to whose discovery of the process which bears its inventor's name he so justly attributed the remarkable development of engineering industries during the last fifty years.

This exceptionally rapid increase of railway traffic during the period in question, however, was never anticipated, even by the most sanguine believers in the new process, including the author himself, and the effect of it is, it must be admitted, somewhat to discredit the estimates then made of the capability of the steel rails enduring the destructive effects of the wear and tear of the traffic for the long periods of time anticipated. This in no way detracts from the high character of the steel material, which has at least maintained all its fine qualities, and great improvements have since been made in the process of the manufacture, and large reductions in the price of the material.

As the records of the Institute proceedings testify, an intimate knowledge of the constituents of the material has been obtained by chemical analysis; but what in the case of steel rails are conspicuous by their absence in all these analyses are particulars of the physical qualities of the steel, and the amount of the tonnage and of the speed of the trains to which the rails have been subject, together with an exact measure of the wear of the rail-head during a given period.

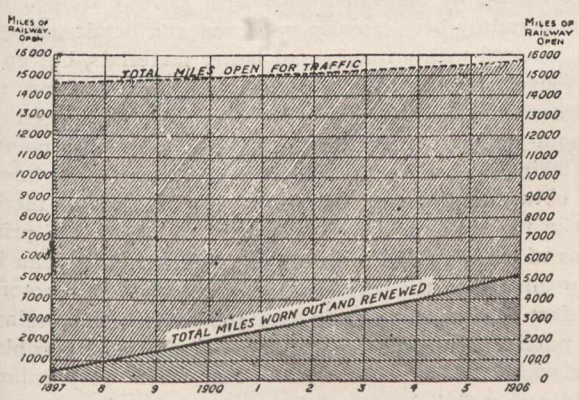


**Fig. 2.—Mileage Open of 15 British Railways.**

Full information on these points, together with Mr. Riley's chemical analyses and the late Mr. Kirkaldy's physical tests, are given in the author's paper read at the Institution of Civil Engineers in 1866. Several methods have been adopted for ascertaining the amount of wear of the rail-head at an early period, notably that of the late James Price, M. Inst. C.E., by means of a sort of 40-ft. turn-table, the rails of which were subjected to the wear of wheels loaded with given weights rotating at definite speeds round the 40-ft. table, which gave approximately the amount of abrasion of the rail-head and check of the rail on a circular curve. Recently two other very ingenious methods were described in papers read at the Institute—one by Dr. Stanton, and the other by Mr. Saniter; but in none of these cases is any account taken of some of the most destructive effects which rails are subject to in practice, such as that of impact, the oscillations and concussions of the train, particularly on curves, the shearing away of the rail-head metal in flakes, and other effects. The late Professor De Morgan, of London University, stated to the author that in the case of a train travelling at a great speed on a curved line, the oscillations and concussions partook of the character of a projectile fired from a curved cannon, and must be of a most destructive character.

In view of these facts, the author considers that nothing short of the actual experience derived from a careful register of the number, character, weight, and speed of the trains on those portions of a railway most severely worked will suffice to afford the requisite information.

The manufacturers of steel rails, to their great credit, have done all in their power to improve the quality and to increase the durability of the material; it behooves the railway engineer to see that this part of the business is carefully seen to. The result will, in the author's opinion, lead to large economies. No one, however, with any experience of railway working but must admit that the principal railways in this country are maintained in a thoroughly standard condition of efficiency for working the constantly increasing traffic, as is testified by the large annual amount per mile expended on maintenance and renewals.

As already stated, the working expenses of railways in the United Kingdom have now reached the exceptionally high average of nearly two-thirds of the gross receipts, whereas in 1860, the date immediately preceding the introduction of the Bessemer steel rail, the working expenses only amounted to 47 per cent. of the gross receipts, and during the previous twenty years which the author can recall, they had scarcely ever exceeded what in nearly all other great and well-administered commercial undertakings is regarded as the requisite normal expenditure of 50 per cent. It is not the purpose, however, of this paper to deal with this aspect of the question, but it is as well to bear in mind that nearly two-thirds of the total working expenses of these British railways have exclusive relation to the great iron and steel industries which supply most of the material required not only for the permanent way, but for the locomotive stock and large portions

**Table III.—Ten Years' Working Expenditure of Fifteen Principal British Railway Companies, (1897 to 1906).**

| Class of Expenditure. | Wages. | Material. | Totals. | Per Cent. | Average Annually. |
|---|---|---|---|---|---|
| Conveyance. | | | | | |
| Maintenance and Renewals— | £ | £ | £ | | £ |
| Permanent Way ..... | 24,624,096 | 19,134,177 | 43,758,273 | 12.30 | 4,375,827 |
| Locomotive Stock .... | 21,098,706 | 19,985,914 | 41,084,620 | 11.56 | 4,108,462 |
| Carriages and Wagons. | 17,524,413 | 26,519,282 | 44,043,695 | 12.38 | 4,404,370 |
| | 63,247,215 | 65,639,373 | 128,886,588 | 36.24 | 12,888,659 |
| Locomotive running and Coal ..... | 50,954,022 | 47,511,494 | 98,465,516 | 27.68 | 9,846,551 |
| | 114,201,237 | 113,150,867 | 227,352,104 | 63.92 | 22,735,210 |
| Traffic Expenses ..... | 128,322,469 | ..... | 128,322,469 | 36.08 | 12,832,247 |
| | 242,523,706 | 113,150,867 | 355,674,573 | 100.00 | 35,567,457 |

of the material of the carriage and wagon stock, as will be seen from reference to Table III., all of which are purely engineering matters affecting the cost of conveyance of traffic apart from the question of the administration of a railway.

### Permanent Way.

The permanent way of a railway in its widest sense, as the word itself most fittingly betokens, recognises no period of finality for its existence, so long as it continues to be the best available means for the conveyance of passengers, goods, and mineral traffic. It serves as a thoroughfare between different places and centres of traffic, and is equipped with mechanical appliances requisite for the transport of such traffic. The permanent way in this sense does not comprise merely the steel rails, sleepers, cast-iron chairs, points, crossings, and ballast, involving only an annual charge for their maintenance and renewal; but all that is essential to ensure safety and security in the conveyance of passenger and other traffic, the renewal of which, although indisputably constituting the main source of the permanent way working expenses, includes also the renewals or partial renewals rendered necessary by the natural decay of the "works of line," and other structures at much more distant periods; and the variations in the serviceable life of steel rails on different portions of the permanent way, render it impossible to determine the