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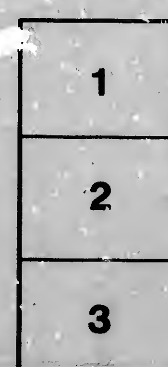

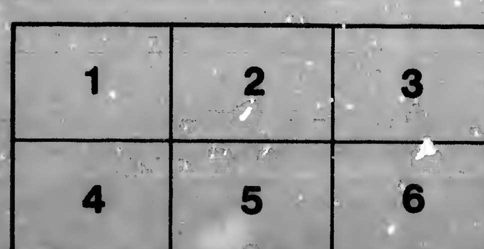

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ADDRESS

OF

MR. EDWARD WOODS,

President

OF

THE INSTITUTION OF CIVIL ENGINEERS.

9 NOVEMBER 1886.

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THE INSTITUTION OF CIVIL ENGINEERS.

Sect. I.—MINUTES OF PROCEEDINGS.

9 November, 1886.

EDWARD WOODS, President,
in the Chair.

Mr. Woods, President, addressed the meeting in the following terms on assuming the Chair, for the first time, after his election:—

Gentlemen,—The honourable distinction which you have been pleased to confer upon me by your election of me as President demands my grateful acknowledgment, and I can only hope that my qualifications for performing the duties of so responsible and important an office may be found in some small measure commensurate with my anxiety to promote and to sustain the interests of the Institution.

I shall need to claim your kind indulgence for whatever may be my shortcomings in this respect.

The difficulty of selecting appropriate matter for an address on the occasion of first occupying this Chair, arises not from the paucity of subjects which it falls within the province of the engineer to consider, but from the fact that my distinguished predecessors in office have already dealt with many of paramount interest, whilst it would seem almost an act of presumption on my part to assume that other topics, to which I may now have occasion to advert, will present any special feature of novelty, or perhaps even of interest to gentlemen whose attention has been specially directed to their consideration.

My connection with our profession dates from the time when I entered into the service of the Liverpool and Manchester Railway Company, so that it has been my good fortune to have witnessed, and to have had the opportunity of observing, the gradual and progressive development of the railway system.

The circumstance I have mentioned may perhaps be considered to offer an excuse for my venturing to recall to your notice some of the steps by which this system of inland transport has attained the degree of perfection at which it has now arrived.

Within a period of scarcely six months after the opening of that line for public traffic (which took place in September, 1830), the directors were enabled to report to their shareholders that "a new and extensive system of intercommunication, highly important to the interests of the mercantile community, and so extraordinary and complete in its character as to form an era in the progress of national improvements, and a striking epoch in the advance of mechanical science," had been inaugurated.

This statement has been, as we all know, abundantly verified in the course of the half century which succeeded the event in question.

The vast capability of railways for the transport of merchandize as well as of passengers was then foreshadowed, and the assertion fortified by a reference to what was then considered an extraordinary performance, viz., that of "a new and powerful locomotive engine, the 'Samson,' made by Messrs. Robert Stephenson, which conveyed a load of 107 tons of merchandize from Liverpool to Manchester, at an average speed of 12 miles per hour, having been assisted in the ascent of the Rainhill incline plane (1½ mile of 1 in 90) by three other engines." The experiment, as the Report goes on to state, exhibiting "a practical answer to the confident, but ignorant assertion, that railways are not calculated for the conveyance of heavy goods."

Scarcely, however, could it then have been foreseen that within the period of the next fifty years the railway and the locomotive would constitute the most important and nearly universal system of inland transport throughout the civilized world.

Until the opening of the Grand Junction Railway in 1837, and of the partial opening of the London and Birmingham Railway during the same year, and its final completion in the autumn of 1838—undertakings commenced shortly after the success of the Liverpool and Manchester Railway had been well established—no Great Trunk lines existed, and only a few short local lines, some of them being branches from, or dependencies of, the Liverpool and Manchester Railway.

Meantime engineers and deputations, from Canada, from the United States of America, from France and other continental States, flocked to England to study the working of the new system. Amongst these was Monsieur de Pambour (afterwards Comte de Pambour), an officer of the French Government. He, with the permission of the directors of the Liverpool and Manchester line, spent many weeks in investigating all the details of its working, and in recording the performances of its locomotives.

The work which he afterwards published (in 1836), entitled "On

Locomotive Engines on Railways," was a valuable contribution towards the elucidation of the true theory of the application of steam as a motive power, and served to dispossess many of the accepted empirical rules which, being in the main founded on practice, in view of the special conditions under which steam had been theretofore applied, had no adequate scientific basis on which to rest the computation of the duty of the steam-engine under the new conditions imposed by the requirements of the locomotive engine.

The Liverpool and Manchester Railway, therefore, may be regarded as having afforded the pattern and example upon which (with such modifications as the experience of the first few years of its working had suggested) its immediate successors were designed and framed.

It may be of interest to recall a few of the principal steps of development which have led up to the state of efficiency which is now found to prevail, in regard both of road and rolling stock.

The line from Liverpool to Manchester was originally laid on so-called fishbellied rails of 35 lbs. per yard, resting in iron chairs, supported on stone blocks wherever solid ground permitted their use. Wooden sleepers were only availed of as a temporary measure where the road was on embankment, or on soft moss, and simply as affording ready means of lifting and adjustment until the bed had become well consolidated.

So much importance was at that time attached by the engineers to the provision of a firm and rigid foundation for the rails, that we find Mr. George Stephenson availing of the rocky floor of the Olive Mount cutting, near Liverpool, to form a bed on which the chairs should directly rest.

Again, Mr. Jesse Hartley, the engineer to the Liverpool Docks, and possessing large experience and great faith in masonry constructions, when appointed engineer of the Bolton and Manchester Railway, commenced, and carried out to a large extent, the system of building up, from the ground level, solid stone walls on which he rested his rails.

Mr. Brunel, preferring timber supports for the Great Western lines of rail, drove in piles to hold down the longitudinal half balks of timber, on which he placed bridge rails.

All these methods were found, from one cause or another, to be defective; and, chiefly by reason of injury done to the rails through excessive rigidity, had soon to be abandoned.

It was fortunate that, with the exception of the case of the Bolton and Manchester Railway, no great expense was incurred in acquiring the experience these trials afforded.

On the Liverpool line the increasing weights of engines and speed of travelling soon necessitated a more substantial roadway, and led to the ultimate relaying, in successive portions, of the entire road, first with rails of 50 lbs., then of 62 lbs., afterwards of 72 lbs., and finally of the still heavier type now in use, made latterly of steel instead of iron.

The fish-bellied form was superseded at an early period by a rail of uniform section throughout, an improvement resulting partly from the experience of a sample piece of the line so laid, and partly from the conclusions arrived at by Mr. Robert Stephenson in determining the form to be adopted for the London and Birmingham Railway, after an exhaustive inquiry, conducted by the late Professor Barlow, at the instance of the Board of Directors of that railway.

Mr. Locke had elected to adopt a similar form of rail for the Grand Junction Railway, and to lay the entire line on wooden sleepers. Since then stone blocks have been almost universally abandoned, as it was seen that, although wood was of a perishable nature, its elasticity, and the facility which it afforded for repairs, materially diminished the cost of maintenance, and contributed greatly to relieve the rolling-stock from the shocks and jars it encountered in passing over a rigid road.

The same considerations led to the general adoption of the compressed wood key in preference to the iron key, for securing the rail to the chair.

These variations, together with the subsequent application of fishing the joints of the rails, and the substitution of steel for iron, are embodied in, and constitute the accepted practice of, the present day.

Cast-iron sleepers have been used somewhat extensively on foreign lines, but it is not improbable that ere long steel sleepers may take the place of these as well as of wooden ones, and we already see such coming into use on several of our leading Trunk lines in England as well as on the continent, whilst large quantities are exported to India, where, in addition to their other qualities, they afford exemption from the attacks and ravages of the white ant. The ingenuity of our mechanics is being successfully directed to the devising of simple and effective means of securing the rails to such sleepers.

Generally the substitution of steel for iron rails has been attended with most beneficial results to all railway companies, a change which was rendered possible by the inventions of Sir Henry Bessemer, and of the late Sir William Siemens, and by the keen competition of manufacturers, enabling supplies of this material to be obtainable at less than half the price which iron rails commanded not many years ago. Within a recent period contracts have been made for steel rails of heavy double-headed section delivered free on board at less than £3 10*s.* per ton, whilst in 1870 the market prices of iron rails of similar type ranged as high as £7 10*s.* per ton, steel rails then ruling at £10 per ton.

The original rails of the Liverpool and Manchester Railway were, as far as my recollection serves, delivered at the price of about £11 to £12 per ton (1829).

On the main lines of this country steel rails weighing from 86 lbs. to 90 lbs. per yard are now coming generally into use, lighter rails being no longer adapted to sustain the heavy weights which in our modern and powerful locomotives are concentrated on a single pair of wheels, a weight in some cases amounting to 17½ tons.

In other cases, where it is permissible to couple two or more pairs of wheels and distribute the weight of the engine over a larger number of them, lighter rails can be, and are, used with advantage. In this way rails varying from 42 lbs. to 65 lbs. per yard are employed very extensively on the lines of the American continent and elsewhere.

The question of gauge elicited scarcely any discussion in the case of the Liverpool and Manchester Railway.

The gauge of 4 feet 8½ inches was adopted without question as a convenient one, being identical with, or closely approximating to, the gauge of the Stockton and Darlington line.

It was in 1838 that the question assumed importance, and the battle of the gauges raged fiercely in consequence of the adoption, by Mr. Brunel, of 7 feet as the gauge of the Great Western and its tributary lines.

Whatever may have been the mechanical advantages due to such increase of gauge, these, as time passed on, were shown, as regards English railways, to be far outweighed by commercial considerations incidental to the obstructions arising from breaks of gauge and to consequent diversion of traffic into the lines of other companies.

These considerations eventually determined the Great Western Railway Company to adopt the mixed (broad and narrow) gauge over nearly all portions of their system, which theretofore had been laid on the broad gauge.

The history of the events which led up to conviction that steam power was destined to become the chief agent for land transport in the immediate future is too familiar with all to bear repetition, but it may not be out of place to observe that even the most advanced type of locomotives of the present day retain the essential characteristics of those which held the field at the commencement of the era to which I have referred. The important features common to both included the water-surrounded furnace chamber—the multitubular boiler—the wheels mounted either on crank or on straight axles, whether single or coupled, driven by a pair of horizontal or inclined cylinders, the smoke-box and the steam blast to intensify the draught.

As time went on, great improvements, it is true, have been effected in most, if not in all, constructive details, whilst the progressive increase of traffic called for a corresponding augmentation of the power necessary to haul the trains.

Hence we find that locomotives of the present day possess, as a rule, at least four times more steaming power coupled with six-fold weight than those of the class represented by Messrs. Robert Stephenson and Co.'s engine, the "Planet," the approved type of the period from 1832 to 1836.

The "Rocket" class had before this period proved too deficient in power for conveying the regular traffic.

Contrasting the two types, we see that the approximate comparison as regards weight is as 7½ tons to 45 tons; as to fire-grate area, as 7 square feet to 20 square feet; as to heating surface, as 300 square feet to 1,400 square feet.

The successive changes and improvements from time to time effected have not only served to enable our traffic managers to cope with the ever-increasing volume of traffic, but have also been the means of procuring great economies in the conduct of it.

I may refer to a few out of the many instances in which a marked and enduring influence has been exercised.

In the article of fuel a great saving was effected on the Liverpool and Manchester Railway by an improvement in construction of the slide valves. This, by permitting the free discharge of steam after its work in the cylinders had been done, relieved the engines of a resistance which theretofore had absorbed and neutralized a large portion of their power. The alteration throughout the stock could only be carried out gradually as the engines came in for repairs, or as new engines could be built in the company's workshops to gradually replace such as did not admit of alteration. The result, in great measure attributable to the change in question, was that whereas 12,600 tons of coke were consumed in the service of the traffic in the year 1839, only 3,100 tons, or one-fourth that quantity served four years later, viz., in 1843 for the conduct of a traffic of greater volume, the diminution in the meantime being steadily progressive from year to year.

The application of expansive working by mechanism actuating the slide valve, coupled with the use of steam at higher pressures, was initiated as regards the locomotive by the late Mr. John Gray, in the year 1838, and first fitted by him to an engine called the "Cyclops."

This somewhat complicated and cumbrous apparatus was afterwards superseded by the "link motion," a simple and beautiful piece of mechanism, which, as is well known, has been brought into almost universal use. It was the invention of Mr. William Howe, an intelligent mechanic in the employ of Messrs. Robert Stephenson and Co., of Newcastle, and was adopted for the first time in their works in August, 1842.

The idea appears to have been suggested simply with the object of easier reversing, an improvement on the older arrangement of the "double gab," under which the forked or "gab" ends of the two eccentric rods, actuated by their respective eccentrics were connected by a short link, and thus lifted or lowered simultaneously the one into, the other out of, gear, according as it might be required to drive the engine forwards or backwards. This motion involved the stoppage and sudden starting again of the slide valve whenever the operation had to be performed, an operation attended with considerable shock and risk of derangement or fracture when performed whilst the engine was in rapid motion.

For the simple link, Howe substituted a slotted one, with a block sliding in it, carrying a pin to actuate the valve-rod, and adjustable within any given position within the link by the lever under control of the driver, so as to impart to the valve, without arresting its action, the special motions necessary for reversing and cutting off steam.

This invention, if it had been patented, would doubtless have proved a most lucrative one; but the inventor did not possess the means to secure the patent right, nor does it appear that its prospective value was, in the first instance, duly and fully appreciated by him.

Combined with the high pressures of steam now used, 140 to 180 lbs. per square inch, the link motion has contributed greatly to economising of fuel in the locomotive.

Certain substitutes for the control of valve motion by the link gear have been in some cases, and with advantage, adopted both in locomotive and marine engines. They possess the merit of simplification of parts, and of greater accuracy in regulating the points of cutting off and of releasing the steam.

Amongst these the most typical and effective is the invention of Mr. Joy, patented some eight or nine years since.

Eccentrics are dispensed with, and the movement of the valve is produced by a combination of two motions at right angles to each other, taken direct from the connecting-rod and giving both the reversal of motion and the various degrees of expansion required without interruption of the continuity of motion in the valve.

For this form of valve-gear are claimed accuracy of result, reduction of cost, saving of room which can be advantageously applied for introducing larger cylinders, obtaining thereby a higher rate of expansion, and increasing the area of wearing surfaces for all the main bearings.

Express engines on the London and North-Western, Great Eastern, North-Eastern and other lines, have been fitted with this gear. I am informed that the number of locomotives thus provided now amounts to about five hundred.

Valve-gear of a somewhat analogous kind has been used on the American Continent and also in some European countries—the inventions, one of Mr. Stevens, the other of Mr. Walschaert.

On most if not on all the leading passenger lines of this kingdom, coke was the fuel used in the furnace of the locomotive boiler up to the year 1852, owing to its freedom from smoke; but its greater cost as compared with coal led to the consideration of methods by which the combustion of this last-named fuel might be effected without the production of an objectionable amount of smoke.

Increased area of fire-grate, permitting a slower rate of combustion; a larger capacity of furnace, with appliances therein for maintaining high temperature of the evolved gases and for effecting the admission and directing the current of saturating volumes of atmospheric air, sufficed to solve the problem, and thus to secure the vast savings which have been accomplished as due to the difference of cost of the two descriptions of fuel.

The contrast in point of efficiency between the locomotives of the present period and those of half a century ago is sufficiently striking, and it may not be out of place to mention certain characteristic particulars kindly furnished to me by the engineers of several of the leading lines of railway in this country and in North America, illustrative of the most approved types which are now employed in the conduct of the express passenger and heavy merchandise and mineral traffic of their respective lines.

A rough average derived from the corresponding engines of those respective types as in use on the London and North-Western, the Midland, the Great Northern, the Great Western, the North-Eastern, the London and Brighton, the Caledonian, and the Lancashire and Yorkshire Railways, presents the figures given in the subjoined note, as fairly representative of modern practice.[1]

The relation as regards weight and power which these engines bear to those of the early period referred to may be thus expressed.

As to tractive power the increase is at least five-fold, having regard to the proportions of the parts, the steaming capacity of the boilers, and the higher pressures of steam at which the engines are now worked.

Amongst the locomotives above-mentioned are some in which the system of "compounding" now engaging the serious attention of our mechanical engineers, has been successfully carried out.

I note in particular the three cylinder express passenger engines of Mr. Webb, running on the London and North-Western Railway, and the two-cylinder engines of Mr. Worsdell, introduced by him on the Great Eastern and recently on the North-Eastern Railway, in respect of which a considerable saving of fuel is claimed (and I believe justly) to have been effected, amounting to some five pounds per train-mile, or about 20 per cent. on the consumption of ordinary engines.

Success on these and other lines once established will doubtless

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[1] *Express Passenger Engines.*

Weight of engine in working order, say	42 tons.
Greatest weight on a single axle	15 „
Area of fire-grate	19 square feet.
Heating surface	1,300 „
Pressure of steam in boiler	140 lbs. per sq. inch.
Tractive power, assuming an average effective pressure of steam in the cylinders of 90 lbs., per square inch	8,900 lbs.

Merchandise or Mineral Engines not being Tank Engines.

Weight in working order	38½ tons.
Greatest weight on an axle (N.B. axles coupled)	14 „
Area of fire-grate	18 square feet.
Heating surface	1,300 „
Pressure of steam in boiler	140 lbs. per sq. inch.
Tractive power, assuming on an average effective pressure of steam in the cylinders of 90 lbs., per square inch	12,690 lbs.

lead to their more general adoption both for passenger and goods traffic.

Inclines which at one time were regarded as too formidable to be worked advantageously by locomotives, are now readily surmounted by the powerful engines of the present day. Hence we find gradients of 1 in 50 and 1 in 60 common on many railways, whilst important lines, ascending and crossing mountain ranges in different parts of the world, have continuous ascents of many miles in length of 1 in 25, 1 in 30, 1 in 33, &c., worked by engines differing only from such as are common in England in the circumstance of greater dimensions and capacity, and adjusted so that the weight on the coupled wheels shall be sufficient for the utilization of the tractive force they are designed to put forth.

The great length of many of the American and Canadian railways, the heavy gradients occurring in the crossing of mountain ranges and the limitation of the number of trips with a view to economy, are conditions which have led to the adoption of a class of locomotives capable of conveying immense loads, and of coping with the mountain slopes of those regions.

There are many types of these, but the "Consolidation" engine (so called from its being designed at a time when several railways were being united) appears to be the favourite engine in the United States for work on long grades. Those on the Northern Pacific Railroad have a grate area of 30 square feet and a heating surface of 2000 square feet, with four pairs coupled driving-wheels of 4 feet 1 inch diameter, and a four-wheeled bogie truck in front, the weight on the four driving axles being 45 tons, and that on the truck 6½ tons.

These were built at the old-established works of the Baldwin Company, who have kindly supplied me, through Mr. Barnett, the Locomotive Superintendent of the Grand Trunk of Canada Railway, and President of the American Railway Masters' Mechanic Association, with the sizes and sketches of six different designs of "Consolidation" engines, and amongst them that of a most powerful engine for working mountain grades of 316 feet per mile (1 in 17) employed for provisionally working a temporary "switchback" track or zigzag 15 miles in length, crossing the Raton Range of the Rocky Mountains on the New Mexico and Southern Pacific Extension of the Atchison-Topeka and Santa Fe Railroad. It is an eight-wheeled coupled engine with two-wheeled "Pony truck" in front, with a weight of 45 tons on the driving-wheels and a total weight of 50 tons. Cylinders 20 inches by 26 inches. Wheels 42 inches diameter. Tractive power 247 lbs. per 1 lb. per square inch pressure of steam on piston. Area of fire-grate $27\frac{1}{2}$ square feet. Heating surface, 1376 square feet.

The following performances are reported :—

It hauled, exclusive of engine and tender,

On gradients of	1 in 50	= 482 tons gross	at	8	miles per hour.
„	1 „ 29	= 258	„	8	„
„	1 „ 17	= 194	„	6	„

These performances must have involved a tractive force exerted of at least from 26,000 lbs. to 33,000 lbs., corresponding with an effective average pressure on the pistons of 106 lbs. to 134 lbs. per square inch. So high a result could only have been obtainable under favourable circumstances of weather, allowing a maximum of adhesion between wheel and rail.

Another type of locomotive built by the "Strong Locomotive Engineering Company" of Philadelphia, is specially adapted for burning anthracite and low grades of coal. To effect this object the grate of express and freight locomotives attains an area of no less than 62 square feet, or more than double that of the "Consolidation engine above mentioned, the rate of combustion being thereby reduced by 50 per cent., admitting the use of a very thin fire.

The furnace and combustion chambers are corrugated cylinders, their ends are dome-shaped, and thus staying is dispensed with. Their form and construction differs materially from those of the ordinary fire-box. The valve-gear is of special construction, worked from a pin in the connecting-rod through the medium of links and levers, cutting off from 3 to 20 inches without affecting the exhaust.

From a very early date the application of the four-wheel bogie truck, or of the two-wheeled (so-called) "Pony" truck, came to be very general on the lines in the United States, affording great flexibility both laterally and vertically, and therefore specially adapted to traversing the sharp curves and compensating the irregularities of track, which at that time subsisted in the rapidly and economically constructed railways of the period. The advantages accruing from the adoption of this mode of support to the leading, and sometimes also to the trailing end of the locomotive, have led to its extensive application in later times on roads of a more substantial description, both on the American continent, in our own islands, and in some parts of Europe.

By locomotives partaking of the character of those above referred to, whether of similar or somewhat varied dimensions, and as subject to the special circumstances of each case, gradients, thought impossible to be worked by locomotives dependent on adhesion of their coupled wheels by simple contact with the rails, are now constantly and readily surmounted.

Amongst the steep inclines of important railways so worked the following may be enumerated as typical.

The Lima and Oroya Railway crossing the chain of the Andes, with a summit-level of 15,672 feet above the sea, attained in a distance of 100 miles by gradients of 1 in 25, and 1 in 34.

The Arequipa and Puno Railway, also crossing the Andes, at a summit-level of 14,666 feet above the sea, with maximum gradients of 1 in 25.

The Denver and Rio Grande Railway crosses the mountain range at a summit-level of 10,850 feet above the sea, with ruling gradients of 1 in 30.

The Union Pacific Railway, crossing the range of the Rocky Mountains at a summit-level of 8,242 feet, with ruling gradients of 1 in 88.

The Mont Cenis and Mont St. Gothard Railway, crossing the Alps at elevations of 4,379 feet, with ruling gradients of 1 in 33 in the case of the Mont Cenis line, and 1 in 40 and 1 in 38 in that of the St. Gothard.

The Brenner and the Sömmering Railway, having ruling gradients of 1 in 40 to 1 in 43.

The railway over the Blue Mountains (Australia) attains the summit by an almost continuous gradient of 1 in 30 to 1 in 33.

The limit of inclination admitting of being surmounted by locomotives of these types appears to be practically reached at the figure of about 264 feet to the mile (1 in 20), for beyond that limit the weight necessary to be given to the engine to procure adhesion absorbs, by reason of the gravity of its own mass, the greater part of the power it is competent to exert.

Resort must then be had either to the stationary engine and rope, or to one or other of the systems which have within a recent period been reintroduced.

Pending the completion of the Mont Cenis Tunnel, the system of pressure contact between wheels and rails was exemplified in 1867 with considerable success in the Fell Railway laid over that mountain, with maximum gradients of 1 in 12. The traffic across was thus carried on for many months. As adhesion varies between smooth surfaces with the state of the rails, it was seen to be important in such cases to adopt a system which should render the contact independent of the state of the weather, and the attention of engineers in seeking to solve the problem naturally reverted to the idea of the rack and pinion arrangement, which was patented by Blenkinsop in 1811, and applied on one or more colliery tramways in Yorkshire.

The Swiss engineer Herr Riggenbach, of the Swiss Central Railway, constructed the first mountain railway in Europe, from Vitznau on Lake Lucerne to the Rigi Culm, completed in 1871. Its maximum gradient is 1 in 4.

A road of similar construction, viz., with centre rack rail, into which the pinion on an axle driven by the locomotive geared, had been completed in 1869 by an American engineer, Mr. Sylvester Marsh, leading to the top of Mount Washington, its maximum gradient being about 1 in 3.

Whereas Blenkinsop's rack rail had been made of cast iron, with teeth of the usual form, the rack-rails of the two mountain roads were made of wrought iron, ladder fashion, the sides of angle iron, and the rounds riveted in to serve as cogs.

They have worked the tourist traffic successfully, and with considerable profit, ever since.

More recently Mr. Abt, the constructing engineer associated with Mr. Riggenbach, has introduced a new rack system, substituting for the ladder rack a rack rail, built up of two or more elementary racks placed side by side, with broken joints and teeth ranged in steps, giving continued contact, and consequently smoother motion. The driving pinion is composed of as many toothed disks as correspond with the greatest number of elementary rack bars laid down on any given section at the road.

The number of such bars is adjusted in relation to the gradients, so that each bar shall be subject to not more than a specified limit of strain, so as to come within the factor of safety.

Mr. Abt has constructed a line in the Harz Mountains, in which this principle has been adopted. It is about 16 miles in length, of which 3½ miles is furnished with the rack rail. The locomotives, weighing 54 tons gross, with 42 tons on the adhesion drivers, are arranged to work in the ordinary way on the lighter gradients, *i.e.*, up to 1 in 40, the pinion and rack being put into gear when the steep inclines are to be surmounted. These latter range from 1 in 16 to 1 in 22.

The success of this system, as evidenced by the work now being done on this line, augurs well for its more extensive application to districts in which the conditions are similar, and may serve to bring into profitable commercial connection places which otherwise, and without very costly works, would remain isolated.

Our notions with regard to gradients have certainly undergone an important change during the last forty years.

There existed, and still exist, two inclines (each about 1½ mile in length) of 1 in 90 on the main line of the Liverpool and Manchester Railway, which from the first have been worked by locomotives; yet these were considered of such an exceptional character, that Mr. George Stephenson had originally contemplated and provided for the erection of fixed engines at their respective summits for working the ascending traffic by ropes.

It was considered a bold and even hazardous undertaking on the part of Mr. Locke to carry the line of the Lancaster and Carlisle Railway up the slopes of Shap Fell for 7 miles, on a gradient of 1 in 70, to be worked by locomotive power.

Indeed Mr. Robert Stephenson had, in the case of the London and Birmingham Railway, fixed his limiting gradient at 16 feet to the mile (1 in 330).

No doubt these engineers exercised a sound judgment in the instances I have mentioned, their decisions being arrived at from considerations determined by prescribed conditions and comparison of advantages and disadvantages due to lessening the cost of transport on the one hand, and increasing capital outlay on the other.

Concurrently with the increase of traffic, the increased speed at which it had to be conducted, and the increased number of trains that it was necessary to provide for daily, fresh agencies were brought to bear, without the aid of which those conditions and requirements could not have been satisfied.

To the present generation it would seem difficult to realise that for many years after the inauguration of the railway system the use of distant signals was unknown; that to stop a train, the gateman or signalman had to wave a flag or a lantern, or to mount a ladder at his lamp-post, take out the lamp from its iron, and replace it with its red bull's-eye turned towards the advancing train.

After this came the introduction of lamps, mounted permanently on lamp-posts, and operated by a lever from below; and more recently the introduction of the "distance signal," and the appliances necessary for controlling it from the home signalman's station.

Still later did it become possible to actuate all the switches opening into the sidings and cross roads of a station from a central signal-box, supplemented afterwards by the admirable arrangements for interlocking, and the simultaneous control of signals as depending on the altered positions of those switches, the mechanism contrived for the accomplishment of these objects being brought to a high state of perfection by the inventions of Messrs. Saxby, Messrs. Stevens, and others. * See Note.

Then we had the invention of the electric telegraph, enabling instant communication between station and station, and afterwards the establishment of the "block" system, which, when carried out properly, would seem to have reduced the chances of collision to a minimum, so far as signalling is concerned.

As the power of the engines was increased, so also was the time of getting up speed after stoppages diminished, causing the speed on a long journey to be maintained at a higher average, whilst the average in the case of passenger trains was further augmented by the application, now very general, of the continuous brake.

This apparatus was introduced at a comparatively recent date, for up to the year 1874 the use of the ordinary hand-brake, as applied to the tender and to a couple of vans, or even to a single van, prevailed on our leading lines of railway, with the exception of the Lancashire and Yorkshire and the East Lancashire Railways. It was in 1858, and consequent upon the reports of their inspecting officers, that the Board of Trade had, by a circular of their then Secretary, Captain Douglas Galton, called the special attention of the railway companies to the fact that the amount of brake-power then habitually supplied was insufficient to prevent the frequent occurrence of accidents from collisions, many of which they considered might have been modified or averted had the trains been more adequately supplied with brake-power. Special reference was made to the two systems, those of Newall and Fay, which had come into daily use on the above-mentioned railways.

By the trials of different systems of applying brake-power conducted on the line between Lincoln and Nottingham in 1875, under direction of a Royal Commission, it was shown that whereas by the application of hand-brakes, applied as they then habitually were, a train of 200 tons gross weight, going at 50 miles an hour on a level line, could only be brought to a stand within a space of about 1,490 yards; a similar train of the same weight, travelling at the same speed, but provided with a suitable description of continuous brake, could be brought up in 18 seconds from the time of applying the brake within a space of only 300 yards.

The advantage resulting was so obvious, and the urgency so great, that most of the companies at once saw it to be to their interest to apply some form or other of continuous brake to their passenger rolling-stock, notwithstanding the heavy cost which it

* The original Inventor of interlocking apparatus, was Mr. Austin Chambers, Signal Inspector on the North London Railway. Whose patent was bought by Messrs Saxby & Farmer.

entailed. This general recognition of its value may therefore be regarded as dating from 1875.

Meantime the comfort of the travelling public had not been neglected, and has been largely supplemented by the improvements which have been effected in rolling-stock.

The model at first followed in the construction of passenger carriages was based substantially on the adaptation of the type of the old six-inside passenger stage-coach, and the four-inside mail-coach to the new development. The compartments of the first railway carriages were only slightly more capacious. Each train carrying a mail was provided with a carriage of the orthodox mail-coach colour, attached to the rear, with two compartments containing four passengers each, and a *coupée* for two, and at the back the elevated outside seat of the mail guard, with his "Imperial" for the mail-bags mounted on the roof. In lieu of this we have now the well-appointed separate mail-van, thoroughly lighted, provided with accommodation for clerks and for the sorting of letters *en route*, and for the passengers luxurious carriages of different descriptions, some of them fitted up with all accessories necessary for sleeping and dining on the road. Second-class passengers, who are now conveyed in comfortably cushioned carriages, protected from the weather, were then thought to be sufficiently accommodated in carriages, or rather trucks, the sides of which were only a little higher than the seats, with a roof, it is true, overhead, but with the sides open and exposed to wind and rain, such, however, affording them better protection and greater comfort than could be obtained when travelling on the outside of the old mail coach.

Although it does not fall within the scope of the present address to consider the progress made of late years in foreign countries, otherwise than as bearing directly upon our own railway industries, I may perhaps venture to refer to some engineering works carried out in the North of Spain, which, largely by the application of British capital, have not only been attended with important results as effecting economy in construction and working of railways, but have at the same time contributed to subserve the manufacturing interests generally of this country. I refer to the great movement and change which has taken place consequent upon the substitution of steel for iron in the manufacture of rails, and of various structures which heretofore have been made of iron. The mines in the North of England proved inadequate for the supply of hematite ore, at moderate price, in quantities commensurate with the rapidly increasing demand for steel. Hence, in 1871, the attention of ironmasters in this country was anxiously directed to the procuring of adequate supplies of such ore.

The district around Bilbao, and specially the mountains of Triano, in the neighbourhood of Somorrostro, had from time immemorial been known for the abundance of its iron ore. The ancient workers, the Romans and the Moors, had driven galleries from the hillsides into the lodes seen to be cropping out, and, following up the soft veins of ore, had been able to reduce the iron with ease in their so-called Catalan forges, an iron celebrated for its ductility, its freedom from sulphur and phosphorus, and its otherwise superior quality.

This, then, was seen by our English manufacturers to be a suitable field from which to derive additional supplies. They took measures for having it thoroughly investigated and reported upon.

Of the several mineral lines established by foreign capital for bringing down the mineral to the port, the first and longest (22 kilometres in length), now called the Bilbao River and Cantabrian Railway, was constructed under my direction by a company promoted by ironmasters in Sheffield. It skirts the mountains of Triano, and has for its terminus at one end the mines of Galdames, and at the other a point of the estuary not far from the mouth of the River Nervion. The works were commenced in 1872, and completed in 1875, after serious delay and interruptions caused by the Carlist War. The district through which the line passes had been in the meantime the seat of the most terrible struggles of the war.

Owing to these and other difficulties arising out of the situation, the first shipment of mineral transported over this line took place early in May 1876.

Previous to this date the first enterprise of the kind in Bilbao, the mines of Triano, more generally known as those of Somorrostro, had alone been served by a line which had been in existence since 1865, without contributing very largely to their development. It was constructed, and has throughout been worked by the Provincial Deputation, an administrative body for the management of the affairs of the province.

Starting from the river at San Nicolas (El Desierto), it terminated in a valley at the base of the Triano Hill, the ore being brought down to the terminus in bullock carts, and there loaded into the railway trucks. This mode of communication has been since, however, supplemented by a wire tramway.

The opening of the Galdames line (Bilbao River and Cantabrian Railway) was followed in 1877 by that of the Orconera line, giving access to the very valuable mines of Matamoras, with a branch into the Triano mines, and still more recently by that of the Franco-Belge Company in 1880.

The whole district is now intersected with a network of branches supplementary to the main lines of railway, and consisting of light tramways, self-acting inclines, and overhead wire tramways.

The exportation of iron ore from the Bilbao River during the ten years previous to 1870, had risen gradually from 54,000 to 246,000 tons per annum, a nearly 35 per cent. rate of increase in that period, but still greatly below that which it afterwards attained.

A great hindrance to the rapid development of the trade of the port had consisted in the limit imposed on the size of ships trading thereto, by reason of the deficient depth of water on the bar.

The bar was a shifting one, its position changing from time to time by the variations in the direction of the wind, and the force and volume of the outflowing land-waters.

Vessels of 12 feet draught, carrying 900 tons, could only leave at the top of the tide, and vessels of larger draught and capacity were constantly being detained until spring tides afforded the necessary depth of water.

About the year 1861 the late Mr. Charles Hutton Vignoles, who was engineer of the railway from Bilbao to Miranda, made a survey of the port, and submitted a comprehensive design, consisting in the main of a breakwater outside the bar, connecting the opposite shores of the bay with a suitable entrance for ships.

Means were not forthcoming to defray the cost of the proposed works, and no action was taken in respect to them.

The time having arrived for the matter of port improvements to be seriously taken up, the representatives of the principal interests concerned associated themselves with the Bilbao Chamber of Commerce in engaging Sir John Coode to examine the question and advise on the construction of such works (designed on a more limited scale than those of Mr. Vignoles), as might serve to increase the depth of water on the bar, and improve the river generally for the accommodation of a possible export traffic of from 2½ to 3 million tons of ore per annum.

Sir John Coode made his report in 1873, and having regard to the circumstance "that the bay was totally unprotected from the north-west," and "to the limited normal depth of water over the bar," recommended the following works:—

A breakwater across the bay with a central portion 3,000 feet in length, and two arms of 800 feet each.

Guiding works to direct the currents passing in and out across the bar.

Dredging of the river channel near its mouth to a depth of 16 feet 6 inches at low water of spring tides, and diversion of the channel in two places.

The cost of the whole was estimated at £1,100,000, and the time for completion about eight years.

There is no doubt that this project, if it could have been then carried into effect, would have afforded an admirable solution of the problem; but unfortunately, the resources of the local authorities were not found adequate to the outlay involved, and matters remained in abeyance for a period of four years during which the delays sustained by ships, detained from want of sufficient depth of water over the bar, and the consequent limitation of the amount of exports, aroused the authorities to the necessity of making a vigorous effort to reduce, and if possible to remove the evil.

Accordingly, with the sanction of the Supreme Government, a Board of Works was constituted for the improvement of the river, with power to levy a tax on imports and exports, to be applied to covering the requisite outlay.

The services of Don Evaresto Churruca, a Spanish Government Engineer, were engaged by the Board, and certain works designed and recommended by him after careful study of the various projects of improvements which had from time to time been submitted, including those of the English engineers, were sanctioned by the authorities at Madrid. These were promptly initiated, are now partially executed, and it is expected will be completed by the summer of 1888.

The principal objects kept in view for the port improvements were the opening of the river at high water at all times to all the vessels trading with the port, entrance being then practicable only during spring tides, the admission of vessels of greater draught by increasing the depth of water on the bar; the improvement of the conditions of the river generally by means of training-walls and by dredging; the prolongation of the western mole at Portugalete, at the mouth of the river, to a point beyond the banks of the bar so as to fix the direction of the channel, and intensify the scouring action of the tidal and freshwater currents.

These ends have been steadily pursued with the result that, although some of the works contemplated have not yet been finished, the improvements already affected are of a most marked and important character.

Señor Churruca's report for 1885 states that vessels now leave the river with 17 feet draught at neap tides, whereas they could not venture on more than 15 feet on the highest of spring tides.

In October, 1884, the steamer "Rivas" sailed with 21 feet of draught laden with 3,340 tons of ore, and 130 tons of bunker coal (in all 3,470 tons), while four years earlier the largest cargoes did not exceed 1500 tons.

In the same report Señor Churruca remarks, "The entrance to the river, although it has much improved, is far from exempt from risks when there is a heavy sea, and to overcome these it would be necessary to construct outside sheltering works which are beyond the limits at the Board's disposal."

Such sheltering works in the shape of breakwaters were essential features of Sir John Coode's design.

The dues levied have not sufficed to meet the outlay. They have amounted over the last few years to an average of about £40,000 per annum.

Towards meeting the deficiency bonds have been issued redeemable by half-yearly drawings over a period of twenty years commencing from the 30th June, 1886, for a total sum of 4,000,000 Pesetas, say £160,000.

The impulse given to the trade of the port, due to the increasing demand for this quality of ore, a demand that can now be adequately met by the altered conditions of the river and its bar, is shown by a comparison of the imports and exports of the last few years.

In the year 1879–80, the imports and exports of the Port of Bilbao amounted to an aggregate of 2,000,000 tons, whereas for the year 1884-5, these have amounted to 3,500,000 tons, of which the exportation of ore alone represented over 3,000,000 tons, and in the year 1882 reached 3,600,000 tons as compared with less than 250,000 tons in 1870. During the period of fifteen years, viz., from 1861 to 1876 the total exports had only reached 2,700,000 tons. The Carlist war had just terminated at the latter date, when these mines began to be actively opened up.

To the present time there has been exported from Bilbao river a total of over 25,000,000 tons of ore, and this from a district which fifteen years ago was almost wholly unprovided with means of transport and facilities of shipment, whose port was then only accessible to small vessels of light draught, subject to the frequent delays and constant risks of crossing a shallow bar with a tortuous and constantly shifting channel, but is now, and has been for a considerable period, open at all tides to vessels from 2,000 to 3,000 tons burden, except during the severe storms which at times scourge the whole of this coast and maintain the traditions of the once dreaded Bay of Biscay.

Vessels which were frequently detained for weeks in the river waiting for fine weather and spring tides are now trading with the greatest regularity, and receive such excellent dispatch at the various shipping berths as to be able in the case of most ports to make a couple of round trips per month.

It may be hoped that sooner or later funds may be forthcoming sufficient to justify the formation of outside shelter works which will render the trade of the port altogether independent of stormy weather.

The left bank of the river is now the seat of smelting operations of importance.

There are three distinct works with an aggregate of eight blast furnaces of modern type, so that in addition to the exportation referred to there is a local consumption of from 400,000 to 500,000 tons of ore per annum; and in the case of one of these works, that of Señor Ybarras, a complete Bessemer plant with rail mill has been set up wherein steel rails are now manufactured in Spain for the first time in their own market.

From whatever point of view we may regard the matter, the work of the engineer has upon a relatively small outlay had the most beneficial results, not merely to Spain, which as much as, if not more than, most countries enjoying equal advantages and resources, is in need of material development, but also to this country, which has imported for some years past about 2,000,000 tons of ore per annum from Bilbao, or nearly four-fifths of the total tonnage of foreign ores brought into Great Britain; and only in a less degree to the principal continental consumers, France, Belgium, and Germany. Of the entire quantity of ore which leaves the river 60 per cent. is freighted in British vessels.

Owing to the facilities now given Bilbao ore, which in 1872 realised 35*s.* per ton, delivered at our ports (one half the cost representing freights), is at the present time landed at South Wales (whose consumers import 1,000,000 tons per annum) at a cost of from 10*s.* to 10*s.* 6*d.* per ton, including freight of not exceeding 4*s.* per ton.

The steel rails which in 1873 were introduced into Bilbao for the first English line there at £15 10*s.* 0*d.* per ton f. o. b. at Liverpool, are now obtainable at the reduced price of £3 10*s.* 0*d.* to £4 per ton f. o. b. in South Wales.

Whilst many circumstances have combined to bring about so marvellous a change, a not insignificant portion of the difference is due to the causes which I have enumerated. Our manufacturers aided by these cheap supplies of raw material, have been enabled to tide over the period of depression and anxiety which has prevailed of late, and an enduring benefit has been conferred on the industries directly or remotely connected with steel manufacture.

The benefit is a mutual one, for to Spain a new outlet has been opened for the energies of her people, affording, it may be hoped, a guarantee against the recurrence of the miserable civil wars which, in time past, have wrought desolation and misery in the Basque Provinces.

The works above described as carried out, according to the designs, and under the professional direction which it has been the province of the various engineers engaged on them to afford, have been attended also with far-reaching effects upon the Northern Provinces by the rapid conversion the district has undergone from a state of stagnation into one of industrial activity.

Only a few years since the principal exports of the town of Bilbao (then the second in rank of the commercial ports of Spain) were described as consisting of wheat and flour. One of its chief articles of import, viz., dried cod, was transmitted from thence to all parts of the interior. Not even a passing allusion was made in this account to the resources now developed, and which far transcend all the rest of its trade put together.

Colonial Railways.

The development of the Colonial possessions of our Empire has been brought prominently under our notice by the marvellous display of their productions and material resources, which the interesting Exhibition at South Kensington, now about to close, has afforded us.

There can be no doubt that the prosperity to which our great colonies have attained, whilst in the first place due to natural causes, such as fertility of soil, the possession of rich mineral treasures and facilities of access by sea and by rivers (advantages which have been availed of, and utilized through the energy of our colonists), has been largely enhanced by, and in some cases may be said to be exclusively due to, the construction of works which it has been the function of the engineer to design and carry into effect.

Amongst these, harbours, docks, canals, roads and railways, occupy a prominent place.

We have reason to be proud, that our Institution is worthily represented in the different quarters of the globe, by members who have so effectively executed the tasks entrusted to them, and have shown so much skill, energy, and fertility of resource in coping with and surmounting the difficulties, incidental to carrying out works, many of which are of great magnitude and importance.

I have thought that this occasion might be a fitting one to glance at the progress of railway enterprise in our several colonies, as one of the most important factors contributing to the promotion of their wealth and comfort, as, and to the furtherance, not only of their own commercial industries, but also those of the empire as a whole.

CANADA.

The recent completion of the Canadian Pacific Railway traversing the confederated States, under British dominion, and connecting the shores of the Pacific with those of the Atlantic, marks an epoch in the history of railways, and has brought more prominently before the world the enterprise and resources of those provinces. Nevertheless, the early history of Canadian railways, shows that very soon after the first railways were commenced in Great Britain, and the United States, several projects were discussed for the construction of railways in Canada. It was only, however, in the year 1837, the date of the opening of the Grand Junction Railway connecting Birmingham with the towns of Liverpool and Manchester, that the first passenger railway, viz., the railway from La Prairie, on the St. Lawrence River, to St John's, on the Richelieu River, in the province of Quebec, was worked with the locomotive engine. Its length was 16 miles; its gauge 5 feet 6 inches, with light gradients and flat curves.

The charter had been granted in the year 1832.

It was not to be expected, in a country then only sparsely populated, and having regard to the enormous extent of its territory, that the railway system should make any very rapid progress.

It appears from the journals of the legislatures of Upper and Lower Canada (now the Provinces of Ontario and Quebec) for the year 1851, that up to the end of the session of 1850, Acts of Incorporation had been granted for seventeen railways in Upper Canada and seventeen in Lower Canada, of which number (thirty-four in all), twenty grants were made subsequent to the year 1839;

nevertheless we find that in the year 1850, Canada had only 79 miles of railway completed and at work. No doubt the first great impulse towards the extension of railways in Canada was given after considerable experience had been gained elsewhere, and when the importance of this cheap and rapid mode of travelling had been confirmed by the results of the working of the main lines then recently opened between the metropolis and the manufacturing districts of the north of England.

From 1837 to 1842 little appears to be recorded of the progress made with railway construction in Canada, and the first railway return presented to the legislature was in 1844, giving the traffic results of that, and the two preceding years; the traffic of 1844 being represented by twenty-seven thousand and one hundred and eighteen passengers, and 12,639 tons of freight conveyed at a cost of £11,851, this amount representing 77 per cent. of the gross receipts.

At the date of the return above mentioned, (1850) no passenger railway had been constructed in the provinces of Nova Scotia, New Brunswick, or Prince Edward's Island.

In the year 1848, Major Robinson reported on the route of the present Intercolonial Railway, between Halifax and Quebec. This railway was only begun under the Act of Union by the Federal Parliament, and completed in 1878.

In the year 1851, the railway committee had before it a bill for a charter to construct a railway through British Territory to the Pacific Ocean.

The committee reluctantly reported against it, on the ground that the claims of the Indian tribes, and the Hudson's Bay Company to the lands had just been adjusted.

The committee in their report say:—"At the same time your committee feel bound to state their impression, that the scheme ought not to be regarded as visionary or impracticable. Your committee are strongly inclined to believe that this great work will, at some future time, should this country advance as heretofore in prosperity and population, be undertaken by Great Britain and the United States."

This prediction has, as we know, been verified in its essential particulars by the recent completion, though on a modified route, and without the intervention of foreign capital, of the "Canadian Pacific Railway," the course of which is almost identical with that shown on the map, accompanying a pamphlet, issued by Major Carmichael Smythe in the year 1847, in which he had advocated the construction of a trans-continental line through British territory.

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The development of the present railway system synchronises with the political life of the present Premier of Canada, Sir John Macdonald, dating from 1844, when there were but 14 miles in operation.

Up to the time of the confederation in 1867, the longest lines under separate management, were the Grand Trunk (905 miles), constructed between the years 1852 and 1858, and notable for the great tubular bridge, built from the designs and under the direction of the late Mr. Robert Stephenson, over the St. Lawrence, affording a direct connection between Quebec, Montreal and Chicago; and the Great Western Line (303 miles), opening up important tracts of country in the west.

Canada has not been exempt from the troubles which at an earlier period beset the question of gauge in England and in the United States. The battle of the gauges was revived in 1851 in connection with the Grand Trunk Railway. Engineers were examined, and railway-men brought from the United States to give evidence.

The example of the United States tended rather to confound than to simplify the solution of the problem, for no fewer than five different gauges were in use there.

In the State of New York and the Western States north of the Ohio River, the gauge was 4 feet 8½ inches; in some parts of the Middle States, 4 feet 10 inches; in the Southern States generally, 5 feet; in the State of Maine, 4 feet 8½ inches, and 5 feet 6 inches; whilst the gauge of the New York and Erie Railway was 6 feet.

The Railway Committee of the House finally adopted 5 feet 6 inches as the one, in their opinion, best adapted for the promotion of Canadian interests.

The importance of uniformity of gauge, and the commercial considerations which gave preference to the old English standard gauge of 4 feet 8½ inches have led up by degrees, as has been the case in the United States, to the conversion of most of the Canadian lines to this latter standard.

There now exist only two passenger railways in Canada the gauges of which differ from the standard of 4 feet 8½ inches, viz.:

The Prince Edward's Island Railway, 212 miles in length, with a 3 feet 6 inches gauge; and

The North-West Coast and Navigation Company's Railway, 104 miles in length, with 3 feet gauge.

Out of 853 miles of narrow gauge railways built in Canada, 537 miles have been converted into the standard gauge.

In 1867, the date of the confederation of the Provinces into the Dominion of Canada, it is recorded that there were in operation

2,258 miles of passenger railways distributed in the various Provinces, viz.:

In the Province of Nova Scotia . . .	145	miles.
„ „ New Brunswick . .	266	„
„ „ Ontario and Quebec .	1,847	„

For the period of ten years, 1860 to 1870, there was scarcely any increase in railway mileage in the two Provinces of Upper and Lower Canada.

Since that time, and notably since the Act of Union was passed, construction in Canada has made advances with rapid strides and *pari passû* with a corresponding general development of the resources of the country.

At the end of 1876 the mileage had more than doubled, being 5,157 miles; whilst the mileage existing in June of 1885 had increased to 10,773 miles, and by December 31, 1885, to 11,275 miles, so rapid and steady has been year by year the growth of the railway system.

At this latter date the total expenditure had been $625,754,704, with a remaining indebtedness of $20,000,000, since liquidated, towards which aid from Government, from municipalities, and other sources, had contributed $187,000,000.

About 100,000 tons of steel, and 250,000 tons of iron rails were then in service.

The earnings for the fiscal year 1884–85 were $32,227,469, and the expenses $24,015,321 on a train-mileage of 30,623,689 miles, equal to 74½ per cent. of the gross receipts, giving a return of 1¼ per cent. on the capital invested. Though this is a low rate of interest, the railways have indirectly served to augment the wealth and resources of the Dominion in a marked degree.

The eighteen years following the confederation give an average annual increment of 312 miles of line per annum, which must, under the circumstances of the country, be admitted to be a rapid rate of progress.

The cost of construction in the present day is considerably less than in the early days of railway enterprise in Canada.

Gradients which then were considered inadmissible are now, with the increased power of the locomotive, easily surmounted, and thus the necessity for heavy cuttings and embankments, and of expensive tunnelling, is to a great extent obviated, the lines accommodating themselves more nearly to the profile of the natural surface of the ground.

Several railways are now in progress, and others are projected with the object of opening up large tracts of fertile country by connections with the Canadian Pacific, and of equipping the Province of New Brunswick and the Island of Cape Breton.

Gradients of 1 in 40 are now in some instances used, but 1 in 66 may be taken as the usual limit for gradients, and a radius of 15 chains as the limit for curves.

In the pamphlet above referred to, published in 1847, Major Carmichael Smythe writes with reference to the proposed railway to connect the two oceans: "This great national railway from the Atlantic to the Pacific is the great link required to unite in one powerful chain the whole English race, which will be the means of enabling vessels steaming from our magnificent Colonies—from New Zealand, Van Diemens Land, New South Wales, New Holland, from Borneo and the West Coast of China, from the Sandwich Isles and a thousand other places, all carrying the rich productions of the East, to land them at the commencement of the West, to be forwarded and distributed throughout our North American Provinces, and delivered within thirty days at the ports of Great Britain."

The realization of this project was reserved for later times. The admission of British Columbia into the Canadian confederation in 1871 made it necessary for the statesmen who brought about that political connection to face the question of a trans-continental railway as essential to the preservation of its unity.

Hence Sir John Macdonald, under whose energy, influence and determination the enterprise has just attained its full realization, consented to make the construction of such a road within ten years one of the conditions of the compact between Old Canada and the Pacific Province.

This imperial work, brought to completion within the last few months, has been constructed entirely within the limits of the Dominion, and being thus independent of the interference of any foreign power, constitutes the shortest route from England to China, Australia and New Zealand. It has been remarked as "a singular coincidence and perhaps a prophetic omen of the future imperial importance of this railway, that the first loaded train that passed over its entire length from ocean to ocean was freighted with naval stores belonging to the Imperial War Department transferred from Quebec to Vancouver," and that "it was a remarkable commercial incident that the first car of ordinary merchandise consigned to British Columbia was a cargo of Jamaica sugar refined in Halifax, and sent overland to the Pacific terminus, nearly 4,000 miles in one stretch under the flag of Great Britain."

As compared with the Panama route between England and Australia, the total distance to be traversed is substantially the same, *i.e.* 12,500 miles by Panama as against 12,300 miles by Canada, with a saving, however, in the case of the latter of 3,250 miles of ocean steaming, for which about 3,000 miles of railway travelling is substituted.

The surveys were commenced in 1871, when the Province of British Columbia came under the Government of the Dominion, and extended over several years, under the charge of Mr. Sandford Fleming. At the same time work was commenced by the Government and continued for several years on the section which lies between Lake Superior and Winnipeg.

The Canadian Pacific Railway Company was incorporated in February 1881, under the authority of the Parliament of the Dominion, to whom was transferred the work of constructing such portions of the main line as had not been undertaken by the Government, besides conferring the right of constructing branches along the entire length of the line, of establishing lines of ships or steamers at its termini, the privilege of constructing and working telegraph lines for the business of the public, as well as for their own; whilst in consideration of the completion and perpetual operation of the railway, the Government of the Dominion granted to the Company a subsidy of $25,000,000 in money and 25,000,000 acres of land, all of which is reported to be fit for settlement.

Various other valuable privileges were accorded by the Charter.

Some variations from the originally projected route of the unexecuted portion were now decided upon, and in particular a lower pass was selected (the Kicking Horse Pass) for the crossing of the range of the Rocky Mountains, involving a considerable deviation of the line to the southward.

It is a remarkable proof of the energy which has been thrown into all its operations, that the Company, within the short period of five years, should have built, equipped and put into operation over 2,400 miles of new railway, inclusive of about 500 miles of branch lines.

The Government have built 648 miles of the main line.

Many interesting particulars relative to the character of the country traversed, of the works which had to be executed, of the difficulties that were encountered, of the methods used to overcome them, are to be found in the official reports of General Rosser, and in "Selected Papers" by Messrs. James and Macdougall, Mr. Van Horn, and Mr. James Ross, well worthy of perusal, published in

Part 2 of the 76th volume of our Minutes of Proceedings. It was a triumph accomplished by General Rosser, the engineer, and after him by Mr. James, aided by their assistants, and ably supported by their employers, to have completed and opened the line for traffic five years in advance of the contract time, which was the 1st of May, 1891.

Heavy works were necessitated on some portions of the route, and amongst these may be reckoned an iron bridge of 1,000 feet in length over the River Saskatchewan, and those incidental to about 270 miles of most rugged and difficult country through the Rocky Mountain range; but for the most part its course lay over large tracts of slightly undulating prairie land.

Gradients are seldom formidable, as, with the exception of a short length near the crossing of the Saskatchewan river, the maximum gradients between Winnipeg and a point 4 miles below the summit of the Rocky Mountains, a distance of 958 miles, are only 1 in 132.

The summit level at the crossing of the Rocky Mountains is 5,296 feet above the surface of the sea, and here the gradients do not exceed 1 in 45, whilst on the British Columbian side of the range there are some provisional and temporary gradients of 1 in 22, which it is intended shortly to replace by easier ones.

Up these 1 in 22 gradients the 33-ton Baldwin engines take up an average gross load, exclusive of engine and tender, of 100 tons at 6 to 8 miles per hour.

These heavier gradients are confined to the mountain section, and occur within a space of 150 miles.

On the other hand, the prairie lands are so gently undulating, that light gradients prevail over those portions of the route.

Between the base of the Rocky Mountains and the town of Winnipeg, a distance of 900 miles, the railway is said to traverse one of the finest agricultural regions in the world, hitherto unopened up by reason of the want of railway facilities.

Careful provision has been made against snow on the prairie section by elevating the road-bed so far above the surface of the country as almost entirely to avoid cuttings.

This provision involved a high average of earthwork, derived chiefly from side-cutting, no less than 16,000 cubic yards per mile.

The record of the rate at which the building of the line proceeded is remarkable, taking into account the fact that snow lies on the ground during the four to five winter months when the rivers are blocked with ice, that the temperature in winter sinks to

40° below zero, and that rainfall in July and August is nearly incessant.

During the season extending from the 1st of June to the 1st of December, embracing a period of one hundred and fifty-seven working days, 411 miles of main line were constructed, and 388 miles of track laid and opened for traffic under the direction of Mr. James. This may be taken as the sample and measure of what was effected on other portions.

The total length of main line owned by the Canadian Pacific Company, and extending from Montreal to Vancouver, is 2,906 miles; but including other lines owned, as also branches and leased lines, the total mileage amounts to 4,338 miles, provided with an equipment at the beginning of the present year (probably somewhat increased since that date) of three hundred and thirty-six locomotives, three hundred and forty-five cars of different descriptions for passenger traffic, and upwards of eight thousand cars for merchandise and cattle traffic, &c.

The fixed capital as on the 1st of July last was estimated approximately at $126,884,613, in respect of which liabilities exist in the shape of interest and rentals of leased lines to the extent of $3,110,434.

The Company are now engaged in constructing a new and large bridge over the St. Lawrence at Lachine, to be completed within twelve months of its commencement, and the 125 miles of line to complete the Ontario and Quebec railway, and bring it direct into Montreal, will, including a very large bridge over the Ottawa river, be completed this year, though tenders were only sent in at the end of May last.

This bridge, the length of which between its abutments is 3,454 feet, will consist of fifteen spans, the roadway being carried on steel and iron girders. The two deep channel cantilever spans, of 408 feet each, will give 60 feet clear headway for passage of ships. The remaining spans, viz., eight spans of 240 feet, two spans of 270 feet, 3 spans of 80 feet, afford 28 feet of headway, sufficient only for smaller craft.

The contract for the superstructure has been taken by the Dominion Bridge Company, Lachine, and includes provision for about 2,800 tons of steel, and 800 tons of iron.

I have referred somewhat at length to this great engineering work, which will doubtless prove of lasting benefit, not only to the Dominion as binding together all the provinces of North America, and opening up therein fertile districts hitherto isolated and unpeopled, but also to the Empire, as affording an important channel of commerce between the dependencies of the British Empire and the mother country.

The line is substantially laid with steel rails of the weight of 56 lbs. per yard, and the rolling stock generally is of the American type, as is more or less the case on the Great Western of Canada and other lines in the provinces.

Although the first introduction of railways into the colonies of Australasia may be said to date scarcely further back than 1853, we now find some 7,600 miles in active operation, returning fair interest on the capital invested, and proving an important factor in their industrial progress, and upwards of 1,800 miles in course of construction.

The discovery of the gold fields in 1851, which gave the first great impulse to immigration, and to the consequent growth of the towns, and of settlements in lands in the interior, led up to the necessity of providing the rapid and cheap means of communication which only railways could afford; the dearth of navigable rivers rendering communication by water impossible otherwise than by sea from port to port on the coast.

The period of greatest activity in the extension of the railway system has been that of the last fifteen years, for up to the end of 1870 only 948 miles in all were open for traffic, whilst seven times that length have been executed since that date.

New South Wales and Victoria, as the largest and wealthiest of the Colonies, have naturally taken the lead, and in point of fact are virtually on a par in respect of population served and mileage constructed.[1] The average cost per mile has been somewhat greater in Victoria than in New South Wales, viz., £13,672 as against £12,412 per mile, the difference being probably attributable to the circumstance of more costly works having been required to meet the conditions imposed by the respectively selected routes.

Queensland and South Australia rank next in order and importance.[2] The populations are nearly equal, the miles of railway constructed are about 14 per cent. less in the case of the latter.

The cost per mile, however, in both cases is only about one-half of that of the lines in the two first mentioned colonies, being for Queensland £6,654 per mile, South Australia £6,629 per mile.

	Population.	Miles of Railway.
[1] New South Wales, Dec. 31, 1884	921,268	1,663
Victoria, June 30, 1885	973,403	1,676
	Population.	Miles of Railway.
[2] Queensland, Dec. 31, 1884	309,912	1,207
South Australia, June 30, 1884	317,116	1,036

In the remaining colony of Western Australia railway construction is in its infancy, the first line having been opened in July 1879.

It is to be regretted that on the initiation of the railways in this continent, the question of the adoption of a standard gauge, applicable to all the colonies, should not have been considered and determined by common consent. Whilst the three colonies of New South Wales, Victoria and Queensland commenced their railway history nearly at the same time, each adopted a gauge differing from the others—New South Wales the standard English gauge of 4 feet 8½ inches; Victoria one of 5 feet 3 inches. South Australia has adopted two gauges, viz., 5 feet 3 inches and 3 feet 6 inches, and Western Australia 3 feet 6 inches. ~~Victoria has subsequently adopted, in the case of some of the branches, the gauge of 3 feet 6 inches.~~

In Queensland and Western Australia all the railways have been constructed upon a 3-feet 6-inch gauge.

In Tasmania 45 miles of line have been constructed on a gauge of 5 feet 3 inches, and 127 miles upon a gauge of 3 feet 6 inches.

In New Zealand there are also two gauges, one of 3 feet 6 inches, and one of 4 feet 8½ inches.

It would be an unprofitable task to endeavour to explain the conflict of opinions which have resulted in this strange diversity of gauges over regions so closely allied to one another as these are, and it is to be feared that commercial considerations have been largely subordinated to questions of comparatively minor importance which have claimed the attention of the respective engineers whose judgment and advice has been sought by the promoters of the various undertakings.

In the year 1872 the Parliament of Victoria was on the point of deciding to adopt, as a general standard for the extension of some of their trunk lines, the gauge of 3 feet 6 inches. The evil was happily averted in time by the Senate, who overruled a resolution of the Lower House fixing the gauge at 5 feet 3 inches.

The question of gauge was then the subject of keen discussion in the Colony, and in view of the divers opinions held thereupon, a communication was addressed to the Right Hon. H. C. E. Childers, Agent-General for the Colony, by Mr. Francis Lingmore, Commissioner of Railways and Roads in Victoria, requesting that the opinions should be sought of engineers here connected with broad and narrow gauge lines, the general tenor of the arguments used by the respective advocates of the gauge hitherto in use, and of the alternative gauge of lesser dimensions proposed, being set forth in the documents submitted. Three or more engineers were consulted, and reported independently and adversely to the narrow gauge, and it may be supposed that the decision eventually come to was influenced by the opinions they expressed.

271 miles of railway of 5 feet 3 inches gauge had been completed, and 183 miles more on the same gauge were in course of construction, whilst three additional lines (together 144 miles), of which the gauge had not been decided, had been sanctioned by Parliament, these being in extension of the existing main lines from Melbourne to Ballarat, and to Castelmain respectively.

341 miles of other railways, viz., the lines from Geelong and from Ararat westward, had been proposed in connection with the authorized lines running in those directions from Melbourne, as also 126 miles of a proposed line from Melbourne to Sale.

The construction, as it was proposed, of these 611 miles to the lesser gauge of, say, 3 feet 6 inches, would have involved no less than four breaks of gauge, occurring at Ballarat, Castlemain, Melbourne, and Geelong, in a system of 1,064 miles of railway in all, with the certainty that that number would be extended as and when branches from lines of the existing gauge should be thrown off.

The Government engineer-in-chief had shown conclusively that the saving in first cost by adopting the 3 feet 6 inches instead of the 5 feet 3 inches gauge would not exceed £351 per mile. Against this had to be set the disadvantages incidental to break of gauge, and which may be shortly summarized.

1. Increased cost of transport by reason of employment in the narrow gauge of less powerful engines, and of vehicles of smaller capacity, thus increasing the daily number of trains and that of their attendants, as required for the transport of a given volume of traffic.

2. The cost and delay incidental to the transfer of goods from the rolling-stock of the broad gauge to that of the narrow, and *vice versâ*, the delay thence arising being specially prejudicial in respect of articles requiring rapid transit, such as luggage, mail bags, fish, fruit, &c., the transfer of which, in many cases, would involve the sorting, re-classification, and redistribution in the different vehicles, with considerable chance of loss and breakage.

3. The necessity of having at hand at all times at each point of contact of the two gauges an ample supply of rolling-stock adapted to both, and inclusive of the varieties of each kind for effecting the exchange, a requirement involving the provision of

a much greater amount of rolling-stock than would otherwise be necessary.

4. The more extended station-room required for accommodating the rolling-stock of the two gauges.

5. The much greater outlay incurred in the provision of rolling-stock for a system of lines of different gauge, by reason of the fact that the two classes of rolling-stock are not interchangeable, and that each section would have to be supplied with a much larger number of engines, carriages, and wagons than would be the case if theseс ould travel over every district in the contemplated systems.

In the Report I had the honour to submit to the Agent-General, I stated that it was desirable that the whole of the railway system in Victoria, as delineated on the map submitted (the lines before referred to), should be made to one and the same gauge.

That the same uniform gauge should be maintained in the case of all future extensions and branches, unless some very special reason should exist to require and justify an exceptional departure from the rule.

That looking to the extent of the railways constructed and in course of construction, in accordance with the hitherto adopted standard of 5 feet 3 inches, and looking to the cost which would be occasioned by an alteration of that gauge on the lines then completed, and by the provision of fresh rolling-stock to work on such altered gauge, it was advisable to retain the then standard, unless Parliament should deem it expedient to assimilate that gauge to that of New South Wales, in which even the ordinary English gauge of 4 feet 8½ inches would become the standard gauge for the colony of Victoria.

The want of uniformity between the gauges of the several colonies will, in course of time, no doubt be severely felt in the restriction of traffic and increased cost of working when contact is made between these systems.

The difficulty may, perhaps, be less appreciable in the cases under consideration (seeing that the lines are all Government lines) than has proved to be the case in England and in the United States of America, where the competition between narrow and broad gauge lines had resulted in abstracting the traffic from broad gauge lines and directing it over those of the narrower gauge, thus compelling the proprietors of the broad gauge lines in self-defence to incur the cost of conversion, or of laying down a narrow gauge track in addition to that of their broad gauge.

One of the earliest of the United States lines thus altered was the Ohio and Mississippi Railway, 340 miles in length, with 150 miles of sidings, the original gauge of which (viz., 6 feet) was changed during the summer of 1871 to one of 4 feet 8½ inches. In all no less than 20,000 miles of railway in the United States have in course of time been altered to the standard gauge.

It is well known that in England the Great Western system has been adapted to the same old standard, for it was found that traffic made its way by circuitous routes to districts served by the broad gauge railways, rather than encounter the obstacles interposed by breaks of gauge at Gloucester and elsewhere.

Railways in Australasia.

In New South Wales the first railway, viz., the line from Sydney to Paramatta, 14 miles in length, was opened for traffic in the autumn of 1855, or just a quarter of a century after the railway system had established a footing in Europe. This line had been undertaken by a private company, but owing to financial difficulties encountered before completion, the Government, having obtained an Act enabling it to purchase the railway and plant, took over the line, and, at about the same time, undertook the construction of the short line of railway from Newcastle to Maitland, 19 miles in length, which had been projected by a private company.

Thenceforward railway construction has been carried on almost exclusively by the Government.

There is at present one public line in the hands of an independent company, connecting with the Victorian railway system, 45 miles in length, and of 5 feet 3 inches gauge, and paying a good dividend to the shareholders.

The crossing of the Central Mountain range caused considerable delay in the progress of the construction of the three great arterial lines leading westward and northward from Newcastle and Sydney respectively. The difficulties, however, were eventually overcome, and these main lines of railway now collect and distribute traffic over extensive districts which had previously been only partially served by common roads of the roughest description.

The conditions attaching to the systems of railways radiating from Sydney and Newcastle are peculiar in the sense of having to cross these rough and precipitous mountain ranges before reaching the interior plains, rendering the gradients to be encountered both numerous and severe.

The "zigzag" tracks by which some of the lines are conducted over these heights, and especially the Lithgow "zigzag" between

Mount Victoria and Lithgow, by which the Western Railway ascends the mountain slopes rising in that distance through a vertical height of 700 feet, have elicited much admiration.

In this way the summits have been attained by gradients not exceeding 1 in 30, and therefore workable by locomotive engines of adequate power.

The principal coal port of the colony beginning at Newcastle, the Great Northern line, from which more than a million of tons of coal are annually shipped, now runs northward as far as Glen Innes, a distance of 298 miles, and by an extension of 16 miles now in progress to Tenterfield (a border town of the adjoining colony of Queensland) will, before long, and on completion of two remaining short links, afford uninterrupted intercolonial communication between Sydney and Brisbane. Those links consist of the Sydney and Newcastle line, now in course of construction, and the interval of 25 miles occurring between the terminus of the Queensland line and Tenterfield.

The line traverses the rich valley of the Hunter river and other lands generally that are fertile, attaining the height of 4,500 feet above the sea-level.

The Great Southern Railway, commencing at Sydney and passing through Goulburn, Junee, and Wagga Wagga, arrives at Albury, the frontier town separating New South Wales from Victoria, traversing 387 miles of country. The last short link of this intercolonial line between Sydney and Melbourne, including a mile or two of railway and a temporary bridge over the River Murray, was finished in midsummer of 1883. Unfortunately the difference between the standard gauges of the respective colonies (4 feet $8\frac{1}{2}$ inches and 5 feet 3 inches) necessitates a break in the transport at this spot likely to occasion some expense and inconvenience in the future when the progress of the colonies comes to demand a considerable amount of interchange of commodities in the shape of merchandise and minerals.

The South-Western Railway, branching off at Junee, is open to Hay, 454 miles to the south-west, and it is expected will ere long be extended to the borders of South Australia.

The Great Western line, also starting from Sydney, passes through Bathurst, Orange, Wellington, and Dubbo, and has reached the town of Bourke on the River Darling, distant 503 miles from Sydney, thereby opening up the whole of the extensive pastoral regions of the north-west, of which it practically forms the metropolis.

An authorized extension of about 360 miles, commencing at the town of Orange, will strike the River Darling at Wilcannia, some 200 miles below Bourke, and open up to settlers a further most extensive tract of country.

At the commencement of 1885, 1,618 miles of line were open for traffic, 391 miles in course of construction, and 1,324 miles more authorized by Parliament.

The progress of railway enterprise has of late years, and notably since the year 1870, been advancing with accelerated speed, and the capital expended on constructed lines has been yielding an increasing return in the shape of interest, a return which for the year 1884 amounted to $4\frac{1}{8}$ per cent. on the total expenditure of £20,088,240.

Under these circumstances, and having regard to the contingent influences of railway extension as effecting close, rapid, and cheap connection between the remote districts and the seaports and the market of settled districts, adding greatly, as has been the case, to the wealth and resources of the colony, the credit of the Government has been such as readily to command the loan of money at the very moderate rate of 4 per cent. per annum.

Such credit is further justified by the fact that the value of trade per head of population, viz., £45 17*s.* 4*d.* per head, was considerably higher at the close of the year 1884 than that of any of the other Australasian colonies.

The Trunk lines are to be connected by railways which will unite the whole system of the colony into a vast network, forming feeders to the main lines, and completing railway communication as already mentioned between the several colonies of the Australasian continent.

Many important and costly engineering works in the shape of iron bridges over rivers and creeks have been constructed, and quite recently a contract has been entered into with an eminent firm of American bridge-builders for the construction of a large iron viaduct over the Hawkesbury river of seven spans of 415 feet between the centres of the piers for a double line of railway.

The contractors undertake to furnish the ironwork and erect the bridge *in sitû*, taking all risks connected with the sinking of foundations, as well as those otherwise incidental to the due completion of the structure, for a specific sum of money. It appears that their tender was considerably lower than that of any English or foreign firm. Nevertheless it is a remarkable circumstance that the sub-contracts for the material—ironwork and steel—have, as it is understood, been placed with English or Scotch manufacturers, whence it may be inferred that the difference in the amounts of the respective tenders are presumably due in the first place to differences in appreciation of the contingent expenses that may have to be incurred in connection with foundations, &c.; and, secondly, to designs differing considerably in the weight of the material to be employed, the contractors having been allowed to work out their own designs subject to certain specified conditions.

Victoria.

For the various railway lines forming the system carried out in the colony of Victoria the gauge of 5 feet 3 inches has now been adopted.

Under the plea of diminishing their first cost and of reducing working expenses, the proposal to which I have already adverted, that of resorting to light lines of narrow (3 feet 6 inches) gauge, was at one time strongly advocated and seriously entertained, although disapproved of by the Government engineer.

This project related not merely to contemplated branch or subsidiary lines, but also to extensions of trunk lines, which had been sanctioned by, or were awaiting the sanction of, Parliament.

Fortunately for the colony time was allowed for a full and careful consideration of the matter, and the disadvantages seen to attach to the introduction of a second gauge led to the wise decision of laying down the trunk lines in question on the heretofore adopted standard gauge, and of constructing them in a substantial manner. A serious evil was thus averted.

The development of traffic on these lines has fully justified the resolution then adopted. This development has been so considerable as to show that light railways would have been unsuitable for so large and increasing a traffic, whilst the numerous breaks, which at different points of the system would have occurred by contact of the two gauges, would have caused great interruptions, delays, and increased cost in working.

The characteristics of the country, which is comparatively level, have generally permitted very easy gradients. In a few instances, however, some steep ones occur, but the highest elevations surmounted do not much exceed 2,450 feet above sea-level.

The railway system in this colony was inaugurated in 1856 by the opening of the line from Melbourne to Sandridge. The line from Melbourne to Geelong, then in course of construction, was not available for traffic until the following year. From that period we may date the steady growth of the systems now developed.

At the present time all the railways are under State control. They are vested in three commissioners, who are a body corporate with perpetual succession under a common seal, and hold office for a term of seven years, at the expiration of which they are eligible for re-appointment. They are charged with the duty of constructing such lines of railway as are authorized by Parliament, and of maintaining works, and controlling and managing all the lines, subject in some respects to the control of Parliament.

The Hobson's Bay Railway, now a double line of 16½ miles in length, was originally projected, and was worked for many years, by a private company. It was only taken over by the Government in 1878, the price paid being £1,320,800, or £8,000 per mile.

The line from Melbourne to Geelong was purchased from a private company by the Government in 1860.

In the summer of 1884 the extent of railways open was 1,624 miles, consisting of 205 miles of double and 1,419 miles of single line, constituting a compact network, extending from the important seaports of Melbourne, Geelong, and Portland Bay as a base, and embracing a large area of the colony.

Taking Melbourne as the principal terminus, three main arteries with lateral interlacing branches may be said to proceed therefrom, viz., the north-eastern, leading to the frontier of New South Wales on the River Murray at Albury, there joining the line to Sydney; the northern also reaching the Murray at Echuca, and shortly to be continued to Swan Hill, a town lower down the river; the western leading to Portland viâ Geelong and Ballarat, and destined to become the means of direct communication between Melbourne and Adelaide on completion of the line now under construction in South Australia, and an authorized line in extension of the existing line from Ararat to Portland.

The eastern system connects Melbourne with Sale (127½ miles).

In addition to the above is the system of suburban lines radiating from Melbourne.

The lines already opened have cost £18,752,876, or an average of £11,549 per mile. Besides these, 71 miles were in progress, authorized to cost £382,578, and 1,201 miles more had received the sanction of Parliament at an authorized cost of £6,804,730.

Of the 1,624 miles then open, 268 miles may be taken to represent trunk and suburban lines of a specially costly character, inclusive of 101 miles of double line between Melbourne and Sandhurst. On these the sum of £9,673,841 have been spent, giving an average of £36,093 per mile, including a heavy outlay on the station at Melbourne, whilst the remaining 1,356 miles of branch and cross country lines have cost £9,079,035, or an average of only £6,700 per mile.

The net revenue accruing on the entire capital expended on railways opened for traffic was, according to the return for the half-year ending the 30th of June, 1884, at the rate of 4 per cent. per annum, a satisfactory return for a country having a population of only ten to the square mile.

Queensland.

The introduction of railways into the colony of Queensland dates from the year 1864, when a commencement was made with the line which connects Brisbane with the western cities of the plains, and with those on the southern border of the colony of New South Wales.

It was decided at the outset that 3 feet 6 inches should be the standard gauge, and this gauge has been adopted throughout.

The greatest obstacle to railway communication with the interior was the precipitous main coast mountain range; but this has been, at considerable cost, surmounted by gradients not steeper than 1 in 50 carried around the spurs of the mountains, through tunnels, and across deep gorges.

1,339	miles	are opened for traffic.
139	,,	are under construction.
279	,,	have legislative sanction.

They constitute three main groups—northern, central, and southern—their general direction being westward from their respective termini of Townville, Rockhampton, and Brisbane on the coast. Connection with the New South Wales system will be effected in the neighbourhood of Tenterfield by two short links which have been authorized, and of which one is now under construction.

Here the break of gauge will occur, subjecting the direct through traffic between Melbourne and Brisbane to two breaks during the journey.

Extensions further westward are contemplated.

The cost of the lines now at work has averaged £6,654 per mile.

The cost per mile of lines has ranged from £2,034 on the Clermont branch to £21,019 on the Brisbane and Ipswich line. The working expenses have averaged 52 per cent. on gross receipts, and the interest returned on capital in the shape of net earnings has been a little under 2 per cent.

All are Government lines. The districts which are, or will shortly be, served bear but a very small proportion to the area of the entire colony, so that there remains a vast field for future enterprise as population increases.

In 1880 a company of English capitalists sought from the Government the concession to make a line on the "land grant" principle from Charleville to Point Parker on the Gulf of Carpentaria; the company to receive from 10,000 to 12,000 acres of land for every mile of railway constructed. The agreement come to was, however, negatived by Parliament, who were indisposed to entertain any land grant railway system on a large scale.

Amongst the projected lines is one to Brisbane, with the Gympie gold-fields, passing through fine agricultural districts and forests abounding with valuable timber.

South Australia.

The first locomotive line opened in the colony of South Australia was in 1856, a line of 7 miles, connecting the city of Adelaide with the port.

Its gauge was 5 feet 3 inches.

Thenceforward railway construction made steady advances, although much yet remains to be done towards the opening up of extensive, but at present sparsely populated, districts.

The total length of line which was open for traffic on the 30th of June last year was 1,076 miles. At that date an additional 407 miles were under construction, and a further 315 miles authorized.

It is to be regretted that a diversity of gauge should have been introduced also into the colony. We find that of the 1,798 miles completed, under construction, and authorized, 521 miles are on the 5 feet 3 inches gauge, and 1,277 miles are on the 3 feet 6 inches gauge.

The narrow-gauge lines are arranged in three groups, involving as many breaks of gauge, the first extending northwards and westwards from the town of Terowia, forming a junction there with the northernmost extension of the broad-gauge system; the second westward to the coast from or near the broad-gauge line at Stockport; and the third starting from the southern terminus of the broad-gauge system at Border Town, and proceeding southward to Mount Gambier with lateral lines, striking the coast at two points, viz., Lacipede Bay and Rivoli Bay.

It fortunately happens that by the central or broad-gauge system radiating from Adelaide, the connection between that city and the lines in the colony of Victoria will be effected by a continuous broad-gauge line so soon as the lines now under construction in the two colonies meet at Border Town, and thereby afford a direct route between Melbourne and Adelaide free from interruption.

The lines now in operation appear to have cost on an average, inclusive of stations and rolling-stock and other plant, about £7,250 per mile. Few physical difficulties have to be encountered, hence the very moderate cost. With the exception of two suburban lines near Adelaide, all are the property of the State.

As an arm (149 miles in length) of the northern group of 3 feet 6 inches lines, the contract has been let for a railway from Petersburg, proceeding in a north-westerly direction to the border of New South Wales, where it will eventually come into contact with the 4 feet 8½ inches gauge of that colony.

It seems intended to construct this extension at the least possible cost, and as much as possible on the surface, laying it with 41 lbs. flanged rails spiked on to wood sleepers, with scant provision of ballast; constructing no intermediate stations, but providing simply platforms and sidings for local traffic; the speed of passenger trains to be limited to 15 miles, and that of goods trains to 12 miles per hour.

West Australia.

Railway enterprise in the colony of West Australia was initiated in 1878 by the completion of a local line 34 miles in length, of 3 feet 6 inches gauge, connecting the town and mining district of Northampton with the port of Geraldton, Champion Bay, at a cost on an average of £4,364 per mile.

Unfortunately, and owing in great part to the fall in price of copper and lead, and consequent prostration of the mining industries, the traffic has proved unremunerative.

Indeed, as yet very little progress has been made towards opening up the interior of this large colony, for the only other public line which has been opened for traffic is the main line termed the "Eastern Railway," commencing at Fremantle, a seaport town at the mouth of the Swan River, 12 miles below Perth, the capital, and terminating at the town of York, the entire length being 68 miles.

The cost of the first 20 miles averaged £6,223 per mile.

With reference to this railway, the Engineer-in-chief remarks, in his report of the 24th of August, 1885, that "no more utterly false step can be made on a main trunk railway like this than that of cheap construction, regardless of the cost of future working expenses, so long as the capital outlay at the first be kept down, and this is what unfortunately has been the case here." He points out that had a small additional outlay been made in trial surveys and sections to ensure the best route being selected, and an additional expenditure incurred in earthworks, a railway might have been made of which the working expenses would at the least have been one-third less than they now are, and must continue to be, owing to the severe gradients and curves which now exist.

Doubtless this warning will not be lost sight of in view of the future development of the railway system of West Australia; and it may be worthy of attention by the Government of South Australia in connection with the cheap railway, which I have just mentioned as having been projected in that colony.

Various projects of new lines and extensions have been submitted and entertained by the Government.

Amongst these a proposal by an English syndicate for a "land grant" railway of 3 feet 6 inches gauge from Perth to Geraldton, a distance of over 250 miles, has been accepted and a company registered. 12,000 acres of land are to be granted for every mile constructed.

New Zealand.

In proportion to the extent of territory comprehended by the two principal islands of New Zealand, the length of the Government railways open for traffic is very considerable, and affords remarkable evidence of the rapid development of the resources of this colony. In a recent Report (1886) the length is stated to be 1,538 miles.

It was subsequent only to the passing of the Immigration and Public Works Act in 1870, that their construction had been commenced and prosecuted on a large and comprehensive scale.

It will be remembered that the colonization, in the case of the early settlements, commenced in 1839, and has subsequently been much retarded by a long and arduous struggle with adverse circumstances, and notably the desultory and bloody wars waged with the natives, until the power of the Maoris was finally broken in 1881.

The island railways have cost, on an average, somewhat over £8,000 per mile, and for the year ending 31st March, 1885, had yielded interest on the capital expended on their construction at the rate of 3 per cent.

By the above-mentioned Act, 3 feet 6 inches was established as the standard gauge throughout.

The intention at the time was that the lines should be of light and cheap construction, and worked at low speeds.

In addition to the Government lines, there are 91 miles of comparatively short private lines, some of which are being bought up by the Government.

In the North Island the lines serve four isolated districts, running for the most part nearly parallel with the east and west coasts, at no point penetrating into the interior more than 30 miles. They terminate respectively at the ports of Auckland in the north, Wellington in the south, Napier on the east, and New Plymouth and Wanganui on the west.

By reason, too, of lofty mountain chains in the South Island the slopes of which rise gradually from the coast, the railway system here is virtually confined to skirting the eastern littoral and consists substantially of a single trunk line, commencing at the southern port of Invercargill, and serving, *en route* to its northern terminus near the town of Waiau, the eastern seaports of Dunedin, Oamaru, Timaru, and Christchurch, throwing out on its course short lateral branches toward the mountain ranges.

The connections across the island are, however, about to be made, and workable locomotive lines selected to traverse the mountain ranges.

The so-called east and west route, of 95 miles, will afford direct communication between Greymouth and Christchurch, crossing by the Arthur Pass at an elevation of 2,530 feet, with gradients of 1 in 50 and 1 in 60, and 7½ chain curves.

Twenty-four tunnels, of an aggregate length of 5½ miles, and fourteen viaducts, will raise the cost per mile to more than double the average cost of those already constructed.

The projected West Coast and Nelson Railway (154 miles), proceeding from Greymouth in a north-north-westerly direction, will unite that town and district with the Port of Nelson. This line involves about 3½ miles of tunnelling, and nearly 2 miles of bridging. It is anticipated that their construction will materially stimulate the coal and other mineral industries, as well as the agricultural on the west side of the island.

Rails of from 40 lbs. to 53 lbs. per yard have been, I understand, generally laid down, and, on some steep gradients, rails of 70 lbs. per yard.

The "Fell" system, for working steep gradients, has been applied on the line connecting Wellington with the Wairarapa

Plains, where, for the purpose of diminishing a heavy cost of tunnelling in crossing a mountainous ridge, the colonial engineer laid out a section of $2\frac{1}{2}$ miles on a gradient of 1 in 15. This is worked by Fell engines, the adhesion due to the weight of the engine being, as is well known, supplemented by that derived from the pressure of horizontal wheels against a central rail.

Engines of 37 tons weight take up this incline a train of 53 tons, at 6 miles an hour, at a cost of *5s. 2d.* per train-mile.

At the present day such a gradient would probably be worked to greater advantage on the modified rack-rail and pinion system of Abt.

Useful particulars are given of this work in the Paper by Mr. Maxwell, published in our Transactions (Vol. 63), and in the report of the discussion which arose upon it.

Tasmania.

The railway system in Tasmania is at present in its infancy. Up to the year 1884 215 miles only were open for traffic, and 159 miles under construction.

Unfortunately this colony also is afflicted by diversity of gauge.

A main trunk line, 133 miles in length, trending nearly due south, connects the town of Launceston, on the tidal river Tamar (from whence steamers run to the principal Australian ports) with Hobart, the capital and chief seaport on the southern coast, interrupted, however, by a break of gauge at Evandale, the point of junction with the western railway, some 6 miles south of Launceston. Of the total length of 133 miles, 127 miles are of 3 feet 6 inches gauge, and 6 miles of the 5 feet 3 inches, or "western," gauge.

This line was undertaken by an existing company under a contract with the Tasmanian Government, who gave a guarantee of 5 per cent. for thirty years, on a cost not exceeding £650,000, the Government retaining the power to purchase it at any time on twelve months' notice.

The second, or "western" line, connects the two northern ports of Launceston and La Trobe, being 82 miles of 5 feet 3 inches gauge passing through the town of Deloraine.

The portion between Launceston and Deloraine was constructed by a company, and opened for traffic early in 1871, but eventually taken over by the Government in the summer of 1872. It cost between £9,000 and £10.000 per mile.

The remaining portion, also undertaken by a company, was only partially opened in 1871, and collapsed from want of funds. In

1882 the Government came to the rescue, and purchased it for £120,000, by which it was completed and extended 5 miles further to Formby, near the mouth of the River Mersey, in all a distance of 37½ miles.

Various branch lines, amounting to an aggregate of 159 miles, are now under construction, and further extensions are in contemplation.

Cape Railways.

The railways in the colony of the Cape of Good Hope have been laid out on a 3 feet 6 inches gauge, and the greater part of them are in the hands of the Government, who at the commencement of the present year were the owners of 1,599 miles then open for traffic.

The three systems into which they have been classified—the western, the midland, and the eastern, proceeding from the respective ports of Cape Town, Port Elizabeth and East London, converge towards the diamond fields.

The works have been executed partly by contract and partly departmentally at a total cost of £14,371,306 sterling, which is distributed over the three systems in the following proportions.

	Miles.	£.
Western	718	5,927,104
Midland	589	5,304,473
Eastern	292	3,139,729
	1,599	14,371,306

The average cost has thus been £8,980 per mile, inclusive of stations, rolling-stock, and plant.

The western system has been the least costly, the expenditure being £8,225 per mile; that of the midland is £9,006, and that of the eastern £10,752 per mile.

The lines have been laid, in general accordance with English practice, on wood sleepers, firstly up to 1873 with light rails, and subsequently, under the advice of Sir Charles Hutton-Gregory, Consulting Engineer to the Government, with 45-lb. rails, and later on with 60-lb. rails, these last having been adopted for the last extension of 562 miles. The decay of wood sleepers having proved rapid, trials are now being made of wrought-iron sleepers both of the trough and bowl form.

The Western Railway, running in a north-easterly direction towards Kimberley, traverses a summit of 4,572 feet elevation above the sea-level, whilst that of the eastern line crosses a range at a still higher elevation, viz., 5,446 feet.

On all three lines there occur severe gradients ranging as steep as 1 in 40, over which the traffic is conveyed by English locomotives, of which the general type now apparently preferred is a six-wheel coupled engine with four-wheel leading-bogie, the driving-wheels being 3 feet 6 inches diameter, the cylinders 15 inches diameter and 22-inch stroke, and weight 30 tons. These are said to take nine vehicles up the 1 in 40 gradients.

Clark's chain-brake, and, more recently, the simple vacuum-brake, are in use for controlling the speed.

Beside the Government railways 150 miles belong to private companies.

Thirty more miles now in progress are to be completed this year, at the end of which there would then be 1,780 miles in all open for traffic.

The Government lines entail an annual charge on revenue of £635,954, the nett proceeds serving (in 1885) to reduce this burden to £238,463.

It would appear that the eastern system is the least remunerative, and, in fact, that the excess of cost of maintaining and working expenses above receipts comes as a charge upon the revenue of the colony, an excess which it is thought will amount, taken on the basis of the results of the first three months' working of the present year, to about £41,000.

The loss is attributed mainly to the severe ox-wagon competition which the goods traffic encounters, estimated to amount over all the lines to no less than £50,000 a year. Other causes, no doubt, operate in the same direction, and notably the general depression of trade, and the circumstance of the line being to a certain extent handicapped by its greater cost as compared with the others.

Progress in regard to further railway extensions in the colony has recently been slackened, in view of the financial results and present stagnation, but it may be hoped that these obstacles will be removed when a general revival of business set in.

Natal.

The Government of the colony of Natal possessed at the close of last year 116 miles, on an average, of railway of 3 feet 6 inches gauge open for traffic, since which date the main trunk line to Ladysmith has been completed, making the total length of line now working 217 miles.

Extensions are contemplated up to the borders of the Transvaal, and Orange Free State.

The traffic for the year 1881, when only an average of 98½ miles was open, yielded a nett profit of £63,159 which more than covered the interest chargeable at that time against open railways (£54,000), but in the succeeding years, a great falling off has occurred, which, as the result of five years' working, has placed the railways as indebted to interest account to the amount of £152,000.

This falling off is partly attributable to the loss of the revenue derived from the carriage of material for extensions—partly to a large reduction upon the rates on the traffic, which is the principal support of the railways, and largely to the severe competition with ox-wagon traffic.

On the whole, the railways have earned an annual average return of £2 3*s.* 2*d.* per cent. upon the capital.

It is considered, however, that the balance of interest has been far more than repaid to the colony by the convenience, facility and economy, enjoyed by the public, in respect of the conduct of both goods and passenger traffic, by reason of the construction of its railways.

Ceylon.

The railways in Ceylon have been constructed by the Government of that colony, under the advice of Sir Charles Hutton Gregory, who was appointed their consulting engineer in 1856, on the demise of Mr. James Meadows Rendel.

A uniform gauge of 5 feet 6 inches was fixed for all the lines.

At present the aggregate length of railways open for traffic is 177⅝ miles.

The construction of the main line from Colombo to Kandy, (74½ miles), originally projected by a company in 1847, was not actually commenced until 1863, and was opened for traffic in 1867. The cost was 233,354 rupees per mile.

Twelve years later, viz., 1879, a line of 27⅝ miles in length following the seashore, was completed to Kalutara. This was for the most part a surface line without heavy works, other than the two large lattice girder bridges, each about 600 feet in length at Panadure and Kalutara respectively. It cost 79,356 rupees per mile.

In 1874 a branch of 17 miles, leaving Peradeniya, at 70 miles from Colombo, and constructed at a cost of 157,334 rupees per mile, was opened for traffic, terminating at Nawalapitiya, at a level of 1,913 feet above the sea.

Subsequently communication by rail was effected in 1880, between Kandy and Matalé, $17\frac{1}{2}$ miles, at a cost of 193,826 rupees per mile; and in 1885, between Nawalapitiya and Nanu Oya, $40\frac{3}{4}$ miles, at a cost of 261,607 rupees per mile—this latter being in extension of the above-named branch, proceeding from the Colombo and Kandy line.

In considering the high average cost per mile of the Ceylon railways, it must be borne in mind that, with the exception above stated, all the lines traverse mountainous districts, and are exposed to a tropical rainfall, varying from 80 to 200 inches per annum, the maximum being reached at certain points on the Nanu Oya extension.

On the line from Colombo to Kandy, occurs the Kadugannawa incline of 1 in 45, 12 miles in length, rising to an altitude of 1,618 feet above sea-level, whilst the Nanu Oya extension rises by inclines of 1 in 44, aggregating over 28 miles in length, or 69 per cent. of that extension, to a level at Nanu Oya of 5,292 feet, while the abrupt nature of the hill sides traversed rendered the adoption of curves of 330 feet radius compulsory for the sake of economy.

The bank engines which have been used to assist the passenger and goods trains up these steep inclines are six-wheel coupled outside cylinder engines, 9 feet 6 inches, and wheels 4 feet 5 inches diameter, and $32\frac{1}{2}\frac{1}{2}$ inches on driving-wheels. The cylinders 17 inches by 26 inches, and 1,342 square feet heating surface. The loads usually allotted to the goods engine, and its assistant Bank engine, consist of eighteen loaded wagons of about 11 tons each, and two brake vans; say about 220 tons in all.

The types of goods engine in use, are inside cylinder four-wheel and one six-wheel coupled with four-wheel bogie in front, and are capable of exerting about two-thirds the tractive power of the bank engine.

The total capital expenditure up to June 30th, 1886, is 36,304,133 rupees, giving an average cost per mile of 204,674 rupees. Of this, however, more than one-half has been paid off, leaving an amount of 14,052,464 rupees, on which interest has to be paid, and a sinking fund to be provided.

SUGAR-PRODUCING COLONIES.

The sugar-producing colonies of Mauritius, Jamaica, Barbadoes, Trinidad, and Demerara, have to a limited extent been provided with railways, used chiefly for the transport of sugar to the ports and for goods up to the estates in the interior.

In Mauritius two main lines of railway of 4 feet 8½ inches gauge, laid with 74 lbs. rails on wooden sleepers, were undertaken by the Government, each commencing at the Port of St. Louis on the west coast.

The North line, about 34 miles in length, performing an inland circuit approximately parallel to the coast of the northern half of the island, and terminating at the eastern port of Grand Rivière and the Midland line, 35 miles in length, striking in a south-easterly direction into the heart of the island with its terminus at Mahebourg on the east coast, the two together forming a horse-shoe of about 70 miles in length from point to point.

They were constructed at an average cost of £21,876 per mile, and have been open for traffic more than twenty years, the funds being furnished by Government, partly from surplus revenue, and partly by issue of 6 per cent. debentures secured by sinking fund.

Two branch lines have since been constructed; the one to Savanne, issuing from the Northern Railway, the other to Moka from the Midland.

The Midland Line alone possesses special interest, from the engineer's point of view, by reason of the heavy gradients and sharp curves which the features of the country traversed by it have imposed. Midway between its termini a range has to be crossed at a summit-level of 1822 feet, and this attained by continuous gradients ascending from the coast lines, most of them ranging between the inclinations of 1 in 27 to 1 in 48.

The traffic has been worked by heavy (48 in.) eight-wheeled coupled tank engines, which take up loads of about 100 tons at 10 to 12 miles per hour.

Jamaica.

The mountainous configuration of the Island of Jamaica constitutes a barrier to the construction of numerous railways.

The first line was built in Jamaica by a private company in 1843–1845, running from Kingston to Angelo, and extended to Old Harbour in 1869, the gauge being 4 feet 8½ inches, together 24 miles. Traffic for a time was virtually suspended, consequent upon financial difficulties and the road having fallen into a bad state of repair. On their purchase by the local Government in 1879 for the sum of £90,000, the line was reconstructed, and extended to Porus and Ewarton, under the direction of Messrs. Sir John Hawkshaw, Son, and Hayter, as consulting engineers. The length of the lines at present open for traffic in the island is

63 miles, at an average cost of £5,350 per mile for the Porus, and £16,650 for the Ewarton extensions, respectively, the latter having very heavy works.

A special feature in these works has been the extended use of concrete, of which material the viaducts, bridges, tunnel lining, culverts, and station buildings have been built, stone of good quality and skilled labour being difficult to obtain.

Owing to the depressed state of the colony, and especially of the sugar industry, intensified by prolonged droughts during the years 1880 to 1884, the direct returns have fallen short of what were expected, but the lines have without doubt indirectly contributed to the general welfare of the colony.

Trinidad.

The island of Trinidad had 54 miles open in 1885, all in the hands of the Government.

The opening of the first section of 16 miles took place in 1877. It connected the capital, the "Port of Spain," with Arima, passing through "San Joseph," from whence a railway recently completed proceeds southwards through a sugar-growing district to the port of San Fernando on the southern shore of the gulf. A branch goes off from this line to Princes Town.

The net receipts for the years' working (1885) gave a return of 2·15 per cent. on the total capital expended on the railways.

A project is now on foot, and believed to be favourably entertained by the Government, for a large extension of the system to further open up the forests and fertile districts of the interior to be undertaken by a private company on the basis of a grant of rich and fertile crown lands, which may be expected to yield ultimately a good profit to the European capitalist by the cultivation of the sugar-cane, the cocoa-tree, the coco-palm, and the coffee-plant.

Barbadoes.

Barbadoes possesses one railway only of 3 feet 6 inches gauge, belonging to an English company, and 24 miles in length, fully opened in December, 1884. It commences at Carlisle Bay, the principal and only sheltered port on the south-west of the island, taking the course of the St. George's Valley, striking the east coast at Cousett's Bay, thence following the coast line to Belle Plain, in the district of Scotland. The line has cost about

£200,000, on which the Government has guaranteed for twenty years, from date of completion, an annual payment of £6,000, equal to 6 per cent. on £100,000, applicable for the Preference shares. The traffic, almost entirely sugar, is subject to considerable fluctuation, and has been injuriously affected by the general stagnation of trade, the competition with bounty-fed sugar, and the drought of the present year. Nevertheless, the proceeds have sufficed to pay the interest on its bonds, and for the year 1835 a dividend of 2½ per cent. on its Preference (£5) shares.

Demerara.

The railway in Demerara, of 4 feet 8½ inches gauge, skirts the coast over the low and level lands, extending from George Town to Mahaica. It is 24 miles in length, and traverses the extensive sugar plantations of that district. It was started as early as 1848, but not opened throughout until 1862. On its capital of £280,000 (115,000 of which were represented by 7 per cent. Preference, and the balance by ordinary shares), the dividends have, until quite recently, been good but fluctuating, according to the yield of the estates. They have reached as high as 8 per cent., but last year, which has been an exceptional one, the dividend fell to 2½ per cent. The engineering works have not presented any feature of special note.

Malta.

In this comparatively small dependence of the British Empire, no considerable development of railway enterprise was possible, or to be considered necessary.

Its insular condition allows of access by water for the small amount of traffic passing to and from Valetta to different places along the coast.

The only existing railway in the island is a line of metre gauge 7 miles in length, and ruling gradient of 1 in 40, constructed and owned by an English Limited Liability Company, under a concession of the Maltese Government, dated 28th July, 1880.

It connects the port of Valetta with Notabile, or Civita Vecchia, the old capital in the interior of the island.

It is furnished with rolling-stock of approved English construction.

In the terminal tunnel, 1,000 yards in length, passing under the exterior and interior lines of fortifications surrounding Valetta, are extensive works designed under the orders of the War Office, for the purpose of defence and of destruction, either permanent or temporary, as may be desired.

The line was opened for traffic on the 1st March, 1883.

The authorized capital is £60,000, of which (in June, 1884) £49,830 had been issued and fully paid up, and debentures carrying interest at 7 per cent. to the extent of £30,000 had been issued. The cost of construction and equipment of line, including incidental expenses, is stated to have been in all £80,785.

The traffic is considerable and increasing, but as the fares are low, the expenses of working, including interest payable on the debentures, have so far exceeded the income.

I had at one time contemplated reference to the Indian Railways, of which the aggregate length now open for traffic amounts to between 12,000 and 13,000 miles, but I found that the consideration of so large a subject would impose a heavier tax on your time and attention than would be proper in an address of this kind.

The extent of the Colonial Railways now in operation and to which I have been referring, amounts to nearly 21,000 miles, carried out partially by private enterprise, but mainly as Government undertakings.

From the latest returns it would appear that the population of these several colonies amounts to, in round figures, 14,000,000.[1] It will, therefore, be seen that though the railway-mileage is small in respect of area of territory, it is very large when considered in respect of population, the accommodation afforded being about 1 mile to every six hundred and fifty persons, as against 1 mile to

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[1] The actual figures in 1884 were as follow:—

Dominion of Canada	4,750,000
New South Wales	921,268
Victoria	973,403
Queensland	309,912
South Australia	317,116
West "	33,000
New Zealand	564,304
Tasmania	130,541
Cape of Good Hope	1,122,000
Natal	424,495
Ceylon	2,758,529
Mauritius	370,766
Jamaica	530,804
Trinidad	153,128
Barbadoes	171,860
Guiana (Demerara)	257,473
Malta	156,675
	13,995,274

one thousand nine hundred and twenty-five persons in the United Kingdom.[1]

It is clear from the facts I have put forward as to the returns on capital expended, that such a system could not have been built up without Government aid, afforded either directly by departmental intervention or indirectly by guarantees, or subsidies, or by large land grants.

Colonial experience would on the whole seem to tend more and more to the conclusion that the railways should be constructed and worked at the cost of the local Governments. It may, however be questioned whether the working of the lines might not, in some cases at least, be leased, under proper conditions, to private companies, with advantage to the State.

The example of the Canadian Pacific Railway, partly constructed by Government, partly by a limited company, and now worked, and to be worked, by that company, will be watched with much interest, as likely to afford a satisfactory solution of a problem on which there exists great diversity of opinion.

Continuity in the methods of management, and the retention in service of trained and competent officers would, it may be thought, be better secured under a permanent board of management than under control of a ministerial department liable to change in accordance with the political views which at the time may chance to predominate, and which might tend to influence the selection of competent railway employés.

NILE IRRIGATION WORKS.

Although the works now in progress in the Nile delta, under the direction of Colonel Scott Moncrieff, R.E., are not colonial works, they are well deserving of notice as having been executed under English engineers, and having already been productive of important benefit to that country.

It will be remembered that the great weir spanning the Damietta and Rosetta branches at the apex of the delta (commenced in 1847 and completed in 1862), intended to hold up the waters of the Low Nile some $4\frac{1}{2}$ metres, and to divert them for irrigation purposes into the great system of canals which water the adjoining provinces, failed through alleged defective foundations, and was found to be valueless except for regulation of the flow of water into the two branches of the river.

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[1] The figures for 1884 being: population (estimated) 36,500,000; miles of railway open, 18,962.

The cost of its complete restoration or reconstruction was estimated to exceed a million sterling. The work accordingly had been postponed as being beyond the financial resources of the Government.

Three years ago, however, Colonel Scott Moncrieff, who had had great experience in the conduct of irrigation works in India, was appointed Inspector-General of Irrigation, with full powers to act without being hampered by foreign interference, and allowed to select his own staff of officers.

For this purpose a grant of £1,000,000 was accorded him by the Powers for the general purposes of irrigation.

Believing that the foundations of the weir might be trusted, he came to the conclusion that it might, at a comparatively small expense, be so far strengthened as that with the aid of some subsidiary works, and notably the construction of a second barrage, it might eventually be made capable of holding up 4½ metres of water, in two drops of 2¼ metres each, thus securing a water surface never lower than 14 metres above sea-level.

At the same time measures were proposed for improving irrigation, including a rearrangement of the watercourses, and cleaning out the silt which had choked up many of the channels.

Accordingly the closing of the Damietta branch, which theretofore had not even been supplied with gates, and the strengthening of the foundations and floors of both weirs, and the construction of a second bar of rough stone on the floor of the barrage, so as to distribute the pressure of water by creating two drops instead of one, and removed when the river began to rise, have been so far carried out as successfully to hold up 3 metres of water during the Low Nile seasons of 1885 and 1886 at a cost of less than £50,000, whilst much attention has been bestowed on the details of water distribution. A temporary dam had also been thrown across the Nile below Benha, and two others above Rosetta, so as to allow as little as possible of the precious water to escape into the sea.

By these operations 90,000 acres of land have been brought under cultivation, and a tract supplied with water during the summer months which never received it before.

It was a fortunate circumstance that during these operations Colonel Scott Moncrieff has not only been backed up to a great extent by the Egyptian Government, but has received the constant support of Nubar Pacha, who has shown a most enlightened desire to improve the country.

One able step he has recently enabled the Colonel to take was the partial abolition of the corvée, an army of unpaid and mixed labourers amounting to from eighty thousand to one hundred and twenty thousand, employed annually for half the year in clearing the canals of silt and doing all necessary earthwork.

It was felt that the improvements would be of little avail so long as the scandal and burden of the corvée remained, which place such a cruel and oppressive load upon the poor, who had to find their own tools as well as give their personal labour. During the year 1885, as compared with 1884, the country was benefited by the labour of forty-eight thousand men for one hundred days released from tillage of the lands.

A grant of £250,000 to spend on labour has this year been made in the face of all kinds of financial difficulties and opposition, and this has proved an immense boon to the country.

It is to be hoped that Colonel Scott Moncrieff or some one or more of his able staff of officers, may see their way to furnish our Institution with a detailed and comprehensive account of their valuable labours, and of the means by which these results, so vitally affecting the interests of the Egyptian people, have been attained.

They are, however, to be regarded only as an instalment of the larger benefits which are accruing from the prosecution of the complete scheme of contemplated works.

I take this opportunity of making brief reference to the successful completion during the current year of two difficult and important undertakings nearer home.

I refer to the tunnel under the River Mersey, carried out under the direction of Sir James Brunlees and Sir Douglas Fox, inaugurated by his Royal Highness the Prince of Wales, and to the tunnel under the River Severn which now forms (in the system of the Great Western Railway Company), the direct route for goods traffic, and will soon be opened for passengers between South Wales and the Southern counties of England.

Notwithstanding the depression under which our commerce has been so long suffering, it is probable that at no previous period have engineering works of such surpassing interest and importance been projected, drawing so largely on the skill and resources of the engineer, as those which are now being executed under the direction of Sir John Fowler and Mr. Baker, the designers of the Forth Bridge, and of Mr. William Henry Barlow as regards that over the Tay.

No bridge, I believe, at present existing, will compare with that which is to span the Forth, either in respect of the novel features of its constructive details or of its gigantic proportions.

These structures will link into closer union the counties now separated by the estuaries of those rivers, besides shortening materially the distance between the metropolis and the western towns of Scotland.

I have to express my obligation to many gentlemen who have kindly favoured me with notes relating to various topics to which I have adverted in this Address, and I would especially acknowledge the courtesy of the Royal Commissioners representing our Colonies, the heads of the Locomotive departments on our principal English and some of our Colonial railways—the Secretaries of the Canadian Pacific and Bilbao River and Cantabrian Railways, the Chief Engineer in Ottawa of the "Government Railways in operation,"—and Colonel Scott Moncrieff, for information kindly furnished me.

In conclusion, allow me to say that I enter on the office to which you have done me the honour to elect me, with the earnest desire to promote in every way the interests of the Institution, and to discharge its duties to the best of my ability.

APPEN

LEADING PARTICULARS of the MOST APPROVED TYPE OF LOCOMOTIVES

—	PASSENGER. London and North-Western Railway.	Midland Railway.	Great Northern Railway.	North-Eastern Railway, Express.	North-Eastern Railway, Ordinary.
I. ENGINE.	Compound 3 Cylinders.	Simple.	Simple.	Simple.	Simple.
Cylinders, outside or inside	2 out & 1 in	Inside	Outside	Inside	Inside
Do. dimensions, Diameter	H.P. 14 ins. L.P. 30 ins.	18 ins.	18 ins.	18 ins.	18 ins.
Do. dimensions, Stroke	H.P. 24 ins. L.P. 24 ins.	26 „	28 „	24 „	24 „
Weight of engine in working order	T. C. 42 10	T. C. Q. 42 14 3	T. C. 45 0	T. C. 42 11	T. C. 52 4
Maximum weight on any axle	15 0	15 0 0	17 10	16 4	17 7
Number of axles under engine	3	4	4	3	4
„ driven axles	2	2	1	2	2
Diameter of driving-wheels	6 ft. 3 ins.	7 feet	8 ft. 1½ in.	7 feet	5 ft. 7 ins.
Which end, if either, is carried on bogie-truck	Leading wheels fitted with radial axle-boxes	Front end	Leading end	..	Radial axles leading and trailing radial wheels
Diameter of bogie-wheels	3 ft. 6 ins.	3 ft. 6 ins.	3 ft. 11 ins.	None	3ft. 9 ins.
Description of valve-gear	Joy's	Link	Link	Stephenson	Joy's
Working-pressure, lbs. per sq. in.	175 lbs.	160 lbs.	140 lbs.	140 lbs.	140 lbs.
Area of firegrate	Square feet. 20·5	Square feet. 17·5	Square feet. 17¾	Square feet. 18·0	Square feet. 15·6
Heating surface, Firebox	159·1	110·0	109·0	110·5	98·0
Heating surface, Tubes	1,242·4	1,151·0	1,044·0	1,102·0	994·0
Total	1,401·5	1,261·0	1,153·0	1,212·5	1,092·0
Boiler shell, steel or iron	Steel	Steel & iron	Steel	Iron	Steel
Inner firebox, steel or copper	Copper	Copper	Copper	Copper	Copper
Tubes, copper, brass, or compound metal	67 copper 33 spelter	Copper	Copper	Brass	Brass
Tractive power per lb. per sq. in. pressure	..	100·28	93·04	92·57	116·06
II. TENDER.					Tank engine
Number of axles under	3	3	3	3	..
Weight in working order	T. C. 25 0	T. C. Q. 26 1 1	T. C. 36 0	T. C. 32 0	..
Weight of fuel carried	4 17	3 to 4 0 0	4 0	4 0	2 tons
Capacity of water-tanks	1,800 galls.	3,250 galls.	3,000 galls.	2,651 galls.	1,241 galls.
III. LOAD TAKEN.					
Limit of load allowed	No limit often 256½ tons	No limit	No limit	15 cars	18 cars
Steepest gradient traversed	1 in 75	1 in 100 1 in 90	1 in 200	1 in 96	1 in 40
Length of said gradient	4½ miles	15 miles	12 miles	5 miles	3 miles
Gross load, exclusive of engine and tender, capable of being taken up steepest gradient	..	Tons. 156 up to 1 in 100 speed 35 miles per hour	..	15 cars	12 cars

APPENDIX.

F LOCOMOTIVES USED by the PRINCIPAL ENGLISH RAILWAYS, 1886. — PASSENGER ENGINES BUILT in the UNITED STATES.

	PASSENGER.							PASSENGER ENGINES BUILT in the UNITED STATES.	
	North-Eastern Railway, Ordinary.	North-Eastern Railway, Express Passenger.	Great Western Railway, Express.	London, Brighton, & South Coast Ry., Express.	Manchester, Sheffield, and Lincolnshire Railway.	Manchester, Sheffield, and Lincolnshire Railway.	Lancashire and Yorkshire Railway.	Chicago, Burlington, and Quincy Railroad.	Strong Express, Class 10, A², 20.
	Simple.	Compound 2 Cylinders.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.
	Inside	Inside	Inside	Inside	Outside	Outside	Inside	Outside	Outside
	18 ins.	H.P. 18 ins. L.P. 26 ins.	18 ins.	18¼ ins.	17 ins.	17½ ins.	17½ ins.	18 ins.	20 ins.
	24 "	24 ins. each	24 "	26 "	26 "	26 "	26 "	24 "	24 "
	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C. Q. LB.	
	52 4	42 10	35 0	38 14	41 1	40 11	41 15	36 19 1 4	..
	17 7	16 10	15 8	14 10	15 0	17 0	14 13	12 3 1 6	..
	4	3	3	3	4	3	4	4	6
	2	2	1	2	2	1	2	2	2
	5 ft. 7 ins.	6 ft. 8 ins.	7 feet	6 ft. 6 ins.	6 ft. 3 ins.	7 ft. 6 ins.	6 feet	5 ft. 9 ins.	7 feet
	Radial axles leading and trailing radial wheels	..	..	..	Leading end	Neither	Leading end	Front end	Bogie front end radial axle trailg: bogie, 3 ft. 2 ins.; trailg, 4 ft.
	3ft. 9 ins.	None	None	None	3 ft. 3 ins.	..	3 ft. 7¾ ins.	2 ft. 6 ins.	..
on	Joy's	Joy's	Link	Link	Link	Link	Stephenson's Link	Link	Special
s.	140 lbs.	160 lbs.	140 lbs.	140 lbs.	140 lbs.	150 lbs.	140 lbs.	145 lbs.	160 lbs.
	Square feet. 15·6	Square feet. 17·33	Square feet. 19·23	Square feet. 20·65	Square feet. 15·5	Square feet. 16·5	Square feet. 19·25	Square feet. 17·7	Square feet. 62·0
	98·0	112·0	130·04	113·9	94·0	87·0	90·5	102·1	..
	994·0	1,211·3	1,120·27	1,378·2	922·0	1,057·0	935·5	958·2	..
	1,092·0	1,323·3	1,250·31	1,492·[illegible]	1,016·0	1,144·0	1,026·0	1,060·3	1,858·0
	Steel	Steel	Steel	Iron	Iron	Iron	Iron	Steel	..
	Copper	Copper	Copper	Copper	Copper	Copper	Copper	Steel	..
	Brass	Brass	Steel	Steel	Copper	Copper	Iron	Charcoal iron	..
	116·06	..	92·57	110·0	100·2	88·47	110·59	112·7	114·3
	Tank engine								
	..	3	3	3	3	3	3	4	
		T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	
	..	32 0	28 14	27 7	16 15	16 15	27 2	27 10	
	2 tons	4 0	2 10	2 0	2 10	2 10	3 0	6 10	
.	1,241 galls.	2,651 galls.	2,600 galls.	2,250 galls.	3,000 galls.	3,000 galls.	2,000 galls.	2,750 galls.	
	18 cars	18 cars	..	..	..	..	..	..	
	1 in 40	1 in 96	..	..	1 in 97	1 in 97	1 in 27	..	
	3 miles	5 miles	..	..	858 miles	858 miles	1,056 miles	..	
	12 cars	18 cars	..	..	..	..	90 tons	..	

Note.—This engine is built to burn low quality anthracite or bituminous coal.

LEADING PARTICULARS of the MOST APPROVED TYPE OF LOCOMOTIVES USED

—	GOODS.				
	London and North-Western Railway.	Midland Railway.	Great Northern Railway.	North-Eastern Railway, Heavy.	North-Eastern Railway, Heavy.
I. ENGINE.	Simple.	Simple.	Simple.	Simple.	Simple.
Cylinders outside or inside . .	Inside	Inside	Inside	Inside	Inside
Do. dimensions {Diameter . .	17 ins.	18 ins.	19 ins.	18 ins.	18 ins.
Do. dimensions {Stroke . .	24 „	26 „	28 „	24 „	24 „
Weight of engine in working order	T. C. 29 11	T. C. Q. 36 12 1	T. C. 40 0	T. C. 51 19	T. C. 37 0
Maximum weight on any axle .	10 6	14 12 0	14 17	16 13	14 5
Number of axles under engine .	3	3	3	4	3
„ driven axles . . .	3	3	3	3	3
Diameter of driving-wheels .	4 ft. 8 ins.	4 ft. 10½ ins.	5 ft. 1½ in.	5 feet	5 feet
Which end, if either, is carried on bogie-truck.	..	..	..	{Radial axle-box trailing}	..
Diameter of bogie-wheels . .	None	None	None	{3 ft. 9 ins. trailing}	None
Description of valve-gear . .	Link	Link	Link	Joy's	Joy's
Working-pressure, lbs. per sq. in.	140 lbs.	140 lbs.	140 lbs.	140 lbs.	140 lbs.
Area of firegrate	Square feet. 17·1	Square feet. 17·5	Square feet. 18·0	Square feet. 17·23	Square feet. 17·23
Heating surface {Firebox . .	94·6	110·0	112·0	110·0	110·0
Heating surface {Tubes . . .	980·0	1,151·0	1,240·0	1,026·12	1,026·12
Total . .	1,074·6	1,261·0	1,352·0	1,136·12	1,136·12
Boiler shell, steel or iron . .	Steel	{B. Yorkshire iron}	Iron	Steel	Steel
Inner firebox, steel or copper .	Copper	Copper	Copper	Copper	Copper
Tubes, copper, brass, or compound metal	{67 copper 33 spelter}	Brass	Copper	Brass	Brass
Tractive power per lb. per sq. in. pressure	136	144	164·35	129·6	129·6
II. TENDER.				{Tank engine}	
Nnmber of Axles under . .	3	3	3	..	3
Weight in working order . .	T. C. 25 0	T. C. Q. 29 12 1	T. C. 28 10	..	T. C. 32 0
Weight of fuel carried . . .	4 17	3 0 0	4 0	2 tons	4 0
Capacity of water-tanks . . .	1,800 galls.	2,200 galls.	2,800 galls.	1,241 galls.	2,651 galls
III. LOAD TAKEN.					
Limit of load allowed . . .	35 wagons	No limit	400 tons	400 tons	400 tons
Steepest gradient traversed .	1 in 77	1 in 100	1 in 200	1 in 60	1 in 107
Length of said gradient . .	3½ miles	15 miles	12 miles	10 miles	4 miles
Gross load, exclusive of engine and tender, capable of being taken up steepest gradient .	..	Tons. {360 up to 1 in 100, speed 15 miles per hour}	..	250 tons	360 tons

by the Principal English Railways, 1886.					Goods Engines built in the United States.		
Goods.							
North-Eastern Railway, Heavy.	Great Western Railway, Heavy.	London, Brighton, & South Coast Ry., Heavy.	Manchester, Sheffield, and Lincolnshire Railway.	Lancashire and Yorkshire Railway.	Central Pacific Railroad.	Don Pedro II. Railway, Brazil.	Southern Pacific Railroad of New Mexico.
Compound 2 Cylinders.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.	Simple.
Inside	Inside	Inside	Inside	Inside	Outside	Outside	Outside
H.P. 18 ins. L.P. 26 ins.	17 ins.	18½ ins.	17½ ins.	17½ ins.	21 ins.	22 ins.	20 ins.
24 ins. each	26 „	26 „	26 „	26 „	36 „	26 „	26 „
T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.	T. C.
37 0	36 18	40 7	40 0	37 5	77 0	64 6	51 7
14 5	12 6	14 0	16 19	12 15	65 0	57 3	44 13
3	3	3	3	3	7	6	5
3	3	3	3	3	5	5	4
5 feet	5 feet	5 feet	4 ft. 9 ins.	4 ft. 6 ins.	4 ft. 9 ins.	3 ft. 9 ins.	3 ft. 6 ins.
..	..	..	..	..	Leading end	Single pony truck at leading end	..
None	None	None	None	None	2 ft. 2 ins.	2 ft. 4 ins.	..
Joy's	Link	Link	Link	Stephenson's Link	A. J. Stevens	..	..
160 lbs.	140 lbs.	140 lbs.	130 lbs.	140 lbs.	..	..	..
Square feet.	Square feet.	Square feet.	Square feet.	Square feet.		Square feet	Square feet.
17·23	15·2	20·95	18·25	19·50	..	33·0	..
110·0	103·29	101·0	87·0	90·5	..	160·0	153·0
1,026·12	1,053·8	1,312·0	1,141·0	935·5	..	1,783·0	1,223·84
1,136·12	1,157·09	1,413·0	1,228·0	1,026·0	..	1,943·0	..
Steel	Steel	Iron	Iron	Iron	..	Iron	..
Copper	Copper	Copper	Copper	Copper	..	..	..
Brass	Steel	Steel	Copper	Iron	..	..	..
..	125·23	143·02	139·69	147·45	278·6	279·6	247·6
3	3	3	3	3	*Note.*—The 65 tons are distributed over 5 pairs of driving-wheels.	*Note.*—The 57 tons 3 cwt. are distributed over 5 pairs of driving wheels.	*Note.*—The 44 tons 13 cwt. are distributed over 4 pairs of driving wheels.
T. C.	T. C.	T. C.	T. C.	T. C.			
32 0	28 8	28 8	16 15	27 2			
4 0	2 10	2 0	2 10	3 0			
2,651 galls.	2,500 galls.	2,550 galls.	3,000 galls.	2,000 galls.			
450 tons	..	..	350 tons	480 tons			
1 in 107	..	..	1 in 97	1 in 27			
4 miles	..	..	858 yards	1,056 yards			
400 tons	..	..	395 tons	120 tons			

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