New York, and of the Schuylkill Navigation in Pennsylvania, may be estimated at 700,000 to 1,000,000 tons per annum; and there is no railroad in the United States worked by steam power, which accommodates more than the one-ninth, or one-tenth, of this amount, with the exception of the

\* The cost of repairs of locomotive engines for this road, for the year 1841, was  $9\frac{1}{2}$  cents per mile run, and in a space of seven years, from 1835 to 1841 inclusive, the engines performed an aggregate distance of 850,809 miles, at an aggregate cost of \$84,183; or within a fraction of 10 cents per mile run. The repairs of cars are fluctuating, but the average is in accordance with the formula. This road is not an exception to the rule, though the formula does not apply for the year 1842.

Reading railroad, which has not yet been long enough in operation to yield any useful practical results.

The common half-inch flat bar, under ordinary circumstances, is adequate to the transportation of about 150,000 tons of freight. Such a bar on the Petersburg road, where the freight amounts to some 25,000 tons, would resist the wear of six years' business; but if one year's trade of the Schuylkill canal were poured along it, the iron part of the track would need entire renewal *six times in one year*.

The same remark is applicable to any of the same sort of wooden roads in the country. They would all bear about 150,000 tons net, drawn at the usual speed of ordinary freight engines, but would be completely destroyed by about *five weeks' business* of the Schuylkill Navigation, in the season of active trade.

It must be admitted that we have not yet sufficient data for estimating, with entire certainty, the probable durability of many varieties of rails. We have, however, data sufficient, if we use it properly, to make a much nearer approximation than is generally supposed to be practicable. The durability of the half inch plate rail can be determined with all desirable accuracy, and we can judge from analogies, which the problem presents, the probable wear of other patterns. Great errors have been committed in the consideration of this subject, by overlooking the fact that the progress of the wear is rarely ascertained, or, in the least, appreciated, until the rail is destroyed. The annual charge for iron is very small, because, in general, the track does not appear to give way until it is nearly unfit for use. When repairs really commence, the destruction is so far advanced that the iron must be renewed; and if the directors assert, as they usually do, in their next report to the stockholders, that experience has shown that the original iron was very bad, and has all been crushed, the explanation is satisfactory, and the cost of the new iron is forthwith charged to the account of construction.

We accordingly find, in looking through the reports of railroad companies, that the average annual increase of capital, generally exceeds the dividends even of the most successful enterprises; and *there is not now to be found in the country a single road which has renewed its iron out of the proceeds of transportation*. While the trade continues to be small, and this extraordinary outlay is needed but once every 6 or 8 years, the self-deception can be practiced with considerable success. But there are now works constructed which are intended for a very great business, and which will reduce the extraordinary charge for renewal of iron down to a very ordinary circumstance. The Reading Railroad is contemplated for the conveyance of the present trade of the Schuylkill Canal—from seven to eight hundred thousand—and which will very soon reach one million of tons—and should the experiment succeed, *the cost of iron will be more than equal to the entire renewal of a single track every year*. The question of wear, is, therefore, of immense importance, and can no longer be lightly disposed of by companies of this class.

This, as every other item of railroad expenses, is subject to a cer-

tain law, which must be recognized before we can make any effectual progress in our investigation.

The destruction of iron depends on the grades of the road, on the tonnage, and on the travel. Every ton of freight that passes produces a certain amount of injury; every passenger car and every passenger does some injury, and every engine that traverses the line produces its share of mischief; but the number of engines that traverse the road, in conveying a given amount of tonnage, depends on the limiting gradient—and, consequently, the destruction of iron, *cæteris paribus*, is greatest on those roads of which the grades are most unfavorable to the useful effect of the power.

If we call  $N$  the number of miles traveled by all the engines on the line;  $T$  the number of tons net conveyed one mile; and  $P$  the passengers conveyed one mile, for one year, then

$$aN + bT + cP,$$

will be the form of the expression which represents the amount of injury which the iron has sustained— $a$ ,  $b$ , and  $c$ , being constants to be supplied by experiment. It is assumed, of course, that the weight and form of the rail, as well as the weight, construction, and velocity of the engines, are uniform.

The point, now, is to determine the values of the coefficients,  $a$ ,  $b$ , and  $c$ . For this purpose I take, in the first place, a road on which engines are not used, and but few passengers are conveyed. The wear of iron on such a road gives us the value of  $b$ , or the injury done by the tonnage.

There are two works of this description of which we can find published reports, and which have been long enough in activity to destroy a portion, or the whole, of their iron.

The *Chesterfield Railroad*, in Virginia, constructed with a flat bar, and using horse power and light cars, has required, for some years past, about \$200 per mile for new iron, to replace that which is destroyed by the passage of an average trade of about 50,000 tons of coal. The destruction is here equivalent to *four mills* per ton per mile.

The *Mine Hill and Schuylkill Haven Railroad* was originally constructed with a flat bar, and six miles in length of the road had been renewed with a heavy edge rail, before 400,000 tons had passed along it. Assuming the value of the flat bar at \$60 per ton, or \$1200 per mile, which is below its present value, and that the iron was worn out by 400,000 tons, the result will be three mills per ton per mile. But this road is provided with a double track, and the track which was destroyed was not used by the ascending cars.

The injury produced by the empty cars is certainly more than one-third of that effected by those which are loaded; and the result on this road, therefore, corresponds very closely with the previous example. The wear then obviously will not be less than 4 mills on a road sustaining locomotive power—where the velocity is much greater than on the Chesterfield and Mine Hill roads.

I will not, therefore, be above the mark in assuming  $b = 4$  mills.

The flat bar on the *Petersburg Road* may be considered to have been worn out in six years, by use which was equivalent to 12,000 trips of locomotive engines; 130,000 tons of freight, and 100,000 passengers carried over each mile. If we consider the injury caused by cars carrying 5 passengers, equal to that produced by those carrying 1 ton of freight, and the value of this iron equal to \$ 1200 per mile, we shall have

$$b P + c T = \$ 600$$

for the damage due to the freight and passengers.

The remaining sum of \$ 600 is the destruction produced by the 12,000 miles run by the locomotive engines; whence we have

$$a = \frac{60,000}{12,000} = 5 \text{ cents};$$

or 5 cents for the injury done by the passage of the locomotive engine over every mile of the road.

We obtain, then, from this procedure,  $a = 5$  cents;  $b = 4$  mills; and  $c = \frac{4}{5}$  mill, and for our formula

$$\frac{5 N}{100} + \frac{4 T}{1000} + \frac{4 P}{5000}$$

If these values be correct they will apply to any other similar case.

The first iron used on the South Carolina Road, was destroyed in less than six years—after it had borne about 130,000 through tons, and 120,000 through passengers, and the locomotive engines had made 10,000 through trips. The formula will give for this case,

$$\frac{10,000 \times 5}{100} + \frac{130,000 \times 4}{1000} + \frac{120,000 \times \frac{4}{5}}{1000} = \$ 1,116$$

for the destruction of the iron per mile. This is, no doubt, very near the true value of the first iron used on that road, estimated at the present prices.

There are several other roads, of both descriptions, for which similar computations might be made, and which would confirm the estimate—and I shall take occasion, at a subsequent period, to present much data of the same character in a tabular form. But without discussing this branch of the subject further, at present, it may be stated in round numbers, that the average destruction of the half inch plate rail, caused by engines, freight, and passengers, is equal to about 8 mills per ton net per mile; and by comparing the above expression of the wear of the rail, with that previously obtained for the wear of the cars and engines, we will perceive that they possess very nearly the same value—or that the injury done to this iron, by the passage of a train, is but about 10 per cent. less than the wear and tear of the engine and cars composing the train.

In the application of this formula, however, the fact is not to be overlooked, that it is derived from the destruction of the plate rail, and is intended only to be applied to that description of road. *The destruction of any form of T or H rail, which I have yet seen, will*

*be greater.* It is true that the expenses of maintenance for some new roads, provided with heavy iron, are yet very light, and they will possibly continue to be light until they have carried from three to five hundred thousand tons of freight—when, if the rail is still in existence, they will be very heavy.



It requires but little experience, and no speculation, to bring us to this conclusion. Let us take the two patterns, fig. 1, and fig. 2, for the purpose of illustration. Fig. 1, is a common form of edge rail, of 60 pounds per yard, of which the head, or upper table, A, weighs 20 pounds. Fig. 2, is a common plate rail,  $2\frac{1}{2}$  inches wide, by  $\frac{1}{2}$  of an inch thick, which also weighs about 20 pounds.

This flat bar is supported along its whole length and breadth by the wooden string, S, and the edge rail is supported only in the centre by the vertical stem, P. Is there now any reason why the unsupported flanch, *f*, should do more service than the supported flat bar, B? The vertical stem and base of fig. 1 never wear out; it is the head of that rail which is crushed and rolled to pieces. When the rail is destroyed the lower portions are untouched; but when the head is bruised and split, the whole rail is rendered useless—and when the rail is ruined, 60 pounds of iron per yard, are lost to the company. The flat bar will bear just as much—indeed, being supported, a little more—hammering, and when it is destroyed, but twenty pounds are lost. Besides it may be welded when broken, the ends may be “upset,” and restored when split; new holes, when necessary, may be punched, and it can be returned to the road until the lamination and splintering throughout render it wholly unfit for useful service.

But it is not my intention to speculate here on the relative merits of rails. The present object is to adduce facts and conclusions based on observation of many roads of various descriptions, in relation to the destruction of such rails as are ordinarily adopted. I know that my opinions on this head are not those of the public, nor of many professional gentlemen of much experience; but I believe they are, nevertheless, correct, and I therefore submit them to a test which will speedily be applied, and by which this question will be most conclusively settled.

The rails of the Reading road are, by common consent, acknowledged to be good; the pattern is considered, by the advocates of edge rails, to be unexceptionable; and the mode of manufacture adopted—that of making the lamina horizontal—is considered to render them almost proof against wear.

In regard to these rails—with all their merits, and all their superiority—I affirm,

1st. That they will not withstand the rolling of the trade of the Schuylkill valley for one year.

2nd. That before 800,000 tons of coal have passed down, and the empty cars have been returned on them, the present track will be entirely unfit for safe usage.

3rd. That it will cost from 50 to 75 cents to replace the iron which is destroyed by each ton of coal that descends from Pottsville to Richmond, on the present track. And,

4th. That before next August, if the company succeed in obtaining the trade which they desire, this rail will be pronounced *too light* by the very parties who now think it will last forever.

The fault, however, is less in this particular rail than in *iron*, which is not tough enough for such usage at such prices:

I know that the *Providence road* will be adduced as evidence against me, where the road has been some six years in use, and the iron is yet sound; but the Providence road actually passes but 30,000 tons per annum on a single track, and must yet stand 25 years before it can do one year's business of the Schuylkill canal.

The *Georgia road* may, perhaps, be quoted as evidence, where *experience*, they say, has demonstrated, beyond all question, the ability of railroads to compete with canals, for the conveyance of heavy freight; but the Georgia railroad has been less than three years in operation, and has *not yet carried as much freight as has sometimes passed along the Schuylkill canal in three days*. Pour the trade of the Schuylkill, or Erie, canal, on parts of that road, with such engines as would be needed for its conveyance, and the track would be crushed in less than four weeks.

The *Boston and Lowell road* will be quoted. This road has not yet carried, in the eight years of its existence, an aggregate tonnage equal to the Schuylkill trade—and that tonnage has been sufficient for the destruction of the first track of edge rail, and the company are now, and have been for some time, using the second and third tracks.\*

The *Camden and Amboy road* was originally provided with a "permanent" track. The aggregate trade has not yet reached 300,000 tons net—the reader who feels any interest in such matters can cross the Delaware to Camden, and examine the old rails, and form his own conclusions; he will then be able to judge whether these have given out because they are too weak, or because the material, in this form, is inadequate to a much greater effort.

In *England*, however, it is contended, people have more experience. The *best* experience there, is that of the Liverpool and Manchester Railroad, a work which was opened to public use in the fall of 1830. This road was at first supplied with two tracks of edge rails, weighing 35 pounds per yard. The rail answered very well until the fall of 1833, when the work had passed about 300,000 tons on each track, at which period £150 were expended for *new rails*. In the next half year, before they had transported 350,000 tons, an additional outlay of 3000 pounds sterling was required for new rails, and the adopted pattern was pronounced *too light* for the service. A rail

\* It is proper to say that the rails of this road were taken up after six years' use, because they were too weak; but we never meet with rails that are *strong enough* after they have sustained the passage of 600,000 tons.

weighing 50 pounds per yard was next tried, and subsequent experience showed that that also was *too light*. A new pattern was then projected, weighing 62 pounds per yard, and forthwith submitted to the same rough usage. The trade on this road is great, and soon tests the merit of a fancy. This pattern was also found inadequate, and another, weighing 70 pounds per yard, was fixed upon, which was, *last year*, regarded as the pattern rail. I have not yet heard how it wears, but one year more will test its strength on that road, where there is really a heavy trade, although the net tonnage does not reach one-half, nor much exceed one-third, of the average trade of the Schuylkill, or Erie, canals. I do not believe that either pattern would resist the action of one year's business of one of those works, if it were confined to a single track.

I trust that those who have made observations on this interesting subject, will communicate them for publication in this journal. If there be an edge rail in the United States, which has sustained the passage of a million of tons of freight,\* conveyed by locomotive engines, it could not but be regarded as a most encouraging circumstance, and its history ought to be known; such a rail—weighing 60 pounds per yard—would show the practicability of reducing the average cost of this item for such rails down to 6 mills per ton per mile; and, therefore, below any result which I have yet been able to obtain. My impression is, from the comparisons of the actual destruction which I have been able to make, that its value may be reduced, by the adoption of a suitable flat bar, and a moderate speed, to  $3\frac{1}{2}$ , or 4, mills per ton per mile.

I propose now to continue to produce those details of the cost of transportation on railroads, which enter into the approximate formula for the computation of the average annual charges, preparatory to the indication of certain modifications, which, in time, will be found necessary, in order to adapt the expression more strictly to the various cases which occur in practice. A reference to the table contained in a previous number of this journal, (vol. vi. p. 323) will show with what accuracy the formula, in its present state, applies to almost every variety of roads in the Union.

But it will occur to the experienced reader, that there are certain sections of the country on which the cost of fuel is exceedingly light; others where it is very great; that there are some lines provided with a double track; some on which the engines are unusually large, or on which the company are exposed to peculiar causes of expenditure. It will be readily conceded, therefore, that a formula *strictly* applicable to all these cases, ought to be expressed in more terms than the mere length of the line, the tonnage, the travel, and the miles run by the locomotive engines—which are all the quantities that appear in the rule which has been presented. But yet we have seen that that formula, as it is, does apply and give consistent results, and results

\* In a report on Herron's cast-iron rails laid before the Committee on Science and the Arts of the Franklin Institute, about two years ago, I stated that no road in the United States had yet sustained one million of tons of freight: I have not yet heard of such an instance.

quite close enough for almost any useful practical purpose, without any correction for these varying conditions. This circumstance, therefore, needs explanation; but before explanation can be advantageously offered, I must lay before the reader certain details which have been used in the construction of the formula. In anticipation of this explanation, however, I may observe that the true cause is, that these circumstances, which disturb the action of the general law, have very little influence compared with the value of the great items which compose the formula. I shall return to this subject again; but at present we may proceed with the determination of the values of the detail of expenses, and leave the slight corrections to be applied in consequence of these irregularities—irregularities chiefly in the prices of labor and materials—for the sequel. The reports of the various companies for the current year, will shortly be published; and by introducing the results which it is to be presumed they will exhibit, under an improving system of economy, I hope to be able to make a still closer approximation to the truth. We shall have also, in a few weeks, the results of the year's operations on the Philadelphia and Reading Railroad, from which we shall be able to verify experimentally, the influence on the cost attributable to a very large trade conducted under remarkably favorable circumstances.

I propose to consider next—

*The Cost of Fuel.*—It is obvious to every one that the *consumption* of fuel depends on the construction and power of the engine, the gradients of the road on which it operates, and the load which is conveyed. The *cost* of fuel really depends, in some measure, on these circumstances, but chiefly, in practice, on the *price* of wood; for in this country the price of a cord of wood is much more variable than any other element which affects the value of fuel, or the value of motive power.

The following table of the distance run by locomotive engines in different parts of the country, together with the annual aggregate expense of fuel, and the reduced expense, per mile run, will serve to exemplify this point.

*TABLE of the Expense of Fuel.*

Name of Road.	Year.	Distance run by engines in miles.	Expense of fuel.	Cost of fuel per mile.	Remarks.
Georgia Road,	1842	152,873	\$ 6,405	4.2 cts.	} South'n Roads, Average 5 cts.
Central Road,	1842	102,145	4,810	4.7	
South Carolina Road,	1842	260,324	13,950	5.3	
Portsmouth and Roanoke,	1842	96,000	4,700	4.9	
Petersburgh Road,	1842	131,160	8,200	6.2	
Baltimore and Ohio,	1843	509,765	33,547	6.6	} Roads in Mid- dle States, Average 9 cts.
Baltimore and Susquehanna,	1842	128,349	8,981	7.0	
Utica and Schenectady,	1841	155,828	11,000	7.1	
Philadelphia and Columbia,	1842	261,744	22,000	8.4	
New York and Erie,	1842	24,564	2,744	11.1	
Reading Road,	1842	198,055	19,002	9.6	} New England Roads, Average 13 cts.
Norwich and Worcester,	1842	144,321	14,662	10.2	
Western Road,	1842	397,295	50,774	12.8	
Providence Road,	1842	120,000	17,548	14.6	

[NOTE.—The expense of fuel on the New York and Erie Road, includes the cost of sawing, and the loading of the tenders. The engines on this road, as well as some of those on the Reading and Western Roads, carry very heavy freight trains.]

On inspecting this table we observe that the cost of fuel for each mile traveled by the engines, increases very uniformly as we proceed from south to north. We know, also, that the price of wood likewise increases on the route, though not precisely in the same proportion. Wood is worth, on the average, two and a half times as much in New England as it is in Georgia—but there are roads in New England on which the expenditure for fuel is from three to four times as much as it is on some of those in Georgia. This inference is not wholly attributable to variations in price, but depends, in part, on the size of the engines, and the magnitude of the trains conveyed. The engines on the southern roads, are, in general, not quite so heavy, nor so heavily loaded, as those used on several of the northern lines—a circumstance which somewhat, though not very materially, influences the result. Waiving the influence of this consideration, and regarding the engines as of nearly the same average weight on all these lines, this table will supply us at once with a correction to the formula, which we may apply when we desire to approximate more closely to the actual expenses.

The formula, for computing the aggregate annual expenses of a railroad, is based on an average cost of fuel of 9 cents per mile run.

In making the application, from year to year, we shall find that the results which it supplies will need to be modified, and that this modification will be equal to an addition of 4 cents per mile run for the New England roads, and a reduction of 4 cents per mile run for the Southern roads.\*

*Wages of Train Hands.*—It is the practice of many companies to include the wages of enginemen, firemen, conductors, breakmen, &c. in the item of fuel and salaries; of others to combine them with oil and repairs of engines and cars. Indeed, the heterogeneous mixture of items, which are presented to the public in a lump, cannot but lead sometimes to the conclusion that it is the object of the report to conceal the simple truth. It cannot be supposed that any company mingle such dissimilar items together in their own books; and as it is really easier to copy off the items under their separate heads, than to add them together and present them in a mass, it must be supposed that the object of the condensation of matter is to prevent an intimate acquaintance with their affairs. This inference is strengthened, in my estimation, by the fact that the accounts of those companies which pursue this course, exhibit an annual, and sometimes vast, augmentation of capital. By keeping the items concealed, the public are forbidden from ascertaining what portion of the ordinary current charges go to swell the annual charge to construction, and the deception is thereby practiced longer with impunity. There are certainly some remarkable exceptions which might be named as good models for

\* I propose to present, in a future number, a more accurate and general formula for the determination of the consumption of fuel.

imitation. The accounts of the Georgia Road are always presented with clearness and accuracy; and though they might be greatly improved by the addition of the net and gross tonnage, and travel conveyed one mile, they exhibit, in their present state, a much better appreciation of the importance of knowing the precise and detailed condition of their business, than is observable in the statements of other similar institutions.

The report of the Baltimore and Ohio Company, for the current year, also stands out conspicuous amidst the general confusion; and, as ought to be expected, *every item* of expenditure on that line compares advantageously with the corresponding item on any other road in the country.

The directors of the Norwich and Worcester Road, have published a table which might be made valuable, but it is actually rendered almost useless for want of the amount of the business transacted. The number of tons of goods, and the number of passengers conveyed one mile, ought to have been stated, and the different classes of wages should have been separately given. It is of little use to tell us the exact amount of expenses incurred in the transportation of freight without informing us of the amount of freight transported.

The directors of the Western Road have also produced much valuable detail; but they have failed to present the item of "services" under appropriate heads. No correct judgment can be formed of the economy of the administration of a line on which the salaries of agents and superintendents, president and engineer, train-hands and wood-cutters, clerks and ticket-men, are condensed into one total. The separation of this column—the accurate addition of the number of passengers carried one mile, and the *quantities* of each sort of fuel consumed—would render the report of this company a most valuable document. I trust that they will not be deterred from continuing this detailed exhibition of their affairs, when their road and machinery begin to manifest some of the effects of time and use.

In consequence of this mingling of items, I am unable to separate, with the desirable precision, the sum paid on many roads for wages to the engine-hands, from that paid to the conductors and breakmen. For this reason I find it convenient to include the wages of all the train hands in the item of locomotive power. This item must, accordingly, be expected to vary with the magnitude of the train, and, somewhat, with the acclivities of the gradients: heavier gradients and the larger trains requiring usually a greater number of breakmen. The variations consequent on this cause, are, however, very small; and we will come exceedingly near the truth by this formula,

$$7\frac{1}{2} + \frac{t}{25}$$

for the value of the wages to the train hands, in cents, for each mile traveled by the train—*t* standing for the average number of tons of freight in each train. The correctness of this approximation will be seen by a glance at the following table.

TABLE.

Name of Road.	Year.	Miles run.	Wages to train hands.	Wages per mile.	Remarks.
Reading Road,	1841	83,717	\$ 5,785	7.0	With moderate trains.
Reading Road,	1842	198,055	17,752	9.0	With heavier trains.
Boston and Providence,	1842	132,229	10,799	8.0	Medium trains.
Baltimore and Ohio,	1843	509,765	31,161	6.1	{ Light trains and heavy grades.
Eastern Road,	1842	184,127	14,774	8.0	{ The trains on both these roads are moderate.
Georgia Road,	1842	152,873	12,666	8.3	{
Petersburgh Road,	1841	131,160	14,558	11.0	{ The Petersburg road was worked at disadvantage in 1840 and '41. The freight trains on the N. Y. & Erie road are unusually large.
New York and Erie,	1842	24,564	2,814	11.5	{

The average value of wages, excepting for roads on which the trains are excessively large, may be safely and justly assumed at 8 cents per mile run.

*Oil and Tallow for Engines.*—The expense of oil is certainly a very small matter, when compared with the aggregate yearly charges against a railroad company; but it is a very important matter for every company to know exactly what this, and every other item of expense really is, and ought to be, in order to judge of the possible ameliorations of their management. On the Georgia Road, in 1840, the mere greasing of the engines amounted to more than 4 per cent. of the aggregate charges of the company. In 1842, this item was reduced down to less than 1½ per cent.

As another example of the effect of the same sort of economy in the detail—in small matters—may be adduced the curious fact, that the sum paid for oil by the Philadelphia and Baltimore Railroad Company, in 1841, amounted to \$6,131, and 1842 it was reduced down to \$2,151. In the year 1842 it amounted to 3½ cents per mile run, and in 1842 it scarcely exceeded 1½ cents per mile run by the trains.

The expense of oil is generally included under the head, "fuel, oil, salaries, general and incidental expenses, &c.;" "fuel, oil, salaries, wages, loading merchandize, and miscellaneous expenses;" "wages, fuel, oil, &c." This method of condensing accounts is so general, that out of the reports of more than thirty railroad companies for the year 1842, now on my table, I am able to select but the three following, from which the cost of the oil consumed by the engines, can be obtained separate from other items.

TABLE.

Name of Road.	Year.	Miles run by engines.	Cost of oil for engines.	Cost per mile run.	Remarks.
Georgia Road,	1842	153,873	\$1,411	.9 cts.	Cotton waste is included in the charge on the Balt. & Ohio, and believed to be included in that of the Georgia ro'd. Including oil for stationary engine.
Baltimore and Ohio,	1843	509,765	4,399	.9	
Philadelphia and Columbia,	1842	261,744	3,104	1.2	

This table would seem to justify the assumption of 9 mills per mile run, for the consumption of oil and cotton waste by the engine and tender alone.

There is to be found a considerable list of reports in which the aggregate consumption of oil by *engines, tenders, and cars*, may be separated from all other items. I have also some manuscript statements from which these items can be obtained. The following table exhibits the aggregate cost of oil for various lines, and the cost reduced to the mile traveled by the train.

TABLE.

Name of Road.	Year.	Miles run by trains.	Cost of oil for engines and trains.	Cost per mile run.	Remarks.
Central Road,	1842	102,145	\$ 1,103	1.0	Light trains.
Reading Road,	1841	83,717	1,621	1.9	Heavier trains.
Reading Road,	1842	198,055	3,936	2.0	Still larger average trains.
South Carolina Road,	1842	260,324	2,784	1.1	
Utica and Schenectady,	1841	155,828	3,500	2.2	Not strictly accurate.
Philada. and Baltimore,	1842	177,859	2,151	1.2	Chiefly passenger trains.
Georgia Road,	1842	153,873	1,821	1.2	Trains equal the preced'g.
Norwich and Worcester,	1842	144,321	1,947	1.4	Wei't of trains unknown.
Western Road,	1842	397,295	9,215	2.3	Heavy trains.
New York and Erie,	1842	24,564	481	2.0	Heavy freight trains.
Baltimore and Ohio,	1843	509,765	7,201	1.4	Lighter trains.

The consumption of oil and tallow may be estimated, in general, at 9 mills per mile run for the engine and tender, and an additional allowance of  $\frac{1}{4}$  mill for each ton net conveyed one mile.

I have also the consumption of oil and tallow for some other roads, but as these statements manifest great and censurable extravagance, and cannot be used to show the necessary expenditure on a well conducted work, I have not included them in the preceding list.

*Sawing Wood, Pumping Water, and Loading Tenders.*—It is not easy to collect facts which will exhibit the actual cost of the items included under the present head for many roads; but it is very easy to estimate their average value by direct calculation. We know that it is worth, on the average, about 40 cents per cord to saw the wood suitably for this purpose: and we know also that a cord of wood is sufficient to supply the consumption of the engine while

running about 40 miles. It is, therefore, worth *one cent per mile run*, to cut the wood for this object. To load the tenders, where the business is regular and great, is worth about 20 cents per cord, or *a half cent per mile run*. The cost of raising the water depends more on the conveniences afforded by the situation. If we assume the average lift at 30 feet, the labor of a man will be equal to raising about 40,000 pounds per diem. Engines usually evaporate from 300 to 400 pounds of water per mile run, which brings the cost of pumping to about the  $\frac{1}{110}$  of a day's labor—or about 8 mills *per mile run*. These items make together  $2\frac{1}{2}$  cents per mile run.

The result of experience for two roads is given in the following

TABLE.

Name of Road.	Year.	Miles run by engines.	Cost of sawing, loading, and pumping.	Cost per Mile.
Boston and Providence,	1842	130,000	\$ 3,266	2.7
Philada. and Columbia,	1842	261,774	5,989	2.3
Average,				2½ cts.

*Locomotive Power.*—We have now gone over the items in detail which compose the cost of locomotive power, and are, therefore, prepared to sum them up, and compare the aggregate of the averages with the amount at which it is stated in the formula, proposed for the computation of the aggregate annual expenses. These items are

Repairs of engines and tenders per mile run,	Cents. 7.0
Fuel, per mile run,	9.0
Wages of train hands, per mile run,	8.0
Oil for engines and tenders, per mile run,	.9
Sawing wood, loading tenders, and pumping water, per mile run,	2.5
Cost of locomotive power per mile run,	27.4

It will, of course, be recollected that this result is independent of the injury to the road, which we have considered under the usual head of "extraordinary expenses."

The only division of these expenses which is liable to material variation, is the cost of fuel, the price of which varies with the localities. I have already offered an approximate correction of this item, which may be employed for general investigations; and shall shortly take occasion to present a more accurate formula for its computation, based upon a very extensive experience.

It might seem to the general reader, that after presenting the cost of repairs of the road, engines, and cars; the value of fuel and wages of train hands; the consumption of oil, and the injury to the iron, that there would remain but little more to adduce in the premises; but I have yet a very important division of the subject to discuss, which is much too frequently overlooked in investigations of this character.

There are other extraordinary expenses, and certain contingencies which go far to swell the annual charges on every line—without any exception in behalf of the most favorably situated, or of those which are most economically administered.

I proposed, in a former article, to offer an estimate of the probable expenses for the present year, on a railroad in active operation, which is now the object of much attention and interest, in order to exhibit an application of the formula in anticipation of the publication of the company's next report. I take the Philadelphia and Reading Railroad for this purpose; and assume that it will this year give transit to 250,000 tons of freight, and 40,000 passengers. The application of the formula to this work—making proper allowances for its gradients and drawbacks, the facilities for unloading, and having due respect to its age—will produce, for the aggregate expenses, the sum of \$265,000.

This estimate, of course, refers only to the apparent expenses, and includes no part of those reserved charges—such as the wear of the iron—which are usually denominated “extraordinary expenses,” because they are not generally of annual recurrence. The durability of iron rails I assume at about 800,000 tons—while they are estimated by the enthusiastic friends of the road, at 12,500,000 tons, and sometimes at infinity. Where such immense differences exist, time must decide the question. I trust that time may not show that I even am too sanguine, and expect more from the railroad system than it is capable of rendering.

*Wear of Iron rails.*—It was not my intention to deviate from the course which I had marked out as proper to be observed in the discussion and development of the important subject which I have attempted to exhibit, for the purpose of disposing of collateral points, or of refuting any objections that might be urged against my argument. But the matter presented in the December number of the Journal is of such deep interest to all concerned in the rail road cause, that I have been compelled to make frequent oral explanations and estimates, which could be more advantageously and more appropriately offered in their place in these articles. I propose, therefore, to recur briefly in the present paper, to the momentous question of the probable durability of the iron rails, and the pecuniary loss consequent on their destruction, for the purpose of presenting facts which it was my wish to postpone to a later period.

It is as impossible as it would be dishonest to attempt to promote the cause of internal improvement, or any division of that cause, by deceptive estimates or the expression of extravagant hopes. It is the duty of the engineer, as well as of the statesman, to look at things as they are, at this great system as it is. He must first recognize the weak points before he can hope to fortify them. If companies or their officers, fail to estimate their expenses truly, they will inevitably fail also in their great objects, and instead of bringing blessings and prosperity into the country, public improvements will continue to be, as they have hitherto frequently been, the bearers of private ruin and public dishonor.

The prevailing fault of all writers on rail road policy is that of yielding up their judgment to the dictation of their wishes, and exhibiting the facts as all desire them to be, and not as we find them. Hence the proverbial errors of companies and their agents, in undervaluing the first cost of their work; in over estimating its business, and underrating the cost of its maintenance. Their opinions are but the picture of their hopes, and rarely deductions from an extensive and systematic investigation, and a wide experience.

But we are now in pursuit of truth and shall endeavor to avoid this error.

The rail road system is new. It is not yet twenty-five years since the locomotive engine has been used with any decided success, and it is not fifteen years since its first employment on lines of general and extensive intercourse.

We have, nevertheless, much experience of the wear of iron rails; for a heavy trade—a trade vastly inferior to that of some of the canals of this country—is sufficient to produce great and obvious effects in a very brief space of time.

We cannot seek this experience, however, on the great rail ways recently finished in England. These carry but little freight. Their business is nearly confined to the conveyance of passengers; and though they really transport many tons of parcels and costly merchandize, and make a considerable show of business, the actual tonnage, compared with that of some of our important canals, is insignificant. Indeed, the public have not yet become accustomed to compare the actual weight of the trade which is transmitted along existing lines of rail roads, and that which passes noiselessly through the old canals, and there are consequently few who have yet formed a just conception of their relative magnitudes.

The *London and Birmingham* rail way has already cost about \$30,000,000; and was graded with a view to the heaviest traffic; but the speed and accommodation which it offers are but slight compensation for the price of carriage at which they must be purchased. With all the labor bestowed upon this work; with all the outlay encountered to reduce the cost of transportation—the annual net tonnage upon it is not greater than five or six weeks trade of the *Schuykill Navigation*.

The *Great Western* road has cost some \$32,000,000. The net tonnage upon this line is still less than that upon the *London and Birmingham*. It does not reach 120,000 through tons per annum.

But the traffic upon these works, light as the tonnage is, has been sufficient, at the high velocity permitted, to produce great destruction.

The former commenced with two tracks of edge rail of 50 lbs. per yard, and wore much of it out before the line was finished.

The latter commenced with a 44 lb. bar between *London and Maidenhead*, and had rendered it unfit for safe service nearly a year ago. The still heavier iron which they are now using is not, of course, yet entirely destroyed. But before this time next year—if my calculations do not fail—I shall produce evidence in this Journal, that a

portion of these 75 lbs. bars, has also given way under less than 500,000 tons net.

At present, however, we will confine ourselves to past experience, and endeavor to ascertain from *that*, what sort of expectations we have a right to entertain for the future. The new English roads have added but little to our previous information on this head; but still we are not without a great deal of valuable experience; and it is the duty of those who seek for truth, and who seek to exhibit it to others, to profit by the best experience they can find.

In reference to the subject before us, we know,

1st. That some eight or ten of the rail roads of this country, have worn out the common half inch flat bar, with an average aggregate trade of 150,000 tons net, drawn by locomotive engines.

2d. The Camden and Amboy road has, in places, worn out an edge rail weighing about 40 lbs. per yard, with a trade considerably less than 400,000 tons net.

3d. The edge rail on the Columbia road, weighing 33 lbs. per yard, has not yet borne the passage of 350,000 tons on one track, and is nearly destroyed.

4th. On the Boston and Lowell road, a 36 lb. rail was so much injured, or so much weakened, as to need renewing and replacing before it had sustained the passage of 600,000 tons net.

5th. The Liverpool and Manchester road was opened in 1830. In 1835, the *first two tracks of edge rails*, weighing 35 lbs. per yard, were destroyed and renewed; and the trade was less than 600,000 tons net, on each track.

6th. In 1835, the Liverpool and Manchester Company relaid the portion of their road next to Liverpool with edge rails, weighing 50 lbs. per yard—or just five pounds per yard heavier than those of the Reading rail road. Before the close of 1840, these *new rails* (weighing, I say, 50 lbs. per yard,) were worn out, and taken up, and substituted by two other tracks of iron, weighing 64 lbs. per yard. These 50 lb. per yard rails were destroyed by about 700,000 tons net on each track. So that, in the brief space of nine years, this Company destroyed four successive single tracks of edge rails with an average net trade of about 300,000 tons per annum.

7th. The 64 lb. rails next introduced on this road, were found to be *too light*, and a 75 lb. pattern was substituted, which is now the ad opted weight. These rails of 75 lbs. have already begun to give way at unsound places—the injury “showing itself chiefly in lamination and occasional splitting at the edges.”

8th. The Stockton and Darlington road, considered as a single track, has been *ironed* with edge rails from six to eight times.

Business commenced on this line about the year 1825. In the year 1834, the trade had reached 338,248 tons. In 1840, it had attained the extraordinary limit of 803,784 tons, and up to the year 1842, there had passed along the work a net weight of nearly 6,500,000 tons. At that time six tracks had been destroyed and taken up and replaced, besides the rails that each time were introduced, before an entire change of form was resolved on. How many tracks this patching

may have amounted to, it is probably impossible now to ascertain. *The cars on this road are very light, and the velocity but six miles per hour.*

It is probable that each track of this road has sustained nearly 1,000,000 tons; and with such cars, and at such a moderate speed, it is not improbable that a 50 lb. bar would sustain from 1,200,000 to 1,500,000 tons.

9th. The London and Birmingham 50 lb. iron which was destroyed before the work was finished, sustained about 350,000 tons, on each track. The velocity here was, however, exceedingly great, and the cars unusually heavy.

10th. The net tonnage on the Great Western road, which destroyed the 44 lb. iron, did not reach 300,000 tons of freight and passengers per track. The engines and cars are still heavier than those of the London and Birmingham road, and the average speed 25 miles per hour.

Now, these are facts; and this, whatever it is worth, is *experience*. The intelligent reader must judge from the facts, whether or not, the cost of renewing iron ought to be regarded as one of the current expenses, or as a thing so extraordinary as to require to be excluded from the annual charges altogether, and added, as is now the universal custom, from year to year, to the cost of the road.

But the rapid destruction of iron under the action of a heavy trade, and the measure which, in the December number, I have assigned to its durability on the Reading road, where the velocity is from ten to fifteen miles per hour, is now but faintly denied; or, if denied at all, only by inexperienced parties, and in anonymous communications.

A new view is accordingly taken of the subject, and the important question arises to determine the amount of loss to the company consequent on the destruction of the iron. I mean to offer no conjectures on this head either, but refer to known and admitted facts, as a guide to my conclusions.

I find in the last report of the Boston and Lowell rail road company—the only company in this country, which has renewed a considerable portion of a track of edge rails in one year, and published the cost,—the following charge:

“For labor and sundry materials, in taking up twenty miles of track laid with 36 lb. rails, and replacing it by rails of 56 lbs. per yard, exclusive of the cost of rail iron, \$34,162 09.” The year before the expenditure for this object was \$14,608, so that for changing 25½ miles of edge rail, the company incurred an expense of \$48,770, or \$1,900 per mile.

There are seventy-one tons of rails in a mile of the track of the Reading rail road, and the cost of taking up the old iron and putting down new, is, therefore, \$1900 for 71 tons = per ton, \$ 26.75

A ton of new iron delivered in Philadelphia, will cost, under the present tariff, \$60.00

The old iron is supposed to be worth, along the line, per ton, about 25.00

Difference between the value of new iron in Philadelphia and old iron on the ground, per ton, \$ 35.00

The cost of changing the iron track of the road will then be as follows :

Seventy-one tons of iron, taken up and put down, at \$ 26.75	\$ 1900	
Difference between seventy-one tons of new iron bought, at \$ 60,	\$ 4260	2485
And seventy-one tons of old iron sold at \$ 25	1775	
Seventy-one tons of new iron transported to, and distributed along the line, at \$ 5		355

Cost per mile of changing iron, \$ 4740

This sum of \$4740 will be the amount due to the trade which will destroy the iron, or render it unfit for safe usage. I know of no iron which has yet withstood the action of a million tons; and I know of no iron of 50 lbs. or less, that is likely to resist that weight. If we consider the rails of the Reading Road to be capable of that effort, then we shall have 4½ mills per ton per mile for the value of the iron destroyed by each ton of coal descending the line—or 44½ cents per ton for the whole distance of 94 miles. By adopting the rates of speed of the Stockton and Darlington Road, it is probable that the cost of the iron could be brought down to 50 cents per ton, or near that limit; but if the company adopt the heavy cars, (7½ tons when loaded) and powerful engines, and heavy trains now contemplated, and continue the high velocity now permitted, the destruction of iron will probably be scarcely compensated for by seventy-five cents per ton. This is a calculation from such data as we are able to obtain. But was there ever a calculation of such work, which was not exceeded by the practical result? One of the data assumes that there will be as many tons of iron to sell, as were originally bought. But the weight will not hold out. It is useless to inquire why; yet we cannot spread 70,000 bars of iron along a road 100 miles in length, and beat them and roll them for one or two years, and then collect it all again. This is a practical difficulty which must always be encountered under such circumstance. The calculation assumes that it will all be collected; and, besides, that the 140,000 bolts, and the 70,000 chairs to be distributed and replaced, can likewise be found again.

Many visionary estimates have been made on this head, by parties of little experience in the handling of heavy materials, and in the performance of mechanical work; but the following practical facts are a great deal more forcible, and will be found to furnish data which can be applied with much more certainty than any speculative estimate whatever.

The *South Carolina* rail road was opened in the year 1833; the trade averages about 25,000 tons. In the semi-annual report for December 31st, 1838, five years after the completion of the work, we find the following:—"deduct the following expenditures, as being rather for permanent improvement than current expenses, viz .

Machinery,	\$ 26,888 12
Spikes,	4,582 34
New rail iron,	3,940 00 &c.

This hint, to the experienced reader, is symptomatic of the contents of the next report, (June 30th, 1839,) from which I extract the following:

" Amount paid for rail iron in Charleston,	\$371,679 12
Less old iron sold and unsold,	92,902 27
	\$278,776 85
Cost of transportation of the same on the road, and laying down, including spikes,	74,400 00
Net cost of new iron,	\$353,176 85

Here we perceive that the entire sales of the old iron (when it was all disposed of, it yielded precisely \$92,325 71,) exceeded the cost of putting the new rail in the track, but by some \$18,000, while the net cost of the new iron, after deducting the proceeds of sales was \$353,176. Such is in fact what is to be expected. The old iron will barely pay for putting down the new, and the loss to the company will be about equal to the cost of the new iron delivered at the sea-port.

A writer in the Railroad Journal proposes a scheme for the Reading rail road company *to make money*, by procuring rails free of duty, and selling the old material, after it has been worn out, with the advantages of the duty.

The operation was conducted under precisely those circumstances on the South Carolina road; but the above balance will show that the speculation did not turn out so well in that case. Indeed I have known many instances in which the iron has been renewed, but I have never heard of a company, here or abroad, that found the speculation a profitable one.

In the accounts of the South Carolina road, the new iron is charged to "permanent improvements," (the old iron lasted *five* years,) and the company recommenced with augmented capital.

I have but one word to add in reference to the durability of iron rails subjected to the action of a trade like that of the Schuylkill. I have already stated that if the Reading rail road company expect to obtain the whole trade of the canal, they must prepare for the entire renewal of a single track every year; and I now add, *if the company carry 500,000 tons of coal during the present year*, as they now propose to do, the new iron cannot be put down, before that now on the track will be so nearly destroyed as to be unsafe.

It is understood that this company has recently obtained an additional loan of \$1,000,000. With this it is proposed to stock and equip the line, and procure the additional track, and prepare for the conveyance of the whole trade of the Schuylkill.

I therefore advance this additional proposition. After this money is expended, and the company shall have put themselves, by its aid, in the position which they seek to occupy, they will neither, in the first place, be able to carry more than *half the tonnage* of the Schuylkill, and, in the second place, if they succeed in obtaining half the tonnage, they will not be able to engage vigorously in the business of 1845, without a *new loan* of a million of dollars; and, finally, if they continue to operate through the present and the next year, they can-

not engage in the business of 1846, without another loan of at least one million. In short, it is *impossible for them to carry the Schuylkill coal trade, without borrowing one million of dollars per annum.* And when they cease borrowing they must cease carrying. I now dismiss the consideration of a road, which, in my opinion, was most unwisely commenced—which has been prosecuted in folly, and which can only terminate in disaster. On this result I desire to rest my claim to the public confidence.

*Additional application of the formula.*—In the November number of the Journal, I offered a formula for the computation of the annual expenses of lines of rail way, and exhibited its application and agreement with the actual results on seventeen of the most important roads in the country.

The greatest deviation of that formula from the actual result was 12 per cent., which occurred in the case of the Baltimore and Ohio rail road for the year 1841.

In speaking of the deviations, I added these words: "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.*" Since the publication of that article, I have received through the politeness of Mr. Latrobe, the able engineer of the Baltimore and Ohio rail road, the report of the operations on that work, for the year 1843, together with some valuable manuscript details, of which I hope to make useful application in the further prosecution of my present study. I am also indebted to Charles S. Storrow, Esq., the valuable superintendent of the Boston and Lowell road, for similar statistics in relation to the excellent, and I believe, prosperous work under his charge, in anticipation of the publication of the report. I have also received from Mr. Storrow, similar information relating to his line, for the year 1841, which I had not before obtained, and from the report of the Baltimore and Ohio rail road company, I find the facts necessary for the application of the formula also to the Baltimore and Washington road for the year 1843.

These results have all been procured since the publication of the formula; and I therefore proceed to test it by making the application to those lines.

It will be recollected that I offered, in the first place, a formula for the determination of the expenses for a *new line*, viz :

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

And in the second place, a rule for the computation of the expenses of maintaining an old road, or road which had been opened more than four years, viz :

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

In both expressions N stands for the number of miles run by the locomotive engines; T for the *tons net* conveyed one mile; P for the

number of passengers conveyed one mile, and  $h$  for the length of the road, in miles.

In applying the formula to the Baltimore and Ohio road, it is to be borne in mind, that of the 178 miles in use for the year 1843, but 82 miles were opened previous to 1842, and that the whole of the remaining 96 miles is *new road*.

The result of the application to these several lines is exhibited in the three following tables:

TABLE.

Name of Road.	Year.	Length in miles.	Grades.	Miles run by trains.	Through tonnage.	Through travel.	Actual expenses.	Calculated expenses.	Error per cent.
Bost'n & Lowell,	1841	26	10	125,296	90,113	170,057	\$119,469	\$111,207	
Bost'n & Lowell,	1842	26	10	143,607	93,927	179,819	131,012	119,409	
Bost'n & Lowell,	1843	26	10	134,982	114,711	176,537	109,367	124,004	
Aggregate for these three years,				403,285	298,751	526,413	359,848	354,620	-1½

It will be recollected that I anticipated, in the November number, that subsequent results would be more favorable to the Boston and Lowell Road, than that of 1842. We here find it so. In 1842, the formula fell \$11,603, or nine per cent. *below* the actual expenses. In 1843 the calculated expenses rise \$14,637 *above* the actual expenses. But my remark in the December number should be recollected in these comparisons:—"The formula exhibits what it was intended to show—the average for a number of years." And hence, we have another test. The aggregate expenses on the Boston and Lowell Road for three years are, as we observe by the table, \$359,848. The calculated expenses \$354,620. This is surely close enough.

Again, we will take the Baltimore and Ohio Road, for the year 1843, for the purpose of an additional application.

TABLE.

Name of Road.	Year.	Length in miles.	Grades.	Miles run by trains.	Through tonnage.	Through travel.	Actual expenses.	Calculated expenses.	Error per cent.
Balt. and Ohio,	1841	82	82½	299,617	44,477	34,380	\$220,135	\$192,925	
Balt. and Ohio,	1843	178	82½	509,765	39,519	33,670	287,153	322,075	
Aggregate expenses for two years,							507,288	515,000	1½

I have taken no notice of operations on this work for the year 1842,

because during that year the line was opened, in parts, from Harper's Ferry to Cumberland.

The application for the year 1841, gave a result of \$27,210 *below* the actual expenses. I stated at the time that the subsequent expenses would be likely to fall *below* the calculated expenses. We accordingly find the result for the next year comes \$34,000 below the formula. Here, then, is another, and most conclusive, confirmation of the correctness of the formula, and of the principles on which it is founded. If we take the *sum* of the expenses for the two years, we find the calculation \$515,000, and the *fact* \$507,288.

But we have yet a third case: the Baltimore and Ohio Railroad report for 1843, exhibits, as has been stated, the results on the Baltimore and Washington Road, likewise for that year. These, together with those of 1841 and 1842, are presented in the following

TABLE.

Name of Road.	Year.	Length in miles.	Gr'de in feet.	Miles run.	Thro'h tonnae.	Thro'h travel.	Actual expenses.	Calculat'd expenses.	Error pr. cent.
Balt. & Wash.	1841-2	30½		91,428	27,369	114,260	\$ 73,684	76,166	
Balt. & Wash.	1843	30½		96,716	26,470	86,880	68,866	71,676	4

Here is an agreement within 4 per cent.

When I presented this formula in the November number of the Journal, and exhibited its application to seventeen lines of railway, I stated that these seventeen lines *were all the roads for which I had been able to collect the statistical information necessary for the application.* I had written to many companies, and had generally been supplied with the facts required, and which were not given in their reports. In some instances, however, they were unable to furnish the information which I needed; in two instances I received no reply to my letter; and in one—and I am happy to say one instance *only*—the officer declined making the affairs of the company public.

Since then the three companies above named have published their reports; and *they are the only reports for the year 1843*, which I have yet received. These reports add confirmation to the previous proof. Still, I advance the formula as an approximation only, which I hope, with the aid of my professional friends, and future facts, so to modify and improve, as to render its application general and certain. It is the expression of the true LAW; but the *constants* are to be built up by multiplied facts, until there can no longer be room to doubt its indications.

I have endeavored, so far, to conform to the method which modern science points out as proper to be pursued in practical inquiries. Much injury has been inflicted on the great cause of internal improvement, and especially of railroad improvement, by the erroneous opinions of enthusiastic, but unwise, advocates. But a new order of things has grown up, and a new system of enquiry is rapidly

gaining ground. The seed of true principles have been sown, and the roots have struck deep into the soil of this country. Under the control of these principles, and the direction of cool and honest advocates, the railroad cause will take fresh growth, and flourish with a vigor and heathfulness which it has not yet exhibited. Some visionary and extravagant projects, which are now bearing heavy upon it, will sink under the pressure of their own weight, and serve, even in their ruins, as salutary guides for the future.

During the transition, TRUTH will be for a time obscured, and possibly borne down; but it cannot be overcome. It is sustained by a power which is invincible. Truth makes no compromise of principle—yields nothing for the sake of present popularity—contributes nothing to the cause of public deception—and moves fearlessly, surely, and, in the end, all powerfully, to its mark.

[NOTE.—In the January number of the Journal, I offered an estimate of the probable expenses on the Reading Railroad for the year 1843, in anticipation of the publication of any facts on that subject—assuming the travel at 40,000 passengers, and the trade at 250,000 tons. This estimate was \$265,000. I regret to find, on perusing the last report, that the company have not thought it expedient to publish their expenses for the *whole year*; but have preferred to exclude the last month, along with the heavy bills which the close of the year usually brings with it. The expenses published, for eleven months, amount to \$221,060 89. I should have been exceedingly gratified to know the amount of expenses for the whole year.

The indebtedness of the company since the date of the previous report of January 1, 1843, has been increased, \$ 1,252,659

The receipts for the first eleven months of the year, amount to 385,195

Aggregate expenditure for eleven months, \$ 1,637,854

A statement of the *items* which have consumed this enormous sum would certainly be read with interest and instruction; and it is greatly to be regretted, that at this particular period, when the public are exceedingly anxious for truth and information, the directors have deemed it imprudent to publish it.]

NOTE.—The writer has expressed his opinions on an important subject without reserve, or concealment; should his *facts* be publicly disputed, or conflicting facts be presented, by any of his professional brethren, he trusts that they will have the consideration to do it over their own signatures—that he may have the guarantee of a name for the facts which *they* contribute. He will be found as frank in correcting his errors, if he has committed any, as he is sincere in the expression of his opinions.

To be Continued.