February 2, 1869.

CHARLES HUTTON GREGORY, President, in the Chair.

The following Candidates were balloted for and duly elected:—JOSEPH HAYWOOD WATSON BUCK, THOMAS DALE, PETER GRECK, and HENRY JOHNSTON WYLIE, as Members; JOHN BOWDEN, ALFRED MOUNTAIN FOWLER, CHARLES HART, BLEAMIRE MOODY DE MICHELE, JOSEPH MUSGRAVE, EYRE WILLIAM PRESTON, ALFRED LOUIS SACRÉ, HARCO THEODORUS HORA SICCAMA, AUGUSTUS HORACE STRONGITHARM, and JOSEPH WILLIAM WILSON, as Associates.

It was announced that the following Candidate, having been duly recommended, had been admitted by the Council, under the provisions of Sect. IV. of the Bye Laws, as Student of the Institution:—JOSEPH POMFRET VAN DER MEULEN.

No. 1,202.—"The Mauritius Railways—Midland Line." BY JAMES ROBERT MOSSE, M. Inst. C.E.[1]

THE chief object of this Paper is to give a concise account of the working of the unusually heavy gradients which prevail on the Midland Railway. Before, however, proceeding to this subject, it may be well to notice, briefly, the chief physical features of the island, and the causes which led to the introduction of railways in the colony.

Mauritius is entirely of volcanic origin. The mountains consist of basalt, tufaceous rock, and lava, and have been thrown up on all sides to heights varying from 2,000 feet to 3,000 feet above the sea. In the centre of the island, the table-land traversed by the Midland Railway has an elevation of 2,000 feet above the sea, the distance from the coast being about 15 miles. In the northern and eastern parts, the ground rises gradually; but in the southern and south-western portions, the features of the country are exceedingly broken and rugged.

The soil of Mauritius, though unusually fertile, varies greatly in character. In some places and for a considerable area, the soil is deep and entirely free from rocks; while within a short distance, the rock again crops out on the surface without any soil whatever.

[1] The discussion upon this Paper occupied portions of four evenings, but an abstract of the whole is given consecutively.

Throughout a large portion of the island the soil is covered with loose blocks of basalt and lava of all sizes, which are piled up into parallel rows, 5 feet or 6 feet apart, and the canes are planted between them.

The extreme dimensions of the island are about 38 miles long by 37 miles broad. Its area is about 706 square miles, of which there are under—

Cane cultivation	230	square miles.
Planted with maize, manioc, and vegetables	25	,,
Forest and pasture	168	,,
Waste and uncultivated land	283	,,
Total	706	,,

For so small an area, the population of Mauritius is extraordinary. According to the returns made on the 31st December, 1866, the population of the colony then amounted to 341,165, of which about 75,000 resided in Port Louis, the principal port and the seat of Government. The population thus amounts to 483 per square mile over the whole island, or to 1,338 per square mile over the land in cultivation.

Sugar-cane is well known to be the principal, it may almost be said to be the only, production of Mauritius. With this exception the colony raises scarcely anything required for its consumption, but exports nearly its whole product, and imports all articles required for food and for its other necessities. Everything grown in the country is sent to Port Louis for exportation, and everything required on the estates is brought back from that town; hence arises an amount of traffic between the port and the interior unusually great in proportion to the population and to the area of the country.

For the last seven years the average imports into and exports of sugar from the Mauritius have been as follows:—

	Tons.	Value.
Imports	279,597	£2,131,408
Sugar exported	126,852	2,206,196
Total exports	215,811	2,375,230

From these figures the following results are obtained:—

Per Square Mile per Annum.

	Tons.	Value.
Imports	396	£3,019
Total exports	306	3,364

Per Head per Annum.

	Ton.	Value.
Imports	0·81	£6·25
Total exports	0·63	6·93

From 1860 to 1866 the average population has been 326,214, the revenue £571,931, and the expenditure £578,969, giving £810 and £820 per square mile per annum respectively, or £1·74 and £1·76 per head per annum.

From the hilly nature of the island, from the expense of importing mules from France and Montevideo, grain from India, and oats from Australia or the Cape, it will be evident that the best means of conveying these exports to town, and the imports from Port Louis to the interior, soon became a serious question.

Until recently, the sugar from the estates near the coast was conveyed to Port Louis by schooners, carrying from 60 tons to 120 tons each, and from the other parts of the island it was carted to town by mules. These carts conveyed from 30 cwt. to 40 cwt. of sugar each, and required three and sometimes four mules; but in ascending from Port Louis to the districts traversed by the Midland Line, the return load only ranged from 10 cwt. to 15 cwt. per cart. Conveyance by coasters, though cheap, depreciated the sugar, owing to its exposure to the damp, and to the losses consequent on frequent transhipments and pillage; while the cartage was, for the reasons given, very expensive, notwithstanding the excellent condition in which the roads are maintained by the Government.

The necessity for railway communication being felt by the local Government, Mr. James A. Longridge (M. Inst. C.E.) was in May, 1858, charged by the Right Hon. the Secretary of State for the Colonies, "to investigate by regular surveys and sections, and by careful estimates, complete as to outlay of capital, annual expenditure and traffic returns, the question as yet undecided of the introduction of railways into Mauritius." The Report being in favour of the railway system, the construction of the works was, in May, 1861, authorised by the Imperial Government. For some time hopes were entertained that the railways would be undertaken by a private Company; but, as no suitable offer was made, it was decided that the works should be carried out by the local Government, the funds being obtained from some large balances of revenue then on hand, and by the issue of one million pounds of colonial debentures, bearing 6 per cent. interest, and secured by a sinking fund. The total sum for which the general revenue of the colony thus became responsible was £78,000 per annum. Mr. Hawkshaw (Past-President, Inst. C.E.), who had previously reported on the railways by order of Government, was appointed Consulting Engineer to the Mauritius Government; and in September, 1861, a contract was entered into with Messrs. Brassey and Wythes for the execution of the works, which were commenced early in 1862, under the direction of Mr. Walmsley Stanley (M. Inst. C.E.), as Chief Resident Engineer for the Government, and of Mr. J. A. Longridge (M. Inst. C.E.), as Agent for the Contractors.

The North Line, starting from the central station at Port Louis, traverses the northern and the north-eastern parts of the island, through the districts of Pamplemousses, Rivière du Rempart, and Flacq to Grand River, being a distance of 31 miles. The Midland Line, commencing at the same station in Port Louis, passes through the centre of the island, by the districts of Plaines Wilhems and Grand Port to Mahebourg, a small town containing a population of about 6,000, and distant 35 miles from Port Louis.

The North Line contains no engineering feature of interest, and the only work of importance on the Midland Line is the Grand River Viaduct, already described in Mr. Ridley's Paper.[1] The North Line was opened for public traffic on the 24th May, 1864, and the Midland Line on the 19th October, 1865.

Sufficient land has been purchased for a double line, and the masonry of all culverts and bridges has been built for a double way; but the ironwork for the superstructure of the under girder bridges and the permanent way have only been provided for a single line of rails.

The rails, which are laid to the ordinary narrow gauge, are of the usual double-headed pattern, weighing 74 lbs. per yard, fished with plates weighing 11 lbs. each, the sleepers being placed 2 feet apart from centre to centre at the joints, but averaging 1 yard.

The chairs are of the usual form, weighing 25 lbs. each, but countersunk at the bottom for a length of 2 inches by 2 inches in width, and by $1\frac{1}{4}$ inch in depth. These chairs have not proved sufficiently strong, quantities having broken through the hollow in the bed, where the metal is about $\frac{7}{8}$ inch thick; so much so that the chairs now ordered to replace them are made of increased strength. The keys have held well; the climate being wet in the hot season, they have not shrunk so as to get loose, nor have they swollen so as to break the lip of the chair.

The sleepers are of Baltic red timber, 9 feet long by 10 inches by 5 inches in section, creosoted with 1 gallon of oil to every cubic foot of timber. Some miles of these sleepers have now been in use five years, and few, if any, show signs of decay; nor have they been in the least attacked by the white ants, which destroy all ordinary timber in damp situations, except teak, in the course of two or three years. It should be mentioned that the ballast is composed entirely of broken stone, which keeps the sleepers more than usually dry, and in order to prevent their splitting from the heat of the sun, they are covered with ballast to a depth of 3 inches or 4 inches. The rigidity of this stone ballast may, probably, in some measure, account for the large breakage of the chairs before alluded to.

The cost of these railways may be taken as follows:

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[1] *Vide* Minutes of Proceedings, Inst. C.E., vol. xxv., p. 237.

	£.
Contracts	1,038,641
Extra works	22,927
Central Station, Port Louis	40,230
Purchase of land	195,544
Engineering and management	104,084
Electric Telegraph	6,046
Additional rolling-stock	36,380
Total	£1,443,852

Equal to £21,876 per mile.

For this large expenditure there are many exceptional causes, among others the construction of the line over the Trou Faufaron, and along the streets of Port Louis to the Caudan, which involved a heavy viaduct and the purchase of valuable town property. The ground also at the Central Station being exceedingly soft, extensive piling was required for the foundations of the masonry and of the turn-tables, &c.

The high charge of £104,084 for management, includes all the expenses connected with the loan, as well as the premium of exchange in remitting the funds thus raised from England to the colony.

The unusually heavy character of the Gradients on the Midland Line will be understood from the following summary:—From Port Louis to the summit, at Curepipe, there is a rise of 1,817 feet, the distance being about 16 miles, which gives an average gradient of 1 in 46·68; and from the summit to the terminus at Mahebourg, a distance of about 19 miles, there is a descent at the rate of 1 in 55·61. For about 12½ miles before reaching the summit, between Coromandel and Curepipe, the inclination is on an average 1 in 41·17; and thence between the summit and Union Vale, for about 13½ miles, the line falls on an average 1 in 45·06.

The following tabular statement will show these gradients more clearly:—

From.	To.	Length in Feet.	Rise in Feet.	Average Gradient 1 in.	Total Rise above Port Louis in feet.
Port Louis	Coromandel	14,800	170	87	170
Coromandel	Rose Hill	28,399	748	38	918
Rose Hill	Phœnix	18,670	388	48	1,306
Phœnix	Vacoa	6,200	60	103	1,366
Vacoa	Curepipe	13,963	437	32	1,803
Curepipe	Summit	2,800	14	200	1,817
			Fall in feet		
Summit	Cluny	33,063	819	40	998
Cluny	Rose Belle	12,124	126	96	872
Rose Belle	Union Vale	25,557	625	41	247
Union Vale	32nd Mile	12,210	180	67	67
					Total Fall.
32nd Mile	Mahebourg	18,116	67½	268	0·5
	Total	185,902			

The gradients vary in ascending to the summit from 1 in 27 to 1 in 60, having between these limits a length of 57,362 feet, and a rise of 1,622 feet. In descending towards Mahebourg the gradients vary from 1 in 30 to 1 in 60, having between these limits a length of 57,805 feet and a fall of 1,556 feet. The steepest gradient is 1 in 27, of which there is an aggregate length of 13,526 feet, with a rise of 499 feet, the greatest continuous length of this gradient being 6,163 feet, and the next longest 5,016 feet. The next in severity is 1 in 30, of which there is an aggregate length of 9,526 feet in ascending, and 7,510 feet in descending, the greatest continuous length being 3,000 feet, and four other lengths averaging about 2,400 feet each. After 1 in 27, the gradient of the greatest aggregate length is 1 in 40, equal to 11,460 feet in ascending, and to 8,967 feet in descending, the greatest continuous length being 4,817 feet, the next in length 3,700 feet, with six other lengths of about 1,700 feet each. Of gradients of 1 in 40 to 1 in 50 there is an aggregate length of 9,050 feet in ascending, and 11,974 feet in descending, the greatest continuous length being 5,300 feet of 1 in 44, with four other lengths of about 2,200 feet each within these limits. Of gradients of 1 in 50 to 1 in 60 there is an aggregate length of 6,900 feet in ascending, and 6,100 feet in descending, the greatest continuous length being 3,300 feet of 1 in 50, with two other lengths averaging 2,000 feet within these limits.

The Curves vary from 950 feet radius to 6,000 feet radius, and the lengths of the curves range from 200 feet to 3,200 feet. The ordinary radii are generally from 2,000 feet to 3,000 feet. The following summary shows the least radii which occur on the steepest gradients between Port Louis and Curepipe:—

Radius in feet.	Length of Curve in feet.	Gradient on which Curve occurs.
1,400	1,350	1 in 100
1,500	1,600	1 in 55
1,600	900	1 in 27
1,600	860	1 in 29
1,600	1,930	1 in 30
2,000	1,000	1 in 27
2,000	950	1 in 27*
2,000	970	1 in 27*
2,000	700	1 in 27
2,200	550	1 in 27
2,000	1,300	1 in 30
2,000	700	1 in 30
2,200	600	1 in 27
2,400	1,000	1 in 27

* Reversed curve.

It will thus be seen that 1,600 feet is the sharpest radius which occurs on the steepest gradients of 1 in 27 and 1 in 30, the greatest continuous length of this curve being 900 feet on the former gradient and 1,930 feet on the latter. The next radius in severity is 2,000 feet on the maximum gradient of 1 in 27, the greatest continuous length of this curve being 1,000 feet. At Beau-Bassin reverse curves of this radius, 1,920 feet in length, are also found on the maximum inclination of 1 in 27. On descending from Curepipe to Mahebourg, the line from the 17th to the 19th mile may be said to be composed wholly of reversed curves, of which the following are some of the chief instances:—

Radius in feet.	Length of Curve in feet.	Gradient on which Curve occurs.
1,300	1,100	1 in 31
1,800	450	1 in 30
1,800	550	1 in 31
1,800	1,700	1 in 36*
1,800	950	1 in 44
1,800	160	1 in 44
1,800	400	1 in 44
1,930	1,000	1 in 30
2,000	800	1 in 31

* Chiefly.

These 2 miles are considered to be the worst part of the railway to work: for, although the gradients are not so steep as elsewhere, the line is altogether curved, and, passing through woods, it is impossible to see for more than a short distance ahead. The most severe curvature between the 19th mile and Mahebourg is at the 29th mile, where the radius is only 1,400 feet, the length of this curve being 1,980 feet, chiefly on a gradient of 1 in 30. Of curves under 2,000 feet radius there is an aggregate length of 21,165 feet; of those ranging from 2,000 feet to 4,000 feet radius there is a length of 49,710 feet; and of curves from 4,000 feet to 6,000 feet (the greatest radius) there is an aggregate length of 25,560 feet, the total length of curves being 96,435 feet, and of the straight portions of the line 89,467 feet.

The Locomotives furnished under the original contract for working these inclines are seven in number, and of the following description: they are tank engines, having cylinders 16 inches in diameter, with a length of stroke of 22 inches; the wheels, six in number, are 3 feet 6 inches in diameter, and are all coupled, the length of the wheel base being 15 feet. When supplied with water and fuel, these engines weigh nearly 37 tons, and they are worked with a pressure of steam of 120 lbs. per square inch. The load which these engines are able to convey depends greatly upon the state of the rails; for though there are sand-pipes leading to four wheels out of the six, it is always found that the engines work the best when the rail is perfectly dry.

The original engines having been found inadequate for the traffic, subsequently six larger saddle-tank locomotives were designed by Mr. Hawkshaw, of the following dimensions: Cylinders 18 inches in diameter, with a length of stroke of 24 inches; the wheels, eight in number, are 4 feet in diameter, and are all coupled, the length of the wheel base being 15 feet 6 inches. When supplied with water and fuel, these engines weigh nearly 48 tons, and they are worked with a pressure of steam of 120 lbs. per square inch. The centre pairs of wheels (one of which is the driving pair) are fixed stiff in the frame; but in order to pass easily round the curves, both the leading and the trailing wheels have a play of $\frac{3}{4}$ inch in each journal; and the joints of the coupling rods, connecting these wheels with the driving pair, are fitted with a ball and socket, so as to allow the requisite motion. Four sand-boxes are attached to the engine-frame, leading sand to every wheel; but although the sand is of the sharpest quality, obtained specially from the Cape, it is often found impossible to prevent the locomotives from slipping to a serious extent on the steepest inclines. So much is this the case with the first morning goods train, when the rails are wet with dew, that it has been found necessary to extend the time between Port Louis and Phœnix, a distance of 12 miles, from 1 h. 15 m. to 1 h. 30 m., or to a speed, including stoppages, of only 8 miles per hour.

All the engines were manufactured by Messrs. Sharp, Stewart, and Co., of Manchester, and work very satisfactorily. The carriages and wagons are all of the best description, similar to those used in England, and were manufactured by Messrs. Brown, Marshall, and Co., of Birmingham, the wheels and axles having been supplied by Messrs. Lloyd, Foster, and Co., of Wednesbury.

There are two Passenger Trains each way daily between Port Louis and Mahebourg, and two additional trains each way daily between Port Louis and Curepipe, the great majority of first-class passengers residing between these points, and travelling, as season-ticket holders, to town and back daily. There are also two through Goods Trains each way daily, and occasionally special Goods Trains when required for that traffic.

The ordinary passenger train consists of four carriages and the break-van. The smaller engines can fairly take another carriage, making six vehicles in all, say equal to a load of 42 tons, and this is as much as can be depended upon, though on many occasions they have hauled seven loaded vehicles, and in some instances eight, weighing in all about 56 tons.

With goods trains the ordinary number is six loaded wagons plus the break-van, say equal to 70 tons; but with the 5·45 A.M.

down-train, when the rails are wet, the load (in order not to detain the other trains) is limited to five wagons, making six vehicles in all, or say 60 tons. These may appear very small loads for engines weighing 37 tons, but it should be remembered that to ascend gradients of 1 in 30 requires fully eight times the tractive force that would be requisite on a level.

The larger locomotives, weighing 48 tons each, will take five passenger-carriages and one break-van, equal to a load of 42 tons, though on some occasions they have hauled eight loaded vehicles, weighing in all about 56 tons. With goods trains, the ordinary load in descending is nine loaded wagons and a van, say equal to 100 tons, though occasionally there have been twelve loaded vehicles, or, say, about 120 tons. By reducing the lead of the slide-valves to one-eighth of an inch, the power of the engines was subsequently increased 10 per cent.

Deducting stoppages, the running speed of the Passenger Trains is about 16 miles per hour, or, including seven stoppages, 12 miles per hour, between Port Louis and Curepipe, where the gradient for the whole distance rises on the average 1 in 45·83; and 15 miles per hour, including four stoppages, from Mahebourg to Curepipe, where for 19 miles the ascending gradient averages 1 in 55·61. This speed is quite as much as can be realized in ascending in ordinary weather. On wet days, notwithstanding all that can be done with sand, the engines slip; and in many cases, on gradients of 1 in 27 and 1 in 30, with the smaller locomotives, the speed has fallen to 4 miles per hour, even with a train of five vehicles, or, say, of 35 tons.

The average running speed of the Goods Trains is 12 miles per hour, or, including the frequent stoppages, about 9 miles per hour; and this, as the engines are always loaded to their maximum, is as much as can be attained. Speed over these gradients is of less importance than economy of motive power.

Whenever two locomotives are required with any train, either Passenger or Goods, the second engine is placed in the rear of the train, to ease the great strain on the couplings, and control the vehicles, should any of them break loose. This plan, though open to some objections, has hitherto worked well, and there has been no instance in which the vehicles have mounted the rails in consequence of the pushing from behind.

According to the usual formula, the tractive force required per ton, on a curved line with a gradient of 1 in 27, at a running speed of 6 miles per hour, is found to be 95 lbs. With a load of 100 tons, or, including the engine, of 148 tons in all, 6 miles per hour may be taken as the average speed up 1 in 27. Then,

$$\frac{\overset{\text{lbs.}}{95} \times \overset{\text{tons.}}{148} \times \overset{\text{miles.}}{6} \times 88}{33{,}000} = 225 \text{ H.P. exerted, or, excluding the weight}$$

of the locomotive, it is equal to 152 H. P., and this divided by the weight of the engine becomes 3·16 H. P. per ton of motor. To obtain this tractive force (14,060 lbs.) an effective pressure in the cylinder of nearly 87 lbs. per square inch is requisite; but as 60 lbs. is nearer the average pressure, the tractive force becomes

$$\frac{4 \times \overset{\text{ft.}}{2} \times \overset{\text{lbs.}}{60} \times \overset{\text{sq. in.}}{254 \cdot 47}}{12 \cdot 566 \text{ feet.}} = 9{,}720 \text{ lbs.}$$

In the former case the adhesion required would be 13 per cent., and in the latter 9 per cent. of the weight of the locomotive. Taking the average gradient from Port Louis to Curepipe at 1 in 45·83, the mean tractive force required is 60 lbs. per ton, equal to a force of 8,880 lbs. for a load of 148 tons.

The following are the results of a particular trip made on the 12th December, 1867, when the fuel and water were noted more accurately than usual: The distance from Port Louis to Curepipe is 15·65 miles, in which there is a rise of 1,803 feet. The train consisted of ten loaded wagons, weighing 83 tons, and of an engine weighing 48 tons, together 131 tons. The running time was 1 hour 25 minutes, and the average speed 11 miles per hour. The coal consumed on the trip amounted to 986 lbs., giving 63 lbs. per mile, exclusive of lighting, and 0·48 lb. per ton per mile including the weight of the locomotive, and 0·76 lbs. per ton per mile, excluding the weight of the locomotive. This consumption was at the rate of 696 lbs. per hour, of 39 lbs. per square foot of grate per hour, and of 4·75 lbs. per H.P. exerted per hour. The total water evaporated on the trip weighed 7,888 lbs., so that 8 lbs. of water were evaporated by 1 lb. of coal. The quantity evaporated per hour was 5,568 lbs., giving 309 lbs. per square foot of grate area, and 4·6 lbs. per hour per square foot of heating surface, and 38 lbs. per H.P. exerted per hour. The gross weight of this train being 131 tons, the average power exerted would be

$$\frac{131 \times 60 \times 11 \times 88}{33{,}000} = 230 \text{ H.P.},$$

or, not including the weight of the engine, 146 H.P., and this divided by the weight of the locomotive is equal to 3·04 H.P. per ton of motor. The coal used on this trip was obtained from the Warattah Colliery, near Sydney, New South Wales, and was of the usual quality; but the evaporation of water per lb. was rather above the average, the ordinary quantity being about 7½ lbs. of water evaporated by 1 lb. of coal.

With the exception of the first-class carriages, all the others on the railway have a Break on every wheel, worked from the inside. The ordinary Passenger Trains consist of one first, one second, and two third-class carriages, with one break-van; and to these trains

Mr. Clark's continuous break is attached. This apparatus is worked by a chain, which tightens the breaks on every one of the wheels simultaneously. The breaks are taken off by heavy counter-balance weights, resting longitudinally over the chain in the centre of the carriage, between the front and end wheels. This apparatus is sufficiently powerful to lock every wheel, and has worked satisfactorily; for during two years there has not been a single fracture of the chain, nor of any of the working parts. It however requires careful management, and must be applied gradually, before the train has acquired serious momentum. The friction rollers must be kept revolving, otherwise the break-van wheels wear flat places or segments in the rollers, by which their use is completely destroyed. The continuous chain is also jerked, and an undue strain thrown upon it, and upon the carriage couplings, depending in intensity upon the concavity of the segment worn on the friction rollers, and upon the tension of the chain at the time. There has been much difficulty in getting men to work this break satisfactorily; and great difference has been found in the length of time a set of friction rollers would last, depending altogether upon the care with which they are applied. One Guard has worked a set of friction rollers for fully nine months without wearing them unevenly; while several other Guards have destroyed a set in one week, and in some instances in a single trip. To prevent the wearing of these cast-iron rollers, a wrought-iron strap, or tyre, about $\frac{3}{4}$ inch thick, has been placed on their circumference, and this has been found to decrease the wear and to answer well. In future it is proposed to make these tyres of $1\frac{1}{4}$ inch Bessemer steel. The break-van of every passenger train is now provided with sand-boxes leading to the rails, as formerly the dew on the rails wetted the wheels of the break-van, and prevented the friction rollers of the apparatus from revolving; whereas, as soon as sand was applied, the wheels became dry, and the friction rollers acted efficiently. The cost in London of the continuous break for four carriages and the van was £85 per set, to which must be added freight, insurance, &c., so that the cost in place in Mauritius may be taken at £91 per set.

Every train of four or five carriages has two guards, one to work the continuous break, the other to use the separate break if necessary, attached to the end carriage, or that which was not connected with the continuous break. In general, one additional breaksman is sent for every two carriages, beyond the four which are worked by the continuous chain. During the year 1867, the 7·30 A.M. up train from Mahebourg was much overcrowded, and frequently descended the inclines with eight or nine carriages attached; but, for the sake of giving more accommodation, and greater safety, another train has now been added, so that the ordinary trains at present vary from four to six carriages.

The heaviest passenger train from Mahebourg to Port Louis consisted of fourteen carriages and two break-vans, and conveyed five hundred and thirteen troops. This was on the 14th of November, 1868, and it was kept perfectly under control, when descending the inclines, by the continuous break on four carriages, and by five additional breaksmen, the speed from Curepipe to Port Louis being steadily maintained at 20 miles per hour.

Engines attached to trains have occasionally got off the line at the points, without doing any damage, through the carelessness of the pointsman; but, with this exception, since the opening of the line, in October, 1865, there has been no accident to any passenger or goods train, nor to any passenger. There are but four instances of passenger trains getting for a time beyond control:—First, one morning when the rails were wet, a train, consisting of four carriages and the break-van, descended from Curepipe to Phœnix, a distance of $3\frac{3}{4}$ miles, in five minutes, or at a speed of 45 miles per hour. This is the highest speed on record, and it occurred before the sand-boxes were put on the break-vans. Secondly, in a similar way, another train attained a speed of 32 miles per hour. Thirdly, a train overran the Petite Rivière Station for a considerable distance, chiefly from the want of sufficient care on the part of the engine-driver and guards. Lastly, a train once attained an excessive speed in descending from Curepipe to Cluny, through the dropping off of the nut of the eyebolt which passes through the axle on which the continuous chain of the break apparatus is wound. The last is the only instance of any casualty having yet occurred with the gearing of the continuous break, and was moreover an accident not attributable to the system.

The speed in descending the inclines is limited theoretically to 18 miles per hour, practically it rarely exceeds 25 miles, and the breaks on the carriages are generally sufficient to control the train, without the necessity of applying the breaks on the engine. It was at first customary to use the engine break; but the iron tyres being then found to heat, so that they would soon become loose, the practice was discontinued, and the engine break is now only applied on emergencies. The present tyres of all the locomotives are manufactured from Bessemer or Krupp's steel.

The goods trains in descending the inclines, as a rule, consist of eight loaded wagons with the lighter locomotive, though ten have been occasionally taken, and as many as twenty empties. There have been instances in which fourteen loaded or twenty-four empty wagons have descended, but only on emergencies and under very favourable conditions. With the 48-ton locomotives the usual number of wagons in descending the inclines is from ten to twelve and sometimes fifteen loaded, or about twenty-four empty, and, in these cases also, the breaks on the wagons control the trains, so that it is rarely necessary to apply the break of the engine.

The break power attached to the ordinary goods train is as follows:—First, two ordinary break-vans, or one break-van and one goods wagon fitted with the ordinary screw break. Secondly, every goods wagon has the usual break handle working two blocks on the wheels, and to the end of this handle a weight, averaging 35 lbs., is attached to every wagon, exerting (including the leverage) a pressure of 90 lbs. on the break blocks.

With every train, both passenger and goods, there are at least two guards. The head guard always works the principal break-van, and the under guard works either the second break-van or a screw break-wagon, one of which invariably accompanies each goods train. In addition, a man specially employed in tightening up the break blocks before descending on either side of Curepipe (or at any other station where it may be required) accompanies each train, both passenger and goods, and works the separate break of any additional carriage, or the second screw break-wagon if there should be two of them on the train in question. The head guard of each goods train always carries in his break-van twelve of the weights before mentioned, one to be attached to every wagon, and he takes them off as the wagons are left at the stations, in order that he may always have these weights with him. Ten spare weights are also invariably kept at Curepipe for use in case of emergency. To expedite the sugar traffic in the crop season, it is found necessary to carry three or four goods wagons with most of the passenger trains, the carriages of which are worked with the continuous break, but in this case, also, a weight is attached to every goods wagon, and the wagons are always placed in front of the carriages. The only instance on record of a goods train getting for a time beyond control occurred on 10th September, 1867. At Curepipe six loaded wagons were attached to a 37-ton engine. The breaks of all the wagons were then tightened up as usual, and the ordinary weights applied, but control of the train was lost between Curepipe and Phœnix, though, on reversing the engine, the train was stopped at the latter station. Two more loaded wagons were then added, and two more at Quatre Bornes Station, making ten wagons and the van, or 110 tons in all, and after leaving Rose Hill the speed again became excessive, and it was not until the engine had been reversed, that control of the train was re-obtained.

The idea of placing Safety Sidings at the foot of the steepest inclines, near Petite Rivière and Vacoa, into which could be turned trains which may get beyond control, has long been in contemplation, but the ground is by no means favourable for the purpose, and from the difficulty of working them efficiently, it is feared that they may become a source of danger rather than of safety.

The electric telegraph, double needle system, is in use on this railway, and the trains are regularly signalled by it, but the telegraph lads have not yet had sufficient experience to be thoroughly reliable, and as notice to the switchman at these points must be sent by telegraph, it would require (although a simple system of signals could be adopted) a class of men very difficult to find in Mauritius.

The following rules are in force respecting vehicles which may get away from a station, or may break loose from a train, through the snapping of the couplings when ascending an incline.

First. That on a vehicle passing any station, the station-master is to telegraph immediately to the nearest station whither the vehicle is proceeding, stating whether there be human beings in the vehicle or not. In the latter case the wording for simplicity is as follows:—

$$\text{Runaway} \begin{Bmatrix} \text{vehicle} \\ \text{or} \\ \text{train} \end{Bmatrix} \text{upset.}$$

Secondly. The station-master receiving this telegram is then to take immediate steps to throw the runaway off the line, by holding the nearest switch-points half open, or by the most available means.

Thirdly. If there be human life in the vehicle or train, or if the first station-master be not certain that there are no human beings in it, he is to telegraph to the nearest station as follows:—

$$\text{Runaway} \begin{Bmatrix} \text{vehicle} \\ \text{or} \\ \text{train} \end{Bmatrix} \text{life.}$$

Fourthly. In this case the instructions to throw the vehicle or train off do not apply, but it is left to the station-master receiving the latter telegram, to act to the best of his judgment under existing circumstances, the first consideration being the preservation of human life.

The following Mauritian woods have been tried for break-blocks: Tatamaca, Calophane, Bois de Natte, and Bois de Pomme; of these Calophane has been found to answer the best. The average duration and cost of a set of break-blocks are as follows:—

	Duration.	Cost per Set.
Continuous break-blocks, four on each carriage . .	21 days .	9*s.*
Ordinary break-van, with four blocks	30 ,, .	7*s.*
Ordinary goods wagon, with two blocks	26 ,, .	3*s.* 6*d.*

All these break-blocks have three holes, each $\frac{3}{4}$ inch in diameter, drilled into the face, for a depth of about 3 inches, and these holes are filled with lead for the sake of increasing the grip upon the tyre, and of preventing the block from firing.

Owing to the short length of flat gradients upon which the stations are placed, the working of the sidings is rendered very inconvenient. So much is this the case at Beau Bassin, that trains are never allowed to pass there, from the fear of a collision if the train in descending from Rose Hill should get beyond control. Union Vale Station is also objectionable; and at all the stations great care has to be exercised with wagons left in the sidings. To prevent wagons from breaking loose, a heavy stop-block, say 12 inches square, passes over both rails of each goods siding previous to its junction with the main line, and these blocks are always kept strictly locked, except when the goods trains are actually passing through them. The rules especially provide, that no wagon is to be moved by hand, either on the main line, or on the through siding, nor beyond the limits of the stop-block, and that no wagon shall be uncoupled from the engine until brought to a dead stand within the stop-blocks. This latter rule, though somewhat relaxed in practice, has been fairly maintained, and only one instance of a wagon running away has yet occurred, and that through the carelessness of the station-master. In general a man is placed to shut the stop-block the moment the wagons have passed through it. As a principle, it is held essential to reduce the number of points on the main line to a minimum, and therefore the goods sidings always branch off from the through siding, and not from the main line itself.

It is impossible to give a fair statement of the traffic returns, on account of the exceptional circumstances under which the line is still working. For the first year's traffic the passenger receipts for 1866 may be taken as a fair commencement, and they are now steadily, though not rapidly, increasing, notwithstanding that the short sugar crops for four years, 1864—67, had seriously affected the prosperity of the colony, and have naturally diminished the amount of passengers, as well as of goods, which would otherwise have been carried. The unusual drought which since 1862 has prevailed in Mauritius has caused a most serious diminution of the sugar crop: the crop for the season 1862-63, which reached 158,161 tons, having fallen off to 108,237 tons in the season 1866-67. Owing also to the want of sufficient locomotives, and to the unusual wear of the iron tyres of the driving-wheels, which, through a defect in the manufacture, required to be two or three times 'turned up' after running on the average only 4,128 miles between each turning, the amount of goods conveyed during 1866 affords no criterion of the capabilities of the line. From February to July inclusive of the year 1867 the colony suffered from an epidemic fever, unparalleled in violence, the number of deaths having been 34,233 out of a population of 341,165, or more than 10 per cent. During the month of April, out of a population of 75,000, the mortality of Port Louis averaged 207 per day, a rate sufficient to have exhausted the population of the town in one year, and, including the mortality in other districts, to have swept off the entire population of the colony in two years and nine months. Many whole families were carried off, leaving none remaining, business of every description was almost wholly suspended, and the revenue of the colony decreased by one half, the loss being about £1,000 per day.

Although it is but natural that the passenger traffic during the first six months of the year 1867 should have considerably decreased, as compared with the corresponding period of 1866, still the traffic for the whole of 1867 will compare favourably with that of 1866.

The following are the figures in each case:—

——	1866.	1867.	Increase.	Decrease.
Number of Passengers	519,524	430,052	..	89,472
	£	£	£	£
Passenger Receipts	31,979	30,225	..	1,754
Parcel Receipts	546	797	251	..
Telegraph Receipts	..	43	43	..
Miscellaneous Receipts	11	102	91	..
Suspense Traffic	173	..	..	173
	tons.	tons.	tons.	tons.
Goods, Number of Tons	18,047	31,998	13,941	..
	£	£	£	£
Goods Receipts	7,675	14,272	6,597	..
Total Revenue	40,384	45,439	5,055	..
Total Expenses	25,319	30,856	5,537	..
Profit for the Year	15,065	14,583	..	482

The passenger rates are as follows:—

First class	.	4*d.* per mile.
Second „	.	$2\frac{1}{2}$*d.* „
Third „	.	1*d.* „

Return tickets for the first and second class being 50 per cent. more than the fare for a single journey.

The rates for goods vary according to the usual classification, but for sugar, provisions, and manure, which form fully three-fourths of the whole tonnage, the charges, including terminals, are as follows:—Sugar and provisions from Mahebourg to Port Louis, 35 miles, or *vice versâ*, 10*s.* per ton, equal to 3·42*d.* per ton per mile. Sugar and provisions from Rose Belle to Port Louis, 24 miles, or *vice versâ*, 9*s.* 2*d.* per ton, equal to 2·60*d.* per ton per mile. The rates for these articles from stations intermediate between Rose Belle and Port Louis are about $5\frac{1}{2}$*d.* per ton per mile. The charge for manure from Port Louis to Mahebourg is 7*s.* 6*d.* per ton, equal to 2·60*d.* per ton per mile.

The short distance of this railway (single line) tells of course greatly against the receipts, and, from the severe character of the gradients, it has never been deemed prudent to run trains by night.

During the year 1866 the locomotive cost per engine mile run was unexceptionally high. The price of fuel then averaged 41*s*. 5*d*. per ton, or, including delivery and stacking, 44*s*. 5*d*. Again, the iron tyres of the side-tank engines wore so rapidly, and the number of locomotives for the work was so small, that a considerable additional expense was incurred beyond their fair repairs. These disadvantages have now been remedied, and the locomotive cost per engine mile run is at present as follows:—

	d.	*d.*
Cost of fuel per mile		10·90
„ oil, tallow, and waste		1·20
„ materials for repairs of engines	2·08	
„ „ „ carriages and wagons	1·84	
		3·92
Salaries of superintendent, drivers, firemen, and cleaners		6·19
„ mechanics repairing engines	2·57	
„ „ „ carriages and wagons	1·40	3·97
Total per mile run		26·18

The consumption of fuel per mile run is . . . . 49·7 lbs.

As these expenses are still double the cost at home, it is necessary to make a few remarks respecting the value of the skilled labour and the supplies obtained from England. The engine-drivers, carriage foreman, and platelayers were all engaged in England to serve in Mauritius for three years certain, it being optional with the Government to extend the agreement to five years, on giving notice to that effect six months prior to the expiration of the former period. The salary of the engine-drivers is for the first year £192, for the second year £216, and for the third year £240. Sunday work is paid for in addition at the ordinary rate, and the drivers have also the use of free quarters. The salary of the carriage foreman was £300 per annum, but this office is now filled satisfactorily by a Mauritian at about £150 per annum. The platelayers receive £150 per annum, with a bonus of £25 per annum on receiving a certificate of good conduct; and they also enjoy free quarters, though this advantage is neither in their agreements nor in those of the drivers. The Government provide free passage for all these men from England to Mauritius and back (except in case of misconduct), the expenses thus incurred being about £130 per man. As yet no attempt has been made to train engine-drivers in Mauritius, it being difficult to find men having sufficient nerve and intelligence, although it is hoped that some of the lads now training in the shops may eventually become drivers.

All other skilled labour is found in Mauritius. The Creole carpenters, masons, blacksmiths, and fitters are fair workmen, though slow and not over industrious. Comparing their wages and amount of work done with the value of similar labour in England, the cost in Mauritius is from 10 to 15 per cent. more than at home.

The maintenance of the permanent way is under the charge of English platelayers, whose districts average 12 miles each, and who superintend the Coolie labour. Every day, wet or dry, Sunday inclusive, each district is minutely inspected on foot by a reliable Indian, who carries a keying hammer; and this man is frequently accompanied by another Indian carrying a spanner. In addition to the ordinary platelayers' rules, special instructions have been given respecting repairs on the Midland line. After a little practice the Indians work well at packing the sleepers, and keep the road in very good condition. The number of Coolies required averages four per mile, and their usual wages are £10 per annum, plus rations, the ordinary value of which is £5. 10*s*. per annum. The cost of all salaries and labour employed in maintaining the road, but without any renewals worth mentioning, none of which have as yet been required, has been as follows:—

	Per Mile per Annum. £.	s.	d.
Salaries of Engineer, Inspector, and Office expenses	20	0	0
Wages of platelayer	14	12	0
Coolies, four at £15. 10*s*. each	62	0	0
Tools, about	3	8	0
	£100	0	0

During the years 1864 and 1865 contracts were made in England for the supply of fully 6,000 tons of Newcastle and Welsh coal, to be delivered in Mauritius at prices ranging from 34*s*. to 49*s*. 10*d*. per ton, and in consequence of freight being then unusually high this coal averaged 41*s*. 5*d*. per ton. Latterly Australian coal, from Newcastle, Wallsend, and Warattah mines, Sydney, has been found very satisfactory, and equal to any English coal imported; so much so that it will be chiefly used in future. The cost of this coal, delivered in Port Louis harbour, is usually 32*s*. to 40*s*. per ton. The cocoa-nut oil manufactured in the colony, and used for the locomotives, and for all machinery, answers well. The ordinary price is 3*s*. 4*d*. per gallon. Tallow is obtained from Australia at 7*d*. per lb., and carriage grease is made by the Department at a cost of about 70*s*. per cwt. With these exceptions the usual stores are chiefly obtained from England, the price of ironmongery and of most articles being fully double their cost at home, and often more. The cost of freight, packing, and insurance on articles received from England, adds nearly 14 per cent. to their original value when delivered in the colony.

Considering, therefore, the high price paid for skilled labour and for fuel, the agricultural character of the district through which the railway passes, the severity of the gradients, the want of anything that can be called a town save at Port Louis, the lack of minerals or manufactures to transport, the peculiar nature of the sugar traffic—requiring a large amount of rolling stock for three months in the year, whereas for the remaining nine months less than half that quantity would suffice—under all these unusual circumstances it is not surprising that the working expenses of the Midland line should, in 1866, have been $62\frac{1}{2}$ per cent. of the receipts, or 5*s*. 5*d*. per train mile.

Fortunately some of these exceptional circumstances have now ceased to exist. The arrival of the 48-ton engines has enabled a larger amount of sugar to be carried; and when the goods traffic becomes further developed, a considerable decrease in the per-centage of working expenses to the receipts will naturally ensue, accompanied also, it is hoped, by a reduction in the cost per train mile.

It may be, of course, sometimes impossible to construct a railway with easier gradients than those on the Midland line; but the difficulty of working these inclines in wet weather has been so great, the load hauled so small, and the speed so low, that the Author thinks the severity of any gradient for a long rise should never exceed 1 in 40; and that it will always be preferable (under the ordinary system of tractive power) to incur, within reasonable limits, any additional expense that may be requisite to bring the inclination within this ratio. It is also suggested that in laying out such inclines, whatever may be the ruling gradient (provided it be not entirely exceptional, and where additional power can be applied) that this gradient be then followed throughout the line, as far as the features of the country will permit; pieces of level being introduced between the different inclinations, as, on descending, these level portions are found of the greatest value in controlling the train. The Author believes it to be safer to work steeper gradients, provided there be pieces of level between the different inclinations, than to work a uniform gradient, extending both over the former inclines, and over the level portions, the ratio of all these inclinations being of course within reasonable limits, or say not steeper than 1 in 40.

The Appendix contains a summary of the gradients and curves (Nos. 1 and 2), the details of the locomotive engines (No. 3), and schedule of the rolling stock (No. 4). Attached to the original Paper, which may be consulted at the Institution, will be found a copy of the "Working Time-table, 1st August, 1867;" return of the imports and exports in Mauritius from 1860 to 1866 inclusive; statement, showing the population, revenue, and expenditure of the island, and the immigration returns between the same dates; a memorandum of the steam machinery, and of the value of labour and materials in the island; and meteorological observations taken at Port Louis in the year 1865. These have been chiefly extracted from Blue Books.

The communication is also accompanied by Maps of Mauritius and of Port Louis, showing both lines of railway, and by a section of the Midland line, from which Plate 12 has been compiled.

[APPENDICES.

APPENDICES.

No. 1.

MIDLAND LINE.

SUMMARY of GRADIENTS RISING from PORT LOUIS to MAHEBOURG.

Ratio.	Length in Feet.	Rise in Feet.
1 in 27	13,526	499·27
1 in 30	9,526	317·85
1 in 34	2,100	61·76
From $\frac{1}{36}$ to $\frac{1}{40}$	4,800	128·23
1 in 40	11,460	286·50
$\frac{1}{40}$ to $\frac{1}{50}$	9,050	195·25
$\frac{1}{50}$ to $\frac{1}{60}$	6,900	133·37
	57,362	1622·23
$\frac{1}{60}$ to $\frac{1}{70}$	2,172	32·50
$\frac{1}{70}$ to $\frac{1}{80}$	4,700	62·69
$\frac{1}{80}$ to $\frac{1}{90}$	3,220	37·82
$\frac{1}{90}$ to $\frac{1}{100}$	350	3·89
1 in 100	1,000	10·00
$\frac{1}{100}$ to $\frac{1}{200}$	7,466	58·56
Over $\frac{1}{200}$	7,180	19·40
Total feet rising	83,450	1847·09

SUMMARY of GRADIENTS FALLING from PORT LOUIS to MAHEBOURG.

Ratio.	Length in Feet.	Fall in Feet.
1 in 30	7,510	250·29
1 in 31	5,340	170·24
1 in 32	5,900	184·37
1 in 34	3,514	102·64
1 in 35	1,400	40·00
1 in 36	3,800	105·32
$\frac{1}{36}$ to $\frac{1}{40}$	3,300	86·20
1 in 40	8,967	224·17
$\frac{1}{40}$ to $\frac{1}{50}$	11,974	276·86
$\frac{1}{50}$ to $\frac{1}{60}$	6,100	116·43
	57,805	1556·52
$\frac{1}{60}$ to $\frac{1}{70}$	11,400	183·93
$\frac{1}{80}$ to $\frac{1}{90}$	2,050	25·35
1 in 100	2,900	29·00
$\frac{1}{100}$ to $\frac{1}{200}$	4,400	33·04
Over $\frac{1}{200}$	6,864	19·75
Total feet falling	85,419	1847·59

Total level 17,033 feet.

No. 2.

MIDLAND LINE.

Summary of Curves.

Radius in Feet.	Length of Curve in Feet.	Feet.
950	1,200	
1,300	1,100	
1,400	3,330	
1,500	1,600	
1,600	3,690	
1,750	750	
1,800	5,260	
1,900	2,485	
1,930	1,000	
1,950	750	
Total length under 2,000 feet radius .		21,165
2,000	20,050	
2,200	600	
2,250	390	
2,300	400	
2,400	7,500	
2,500	550	
2,700	830	
2,800	780	
2,930	2,060	
3,000	3,200	
3,070	600	
3,200	8,010	
3,260	1,740	
3,400	700	
3,600	2,300	
Total between 2,000 and 4,000 feet .		49,710
4,000	11,890	
4,265	2,000	
4,700	250	
5,000	5,730	
5,600	600	
6,000	5,090	
Total above 4,000 feet .		25,560
Straight . .	.. ..	89,467
Total length .	.. ..	185,902

No. 3.

MAURITIUS RAILWAYS.

Principal Dimensions of Tank Engines on Midland Line.

Class of Engine.	Number of each Class.	Wheels. Diameter.	Wheels. Number (all coupled).	Cylinders. Diameter.	Cylinders. Length of Stroke.	Tubes. Number.	Tubes. Length.	Tubes. Diameter (outside).	Heating surface, Square Feet. Tubes.	Heating surface, Square Feet. Firebox.	Heating surface, Square Feet. Total.
		' "		in.	in.		' "	in.			
Side Tanks	7	3·6	6	16	22	166	10·6	2	919	82¼	1,001
Saddle Tanks	6	4·0	8	18	24	159	13·6	2	1,122	90·7	1,213

Class of Engine.	Grate Area, square feet.	Blast-pipe. Diameter (inches).	Blast-pipe. Area (square inches).	Wheel base. Front to Middle.	Wheel base. Middle to Trailing.	Wheel base. Total.	Capacity of Tank, gallons.	Weight in working order in Tons and Cwts. Leading.	Weight in working order in Tons and Cwts. Driving.	Weight in working order in Tons and Cwts. Trailing.	Weight in working order in Tons and Cwts. Total.
	' "	in.		' "	' "	' "					
Side Tanks	15·8	4¼	15·9	7·0	8·0	15·0	1,200	11,1	12,14	13,3	36,18
Saddle Tanks	18·0	4¾	17·7	To 2nd leading. 4·3 6·1½	5 1½	15·6	1,500	12,3 11,17	12,11	11,2	47,16

Class of Engine.	Ratios. Tubes to Firebox.	Ratios. Heating surface to Grate.	Ratios. Fire-grate to Blast-pipe.	Capacity of Cylinder in cube feet per mile.	Heating surface to Cylinder, capacity per mile. Square feet H. S. to cube feet Cylinder capacity.	Weight on each Wheel in per centages. Leading.	Weight on each Wheel in per centages. Driving.	Weight on each Wheel in per centages. Trailing.	Weight to heating surface, Cwts. per Square Foot.	Tractive force. At 60 lbs. mean effective pressure.	Tractive force. To adhesive Weight.	Weight in Cwts. to cube foot of Cylinder capacity per mile.
										lbs.		
Side Tanks	11·13	63·3	143	4,917	0·203	30	34·4	35·6	0·737	8,046	·097	0·1501
Saddle Tanks	12·37	67·4	146	5,940	0·204	25·4 24·8	26·5	23·3	0·788	9,720	·090	0·1609

(Signed) Walter H. Scott,
Locomotive Superintendent.

No. 4.

MAURITIUS RAILWAYS.

Schedule of Rolling Stock.

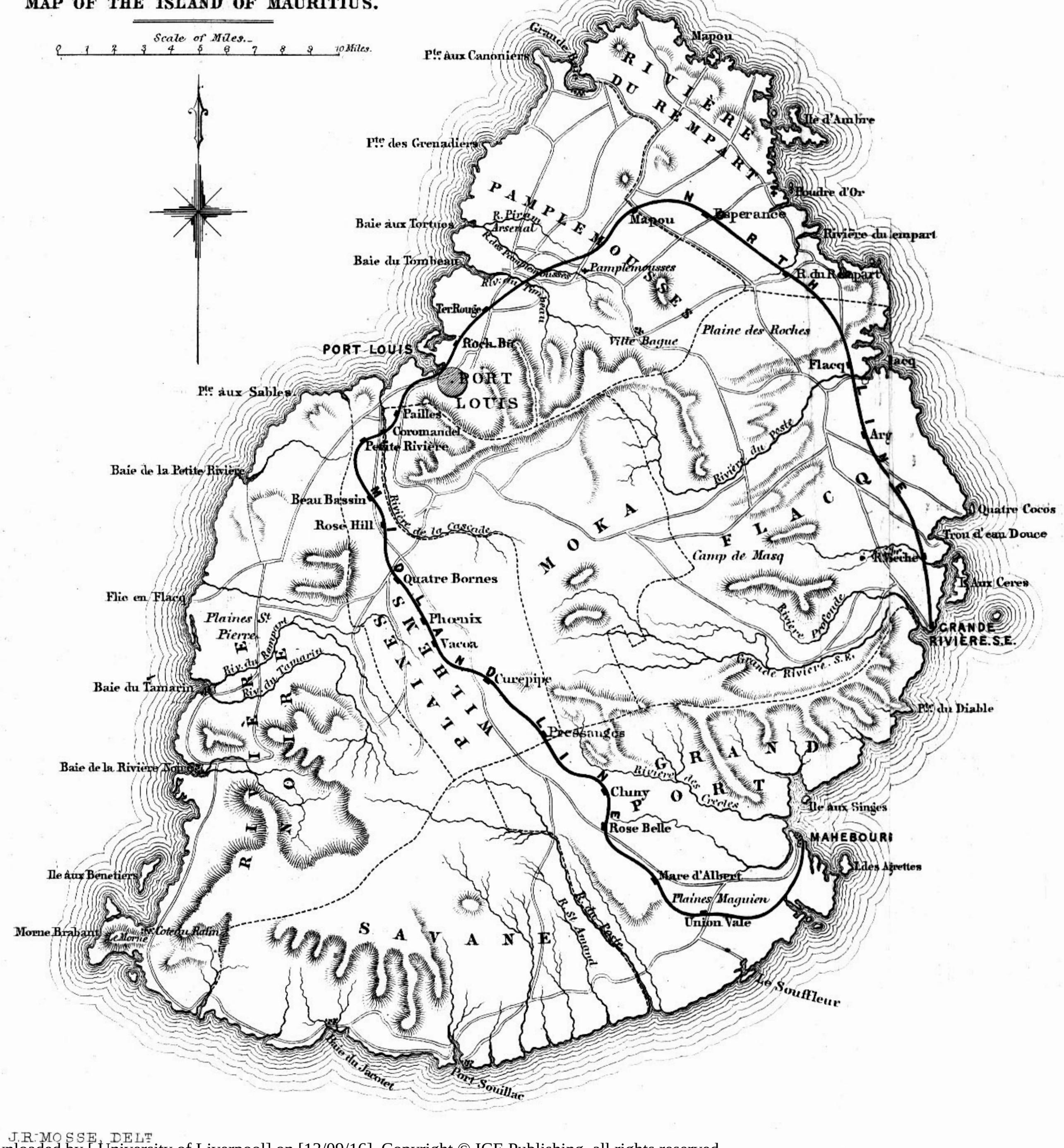
				Total.
North Line.				
Passenger Locomotives	4			
Goods ditto	4			
		8		
Midland Line.				
37 ton ditto	7			
48 ton ditto	6			
		13		
				21
Carriages.				
First class	12			
Composite	11			
Second class	11			
Third ditto	60			
				94
Horse boxes				6
Carriage trucks				4
Break Vans.				
Passenger trains	6			
Goods ditto	14			
				20
Goods Wagons.				
Covered	62			
High sided	110			
Low sided	16			
Ditto for timber	8			
		196		
Ballast wagons		28		
Coal ditto		6		
Total Wagons				230

[Mr. Hemans

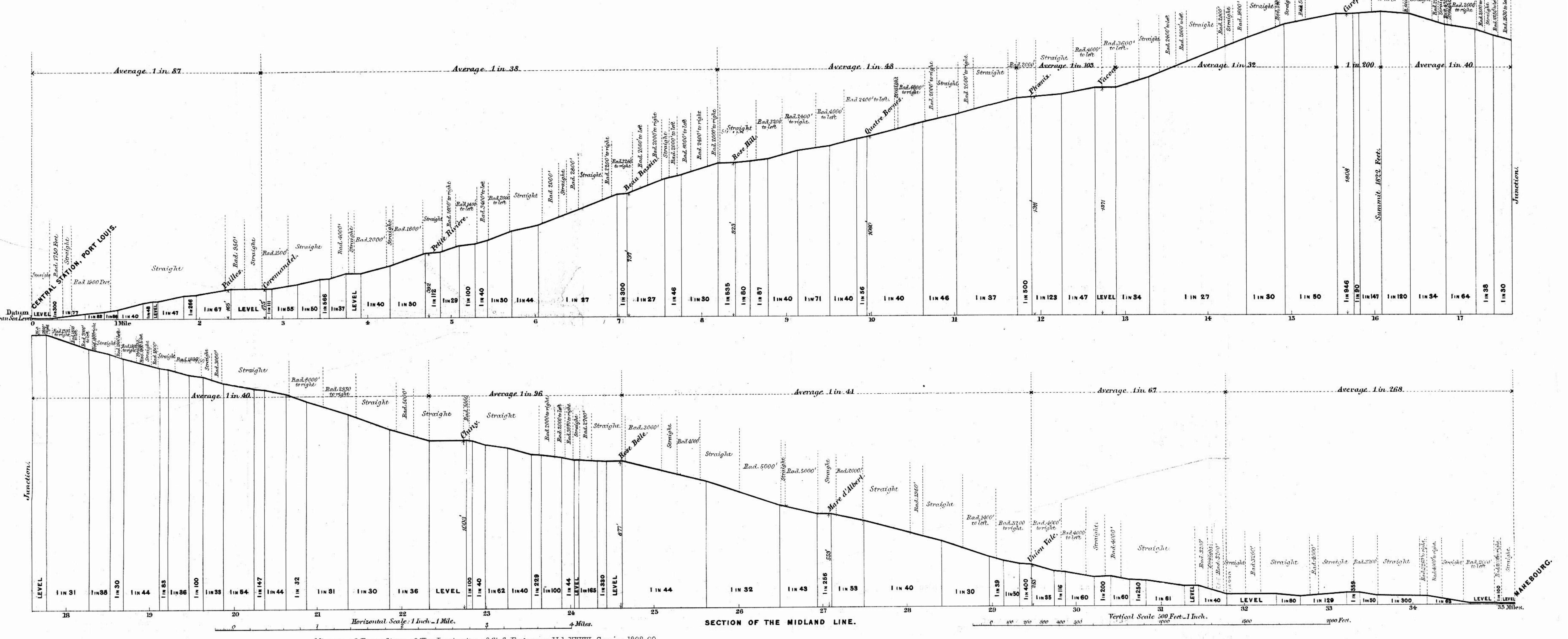
THE MAURITIUS RAILWAYS.

PLATE

MAP OF THE ISLAND OF MAURITIUS.



J.R. MOSSE, DELT



SECTION OF THE MIDLAND LINE.