Statement of the receipts, expenses, and net income, of ten Railroads in Massachusetts, for 1842.—No. 2.

Name of Road.	Length of road.	Cost of construction.	Receipts for passengers.	Rec'ts for freight, mail, &c.	Total receipts.	Expenses of road.	Net income.	Per centage of income for expenses
Boston & Worcestr	44.50	2,764,396	186,610	162,596	349,206	168,509	180,697	48¼
Western,	156.14	7,566,791	266,447	246,241	512,688	266,619	246,069	52
Norwich & Worcester,	58.09	2,158,561	84,343	53,975	138,318	74,459	63,859	54
Boston & Lowell,	25.75	1,978,286	148,042	130,268	278,310	131,012	147,298	47
Boston & Providence,	41.17	1,892,831	163,788	72,680	236,468	112,824	123,644	47¾
Boston & Maine,		1,260,285	109,681	46,199	155,880	79,278	76,602	51
Eastern,	56	2,299,416	237,023	32,145	269,168	119,039	150,129	44¼
Nashua & Lowell,	14.25	380,000	66,305	64,883	131,188	91,577	39,611	70
New Bedford & Taunton,	20	426,122	43,483	12,292	55,775	23,354	32,421	42
Taunton Branch,	11	250,000	55,711	21,459	77,170	57,777	19,393	74¾

March 15, 1843.

Mr. Vignoles' Lectures on Civil Engineering, at the London University College.

[Continued from Page 241.]

LECTURE V.—ON THE COMPARATIVE ADVANTAGES OF DIFFERENT RAILWAYS.

The class will, no doubt, be inclined to think that I have dwelt too long, in the first four lectures of the present course, upon the principles of economy in motive power; but I assure you, that if, in after years, any of you follow up the profession, you will find the subject one of the most vital importance. I shall this evening draw your attention to the different elements of comparison which should guide the engineer in forming a selection from different proposed lines of railway, and shall take, as a text-book for that purpose, Mr. M'Neil's translation of M. Navier's work, *On the Means of comparing the respective Advantages of different Lines of Railway*—a work which I highly recommend for your private study, on account of the clearness and accuracy of the views it contains. M. Navier states "that the elements of comparison of different lines of railway may be divided into two heads; first, the establishment of a very rapid mode of transport—a consideration which should give a preference to the shortest lines, the velocity being supposed to be the same in all; second, the increase of wealth which may result from the establishment of a line of railway. The construction of a railway, like that of a common road, or a canal, is favorable to the advancement of wealth; in the first place, because the actual expense of transport in this direction is diminished; and, in the second place, because this diminution in the cost of transport increases the value of the neighboring properties, facilitates the establishment of new works, and increases production;" and the saving effected is not merely a private advantage to those individuals who may be directly benefited by it, but is so much actual increase of the wealth of the country at large. "The first of these effects—that is to say, the diminution obtained on the actual cost of transport—is the cause of the second, so that this diminution is the principal circumstance, and that which should be principally considered." Taking it as established, therefore, that diminution in the cost of transport is the principal thing, we come to the result that the cost of motive power, on which this is dependent, is the leading point to be attended to in the formation of any line of railway. Indeed, M. Navier goes so far as to say that this is almost the only circumstance to be attended to; in his own words, "we should even say that the rate of reduction which is obtained upon the actual cost of transport, by the establishment of a new communication, is almost the only circumstance which should be thought of;" but he goes on to say, very justly, "it is also necessary to consider the quantity of goods which is carried, or which may be carried hereafter, in this direction," for the very essence of the railway system is to increase its own traffic; "for it is evident that it may be less advantageous to the country to produce a great economy in the cost of transport upon a line where there is but little to carry, and more advantageous to produce a less economy upon a line where a large quantity of merchandise is carried." These are the principles which I have been endeavoring to impress upon your minds, and which, from their importance, I cannot too often repeat. "It is, therefore," says M. Navier, "generally necessary to take into consideration, in the comparison of different lines, the quantity of traffic which may be established on each, and even the increase in the value of properties, and the development of production to which the establishment of these lines may give rise respectively, according to the nature of the countries which they traverse." I would observe, as a passing remark, that the word *developpement*, in French, generally refers to length; thus the development of a line of railway will be spoken of—meaning the length of that line—whilst, in English, the word refers to an extension of superficies. M. Navier does not go minutely into the examination of these last elements of the question, which rather belong to statistics and political economy than to engineering, but confines himself to the "consideration of the reduction which the establishment of a railway can effect upon the actual cost of transport—a most important consideration—to which, as already remarked, it is always necessary to attend; and this will form, in every case, the principal element of the comparison between different lines, and often leads to determinations purely geometrical or mechanical, and, consequently, exempt from arbitrary deductions."

M. Navier then goes on to state, that "the cost of transport on a railway, as upon a road, or canal, depends on two principal points, which it is necessary to distinguish and consider separately; the first of these is the expense of constructing the railway, and the second is the expense of conveying the goods on the railway, when it is constructed. The expense of the construction of the railway is independent of the quantity of merchandise and of passengers that will pass over it. The expense of transport, properly speaking, upon the railway supposed to be constructed, depends, on the contrary, upon the quantity of merchandise or of passengers—that is to say, all other things being equal, the expense will evidently be in proportion to the tonnage." Now, a few years back, the whole time of the House of Commons was taken up with comparing the merits of rival lines of railway, for no sooner was one line proposed than directly a rival line was started. It is well known that, for the Brighton Railway, four different lines were proposed, the discussion on the respective merits of which extended over a considerable length of time. But it is a curious fact, that, in all these discussions, the principle which has been laid down this evening was never once alluded to. Now, in the practical working of railways, the diminution of expense of transport is generally quite independent of the quantity of goods carried; for, after a line is constructed, the charges are generally arranged with reference to rival lines, or to the competition which may exist with the railway; and the interest of the money laid out is scarcely thought of, however much it may have entered into the *a priori* calculations. The Paris and Versailles Railways may be mentioned; two lines were started, one on each side of the river—the government did not like to treat either party harshly, and passed both bills, and both lines are actually executed; and, from the great competition between them, the charges for transport of goods and passengers will probably bear little, or no, relation to the interest of the capital expended. There is, however, another element which renders the calculation of a very complicated nature. The railways are different from common roads, or canals, over which, after they have been once constructed, the public have been left to find their own way—considerations of public safety render it necessary to incur great expenses in terminal and local stations, &c.; and there are also secondary expenses, such as the annual cost of repairs, police, and management, of which it may be said that they depend partly on the interest of the cost of constructing, and partly on the amount of tonnage carried. Now, from experience a general idea can be formed of the expense of these items, but, before going into the details, I will return to M. Navier, who says,—"We may, therefore, admit, without falling into any serious error, that the annual cost of transport on a railway is, in all cases, formed of two parts—the one proportional to the expenses of the construction of the way, and the other proportional to the amount of tonnage carried; and we should also observe, that the cost of transport of one ton of merchandise cannot be specified, unless the number of tons which shall be carried annually from one extremity of the line to the other, be known." Now, hitherto we have been unable to determine *a priori* what these amounts are; but we can tell with great accuracy what they have been on the different lines of railway now in operation. The following tables give the average of these expenses on several lines of railway:

Merchandise Traffic.

Heads of charge.	Coal on colliery railways in the north.	Goods on the Liverpool and Manchester Railway.
Locomotive power—wages and repairs,	0.355*	0.425*
" fuel,	0.025	0.125
Total,	0.380	0.550
Wagons,	0.190	0.227
Conducting traffic,	0.075	1.080
Maintaining railway,	0.208	0.307
General expenses,	0.100	0.354
Total cost,	0.953	2.518

* Per ton per mile—in decimals of a penny.

Passenger Traffic.

Heads of charge.	Lond. & Manch'r Railway—average 60 passengers per train.	Dublin & Kingstown Railway—av. 40 passengers per train.
Locomotive power—wages and repairs,	0.170*	0.173*
" fuel,	0.100	0.115
Total,	0.270	0.288
Coaches,	0.054	0.031
Conducting coaching,	0.104	0.113
Maintaining railway,	0.085	0.050
General expenses,	0.091	0.174
Total cost,	0.604	0.656

* Per passenger per mile—in decimals of a penny.

Taking the Liverpool and Manchester Railway as an example, we find the number of passengers to average sixty per train. This may, on the whole, be considered as a fair average on all the railroads throughout the country. Seven years' working of the same railway gives, as the average expense of locomotive power, 0.27*d.*, or about ¼*d.*, per passenger per mile. The gradients do not exceed six or seven feet per mile, with the exception of the inclined plane, and this also is an average amount for most railways—in fact, fuel and wages are so nearly the same on all lines, that the expense of this head can be calculated with great exactness. The expense of locomotive power, also, is the only one which depends upon the gradients. The other expenses, which are independent of the gradients, are—coaching, conducting ditto, maintaining way, and general expenses, altogether amounting to 0.33*d.*, which, added to 0.27*d.* = 0.60*d.*, or, in round numbers, three-fifths of a penny per passenger per mile for the expense of transport. Now, let us examine the relative expense of the merchandise traffic. We have, for the expense of locomotive power, 0.55*d.*, or, in round numbers, ½*d.* per ton per mile; for the cost of wagons and secondary expenses, 1.97*d.*, which, added to 0.55*d.*, gives 2.52*d.*, or, in round numbers, 2½*d.* per ton per mile, as the actual cost of transport. Now, let us mark the very striking result of this comparison. Even with all the most recent improvements, and cutting down every expense that can be reduced, the mere transport of passengers costs three-fifths of a penny per passenger per mile, whilst that of goods is only 2½*d.* per ton for the same distance; and of this 1*d.* may be thrown out, arising from other sources, leaving the cost of transport—passengers, three-fifths of a penny per passenger per mile; goods, 1½*d.* per ton per mile. In the first case, we have an amount exceedingly high, in proportion to the present means of transport, whilst the second case presents a result as strikingly low. A ton of goods is equivalent to the weight of fourteen passengers, with 30 lbs. of luggage each.

When the loads to be carried are light, and the velocities at which they are carried considerable, the steepness of the gradients is a matter of comparatively little consequence; but as soon as the engine is loaded to its maximum power, the railway system becomes unable to compete with the canals, so far as relates to the carriage of goods. If these are the results offered to you by past experience, do you not see at once how it affects the question of laying out lines in remote districts, where but a small amount of traffic can be calculated upon? Again, referring to the table, with reference to the difference between carrying slowly and carrying quickly, we find that the expense of locomotive power on the Liverpool and Manchester is 0.55*d.*, or nearly three-fifths of a penny; yet that the expense upon the best railways, where goods are carried at a moderate velocity, is only 0.38*d.*, and the remaining expenses 0.57*d.*, so that it comes to this, that we have —Liverpool and Manchester Railway, 2½*d.* per ton per mile; other railways, with moderate speeds, 1*d.* per ton per mile. M. Navier proposes a case not quite so strong, perhaps, as might be made out, and I will, therefore, refer to the Brighton Railroad for an example, the expense of which, for the 40 miles, has been about £2,600,000, or £60,000 per mile, the interest of which, at 6 per cent., is 10*l.* per mile per day, which is the net receipt, after all expenses are paid, requisite to insure a decent interest to the shareholders. I shall not enter further into the question now; but if those students who are sufficiently advanced will take up the subject, they will soon be able to appreciate my arguments for increasing the limits within which gradients are usually kept—for, supposing the expense of carrying a passenger should be only ¾*d.* per mile, yet, if you will calculate the additional expense of the interest of £60,000 per mile, you will find ruinous results.

M. Navier having said that the cost of transport is the chief point to be attended to in laying out a railway, goes on to determine the amount of power requisite to draw a given train over a given railway. The elder students will, in connexion with this subject, be aware of the opinion which has been generally entertained amongst engineers, that a rise of twenty feet per mile is equivalent to a mile in length. M. Navier says—"Let us observe that, upon a horizontal line, the power required to draw a given weight is considered as being equal to almost the two-hundredth part of this weight;" but, as I have shown in a previous lecture, the formula for the expression of this power will be $\frac{F}{n}$, taking F as the friction per ton, and n the number of pounds in each ton,—so that what M. Navier calls the two-hundredth part of the weight, will be friction divided by the number of pounds in a ton. Taking the friction at 9 lb., we have $\frac{9}{2240} = \frac{1}{249}$ nearly. At 11 lb., $\frac{11}{2240} = \frac{1}{200}$; and I must here repeat what I have so often before stated to you, that, although experiments have been made which give so low a friction as 4 lb. per ton, that, on an average, M. Navier is nearly right, when we take into consideration the numerous causes of friction. M. Navier considers the power required to draw a given weight "to be independent of the absolute velocity of transit, although there is reason to believe that the tractive power increases with the velocity." Now, it has been said that the friction is the same at all velocities. I cannot fully concur in this opinion. I think the axletree friction may be constant under all velocities; but that, from other causes, there appears to be, I will not call it an increase of friction, but an increase of resistance, the amount of which has not been satisfactorily determined. M. Navier goes on: "We conclude from this, that, in order to transport, with any velocity whatever, constant or variable, a weight, W, to a distance represented by a on a horizontal line, it is necessary to employ the power represented by $\frac{W}{200} \times a$—that is to say, the power necessary to raise the weight to the height $\frac{a}{200}$," or, in other words, to transport a weight any given distance on a horizontal line, is equivalent to raising it the two-hundredth part of that distance in vertical height; and, although this is not quite correct, it is sufficiently so for general purposes. We have before assumed that it is the same thing to go a mile round, as to go over a hill rising twenty feet in a mile. Now, a mile being 1760 yards, or 5280 feet, we have $\frac{W}{200} \times 5280$ as the power required, which is equal to raising the weight 26 feet. But, as the friction varies, I think we have sufficient experience now to say it is about the same thing to rise 30 feet in a mile as to go a mile round; but this is quite independent of the question, whether you should or should not allow on one hand, and deduct on the other, when the slope exceeds the angle of repose. I have explained to you, on previous occasions, the difference of opinion that exists on this point. Both Mr. Barlow and M. Navier allow the advantage up to a certain point, which they fix at about 1 in 180, beyond which point they consider the whole advantage gained to be destroyed by the necessity of putting on the brake. Now, in practice, we do not find this to be the case, until we come to 1 in 80, or thereabouts; however, we may take, as a general rule, M. Navier's concluding words on this subject:—"The length of the line remaining the same, the amount of power consumed to effect the transit depends entirely upon the length of the line, and the difference of the level of its extreme points." The practical result which I have endeavored to lay before you this evening is, that the cost of transport is the cost of the power combined with the interest of the original cost of the line, and that the calculation of this combined expense must form the element of comparison between different lines of railway.

(To be continued.)

Facts and Observations on Four and Six Wheel Engines. *By* John Herapath, Esq.

[Concluded from Page 248.]

London and Brighton Railway.

At Horley station it was intended to have the general engine factory of the company, and a large building has been erected for the purpose. On digging, however, for water, to their surprise, they found it would not do for locomotive purposes. *It literally boils out with the steam, and there is no keeping it in the boiler!* It has been analyzed, but what are its component parts I have not heard. With the ladies, however, who send for it, far and near, for tea, it seems to be a great favorite. The depth of this well is 240 feet, and it is distinguished by an intermittent escape of gas. According to several continuous observations, made by myself and some gentlemen who were there, the bubbling up is like water in rapid ebullition, and occurs very regularly every 70 seconds. This ebullition is preceded for a few seconds by a sort of simmering, which increases rapidly, and ends in the apparent violent ebullition mentioned, and then subsides into a perfect calm. We had no means of collecting and ascertaining what the gas was that escaped. A lighted candle was procured and held down to near the surface of the water by one of the men, but was so badly done as not to be satisfactory. Such as the experiment was, it manifested in the candle no signs of being affected in any way. This water rises to the very top of the tank.

On this line I saw one of the most curious circumstances I have seen upon any line. The Earlswood embankment, which is very lofty, and rests upon a sort of clay base, not long after the opening of the line sank about one-half of it down, from one and a half to two feet below the other half, a field below having risen up to the height of six or seven feet. The down line of rails, therefore, now stands