Mr. CHARLES DOUGLAS FOX said, since the Paper was written, a few facts had come to his knowledge, resulting from the system which he advocated having been at work six months longer. The system he was there to support was, that a railway should be made proportionate to the traffic which was to be carried upon it; and in order so to proportion the railway for a light traffic, it should be constructed in such a manner as to carry safely, at a speed of from 15 to 25 miles per hour, a rolling load, in no case exceeding 3 tons on each wheel. Light railways were often heard of; but many were unsuccessful, because they were not only light, but inefficient. He held, that if this system was to be efficient, it must not be started on a false principle; but by constructing the lines in a thoroughly substantial manner, so that they might be worked at a low rate. Therefore, the lines he had alluded to were constructed in the best manner, equal in all their details to the best English railways; but every part was so proportioned, as to be suitable to rolling loads represented by a weight of 3 tons only on a wheel. In laying out the Southern and Western Railway of Queensland, it became necessary to adopt unusually sharp curves and rather severe gradients, and, with the object of overcoming these difficulties, the gauge was reduced to 3 feet 6 inches, so as to allow of the use of curves of 5 chains radius; and in the selection of the rolling stock, all had been done as far as possible to avoid the evils resulting from such sharp radii. Several ingenious plans had been adopted for avoiding those difficulties, but the one to which the chief trial had been given was Adams's radial axle system. That had been applied to carriages with six wheels, the centre wheels being fixed in the ordinary way between horn plates. The traffic manager of the West Hartlepool Railway had found it answer admirably. At first it appeared necessary to have four wheels in the centre of the carriage to steady it, but experiment proved it was not so; and even when a carriage was at the end of the train, there was no unusual swaying movement. He was informed that the trains never ran more smoothly than when fitted with the radial axle boxes, and that there was a large decrease in the tractive force necessary. Experiments were also being made with wheels loose on the axle. That plan had been tried by the late Mr. Brunel, although he believed it did not meet with success; but it would be a great desideratum in this case for the four-wheel carriages, if it could be brought into practical working. It would be seen that a long bearing of 12 inches had been provided, the wheel being 24 inches in diameter, with provision for tightening up the bearings and for thorough lubrication. As materially affecting the question of cost, he directed attention to two specimens of permanent way,—one composed of rails weighing 84 lbs. to the yard, for engines having a load of

7 tons on a wheel, the other, a sample of the rails laid on the Queensland line of 40 lbs. to the yard, suited for a weight of 3 tons on a wheel—the one being adapted for heavy engines and a speed of 40 or 50 miles an hour, and the other equally well adapted to light engines and a speed of 20 or 25 miles an hour. If the railway system was to be extended, not merely to the highways but to the byways of traffic, it would be necessary to find out some means of reducing the cost of construction. The lines in England had cost from £29,000 to £33,000 per mile; those in France about £27,000 per mile. The railways in Ireland had cost about £15,000 per mile, and those in India about the same. It was difficult to make a satisfactory comparison, because some were double lines and others single lines, and in many cases the prices of land varied considerably; but in Queensland, where the rates of wages were excessively high, the average cost of the line, as had been stated in the Paper, was only £8,600 per mile. The Norwegian lines had cost about £6,000 per mile, through the more difficult country, and over the ordinary country, only £3,000. The line constructed by the Indian Tramway Company had been made at an average cost of £3,200, or, including rolling stock for a large traffic, £3,900 per mile, the land being provided by the Government, and the earthworks being generally very light. He wished to add that he was not here speaking of lines in any way inefficient. He believed these lines were as well constructed as any that could be found. The heavy bridges on the Queensland line were constructed of iron, as also the stations, the latter, which were thoroughly substantial, being covered with corrugated zinc. The station buildings were first temporarily erected in England, then taken down and the parts marked, so that there might be no difficulty in fitting them when sent out. The reason why that description of station had been hitherto adopted for Queensland, was on account of the great difficulty of getting skilled handicraftsmen. It had, therefore, been thought better to construct an iron station in this country, take it down again and send it out, than to build masonry or brick stations in the colony. Hitherto the working expenses on these lines had not exceeded 45 per cent. The engines weighed about 15 tons each, and the cost per train mile was $8\frac{1}{4}d.$ for fuel, oil, tallow, and wages. The axle-boxes, which were for oil upon Carr's patent, answered admirably, and the consumption of oil for four wheels was 8 gallons per 40,000 miles run, or 2 gallons for each wheel. Light railways had been constructed in America, but had yielded different results, inasmuch as it was a common practice to make the works light, and then run heavy engines over them; and that was not the way to get good results. This question had now become an important one in this country. There were many places in England, Ireland, and Scotland in great need of railways, which could not

bear the cost of an ordinary line; but if they could be made at from £4,000 to £5,000 per mile, including everything, no doubt there would soon be a rapid extension of the railway system. The Board of Trade had been alive to this system; but the difficulty was, how to prevent heavy engines running on the light lines unless there was a break of gauge. This brought him to the question of gauge. He had described three lines, each having a gauge of 3 feet 6 inches, but that was not the principle he advocated, but putting light weights on light rails. The gauge on these lines had been adopted from a variety of adventitious circumstances. The question of gauge was one which must always be determined by the surrounding circumstances. He did not think the cost of railways, through an ordinary country, would be found to depend so much on the gauge as on the way the lines were constructed. This principle was now being largely tried. The Queensland Government would probably spend two millions and a half on railways within a few years, and it was already constructing 250 miles. The Norwegian Government had completed about 60 miles, and was carrying on further works, whilst the Indian Tramway Company had about 20 miles in working order with satisfactory results; and he had been surprised at the intelligence received from the resident Engineer, that trains had been run at the rate of 40 miles an hour, including stoppages, which, with driving-wheels of only 3 feet diameter, must be regarded as a very high speed.

Mr. G. W. Hemans said, it seemed at the first view that the reduction of the gauge of a railway from 4 feet $8\frac{1}{2}$ inches, to 3 feet 6 inches, being only a difference of $14\frac{1}{2}$ inches, could not possibly result in such an enormous saving as that which had been mentioned. It was stated that an efficient railway could be made complete, and doing all the work as well as a more costly one, for £3,000 per mile, including stations and rolling stock. That no doubt was a solitary instance, but other facts were given which brought out the cost of these narrow-gauge light railways, constructed under the most formidable difficulties, only as high as £12,500 per mile, with long viaducts of great height and heavy works of all kinds. The present period might be regarded as peculiarly the time for railway Engineers to reform their operations, looking at the existing want of confidence on the part of the public in railways as a paying investment. In reference to these cheap lines, it was true the alteration which had brought about such remarkable results was not confined solely to the alteration of the gauge, and no one could doubt that an important step had been taken in the direction of getting locomotive engines which would produce all the results required, without the enormous and ruinous weights upon the driving-wheels, which were now destroying the permanent way of many railways. There had been many discussions on permanent way, steel rails, &c., but the permanent way in point of form was almost what it was twenty years ago; the only great improvements were the fishing of the joints of the rails, the strengthening of the permanent way by adding to the weight and dimensions of every part, and the introduction of steel rails. But this had been done at a cost which produced absence of dividends. In this country only three or four important lines were paying good dividends. Some improvement must be introduced if the public were ever again to bear a fair share in railway speculation. If railway enterprise ceased, the country must suffer; if they could not put guarantees upon the counties and baronies to support the railway system, then there must be found means to produce renewed confidence. In the days of the stage-coach traffic, the weight of passengers, &c., carried was considerably greater than that of the vehicle, whilst in the case of railways the weight of the vehicles was four or five times greater than that of the loads carried. Therefore the suggestions made in this Paper, as to the improvement of engines and rolling stock, were very important. Ever since he had heard of light railways he had been endeavouring to ascertain how to reduce the weight upon the wheels of the engine, and the wear and tear of the permanent way, by the use of lighter rolling stock with steel frames, and by the introduction of bogie frames to diminish the friction on curves; and he had considered whether such light railways as those of Queensland could not be introduced into districts which would not repay the cost of the construction of railways on the ordinary system in use in this country. But he was anxious to hear the views of other Engineers, as he had not in his own conclusions arrived at any means of adopting the light railway system, except in so far as the reducing of the weight of the locomotive and the rolling stock. If a light railway of the usual gauge was adopted, with a road and bridges of strength sufficient to carry only 3 tons on each of the wheels, instead of 6 or 8 tons, what was to insure that, under peculiar pressure of the traffic, the heavy locomotives and existing heavy rolling stock would not be run upon the light railway and destroy it. A light railway of the usual gauge in connection with any other system, would always be open to the incursions of the heavy rolling stock, and for that reason break of gauge must be contemplated if the light railway be used. By employing a 3 feet 6 inches gauge, smaller tunnels, lighter cuttings, and lighter bridges sufficed; very little ballast was required, and altogether the cost of construction was greatly diminished. If a break of gauge were determined upon, a considerable saving in construction would be effected, which might give the proprietors a dividend, where otherwise there would be none; but it must not be forgotten that there were serious objections to a break of gauge, and often those objections were insuperable. He thought the question was one of the deepest importance; but as far as he was personally concerned, he had only in one instance been able conscientiously to recommend the adoption of this new system, and that was in the Isle of Man, where there could not possibly be any communication with other lines. Under such conditions he should be induced to try this system, by which a probable saving of £20,000 in ten miles of line might be effected. But, unless the circumstances of a country were such as to make it worth while to construct an isolated railway that would not carry the stock of the main lines, he thought it would be impossible to follow the suggestions in the Paper, except in the important particular that endeavours should be made as much as possible to diminish the enormous and ruinous weight of the present locomotive engine. As far as he could judge, this had been judiciously done on the Queensland Railway, and he thought the attention of railway engineers should be directed to the consideration of such engines as Mr. Fairlie's, or the inventions of Mr. Adams, by which additional adhesion was obtained by moveable wheels, and by that means reduce the enormous destruction of permanent way now going on from the action of the heavy locomotives.

Mr. G. B. Bruce could not quite agree in the presumed necessity for introducing these light railways into England. His own impression was, that there was really very little difference in the cost between making a line which would carry moderately heavy rolling stock and making a line to carry very light stock. The over bridges would be the same, but the under bridges might perhaps be a little lighter, and to that extent there would be a saving. The permanent way again would be lighter, and that would save something; but when it came to the question of stations, nothing really was saved, because whatever might be the gauge of the railway, the stations must be in accordance with the traffic which had to be carried; and if a comparison were made between two railways, and it was said the stations relatively only cost so much, it conveyed no definite impression to the mind, because the number and extent of the stations depended upon the traffic to be accommodated, which might be very different in the two cases. The other elements in the case, such as land, signals, and all the apparatus connected with a railway must be the same, and he believed the same would apply to the rolling stock, viz., that it would cost more or less in proportion to the number of tons to be carried and the number of passengers to be conveyed, whether the stock was light or heavy. Therefore in all that constituted the capital of the line, he thought the saving was little or nothing when the amount of passengers and goods which had to be carried were taken into consideration. With regard to the adoption of a narrower gauge, the question had been in a great measure answered by Mr. Fox, who said he did not insist upon that gauge, but it was rather dependent on the amount of load brought upon the permanent way. He could not help thinking the Author was reverting to the weights of engines and carriages used twenty-five years ago rather than suggesting anything new; and so also with respect to the specimen rails exhibited; one was the 84 lb. rail of to-day, and the other the 40 lb. rail of twenty-five or thirty years ago. The question was rather one for the traffic-manager—how loads might be conveyed most economically so as to produce the best dividends. It would require a good deal of evidence to show that goods and passengers could be carried as cheaply with a small engine as with a large one. And when a little more iron was put into the permanent way, there was no doubt but that goods and passengers would be carried at less cost than on the lighter road. The saving in the cost of bridges he did not think would be much, even if the bridges were made to carry only $\frac{3}{4}$ of a ton to the foot instead of $1\frac{1}{2}$ ton as required by the Board of Trade. True, the top and bottom members of the girders would be lighter; but the additional amount of iron required to enable the bridges to bear heavier engines was so small, that he considered it would be bad economy to make bridges so as just to carry the light engines and no more. The only novelty with regard to the locomotive was in the employment of the Fairlie engine, in which there were virtually two engines fastened together and working as one engine. He said nothing about the merits of that, excepting that it had the advantage of saving a driver. Ordinarily, when two engines were worked together a driver and fireman were required for each engine; but in this case one set of men worked in the middle. He had no doubt that plan was a good one for steep inclines, and where the engine could be kept at this duty alone; but at the same time it was a good thing, in the majority of cases, to be able to separate the engines and work the two separately, and he doubted whether that engine was applicable except for working up steep inclines in special localities. He thought the idea of introducing a narrower gauge than 4 feet $8\frac{1}{2}$ inches was a mistake. There would be little saving in cost of construction, and little or nothing in rolling stock, because the engines might be just as light as the engines on the 3 feet 6 inches gauge if desired; therefore he thought it would be well to hesitate before introducing the system elsewhere.

Mr. Blair submitted that the expense and construction of a first-class railway, with a single line of way, had been greatly overstated. Mr. Fox had represented that the cost of English railways had been about £30,000 a mile, and, by way of comparison, represented the colonial railway referred to in the Paper as costing only one-fifth of that sum, or thereabouts. Now, under ordinary circumstances, for lines executed through poor districts, such as the north-west of Ireland and parts of Scotland, £6,000 per mile had been found ample for every expense of construction, including commodious stations, extensive sidings, complete signals, and suitable appliances for the traffic being conducted in an economical manner. As an instance of this, he mentioned the Great Northern and Western (of Ireland) Railway of about 85 miles in length, the cost of which, including every preliminary and executive expense, had been only £6,000 a mile. That railway had superior fencing, numerous road-bridges, and other works that in a new country might be dispensed with.

Mr. EDWARD WOODS thought the Author was right in principle, and it was satisfactory to find, that the system had been worked out on so large a scale, with such economical results. It had been his own lot to adopt the converse of that principle, not so much to originate the construction of light railways as to adapt rolling stock to that class of railways. He had, in fact, for many years past adopted the principle Mr. Fox had enunciated, viz., that of fixing a limit to the weight to be placed upon the driving-wheels of the engine, such limit having reference to the light rails in use. The first case Mr. Woods had to deal with was a line of the ordinary English gauge, the Copiapo Extension Railway, originally intended for horse traffic, but for which that mode of propulsion was found to be inapplicable. He had to design a locomotive to run without injuring the rails, which weighed 42 lbs. to the yard. Locomotives of 32 tons weight had worked upon that line for six years, and the road was now in as good order, with regard to the rails, as it was after the first six months' working: but though the engines were of 32 tons weight, the weight was subdivided, so that not more than from seven to eight tons rested on each pair of wheels. In the case of two other railways in Chili, he had to deal with the rolling stock in the same way. He exhibited a photograph of an engine of a class which he was sending out to that country for the Tongoi Railway, a line of about 40 miles in length, with curves of 187 feet radius, gradients of 1 in 19 for four or five miles, and a gauge of 3 feet 6 inches. The gauge of the other line, the Carrizal Railway, was 4 feet 2 inches, and the same class of engine was working satisfactorily upon it. That engine weighed only 15 tons, with six wheels, each 30 inches diameter, and all coupled, having inside cylinders 12 inches in diameter, with a length of stroke of 17 inches. To adapt it to the sharp curves on the line, the leading and trailing axles were fitted with the translation system of Caillet, which worked very satisfactorily. In the first case named, that of the Copiapo Extension, he had adopted the "bogie" system, but there was in it the disadvantage that the adhesion of the bogie wheels was not available for traction. With regard to the engines of Mr. Fairlie, they were virtually a couple of engines combined. He agreed with Mr. Bruce in preferring two uncombined engines, working together if need be. He thought, where there were steep gradients to deal with, it was not an advantage to have too heavy trains, and such long double engines were inconvenient in the stations, and required large and expensive turntables. They might perhaps be well adapted for special purposes, such as that to which Mr. Fox had applied them. In working steep inclines like those in Chili, accidents sometimes occurred, the chances of which were diminished when the load was divided, and the evil consequences of a casualty were much lessened. With reference to the question of the increasing weight of rolling stock, Mr. Bruce had remarked upon the engines of twenty-five years ago, which were about the weight of those described in the Paper. He remembered the time when, on the Liverpool and Manchester line, an engine of 10 tons was thought a heavy one, and 12 tons very heavy. The rails at that time weighed only 35 lbs. to the yard, and with engines of 12 or 14 tons, those rails stood well enough; but as the traffic increased, engines of greater size and weight were introduced, and the consequence was, the rails were soon destroyed, and the line had to be relaid with rails of 50 lbs. to the yard; but the gradual introduction of larger engines rendered those heavier rails useless, and they were replaced by others weighing 60 lbs. to the yard. The Grand Junction Railway works were at that time commencing, and Mr. Locke adopted a rail of 62 lbs., which was then considered very strong. That answered well with the Grand Junction engines for several years; but the increased weight of those engines eventually rendered the rails unserviceable, and now the rails weighed 80 lbs. to the yard. He thought if the principle advocated by Mr. Fox had been earlier considered and adopted in this country, that to a certain extent much of the cost of altering lines might have been avoided. As an engine of 32 tons was made applicable to 40-lb. rails, so he thought engines of sufficient power to meet the demands of a growing traffic might have been devised for the Liverpool and Manchester, Grand Junction, and other lines, which would have allowed the rails to last double the period they did. It not only affected the question of the permanent way, but also the structures which carried the permanent way. In the year 1844, Mr. Hawkshaw and himself conjointly constructed a viaduct a furlong in length, connecting the Liverpool and Manchester and the Leeds and Manchester railways, at the part which adjoined the Bolton and Manchester line in Salford. That viaduct was constructed of cast-iron columns and girders. Three or four years ago, looking to the greatly-increased weight of the engines of the London and North Western Railway, they came to the conclusion to call the attention of the Directors to the fact, that as that structure had been designed and executed at a time when the engines were 30 or 40 per cent. lighter than they were now, it might be desirable that it should be looked into, and their joint representations resulted in the strengthening of the whole structure. Similar costly alterations of works had been carried out, and were now going on in other parts of England. He had found, whenever the Government inspectors came to pass a railway, that increased strength of rails and fastenings was demanded. What was admissible a year or two ago was not so now, and this had been the tendency for the last ten or fifteen years, and where it would stop he could not tell; but the subject was one that deserved the greatest consideration of all the members of the profession in order that, if possible, some limit might be assigned to this constantly-increasing expense.[1]

Mr. HODGE remarked that, in the early days of railways, he had

---

[1] The following additional information has been handed to the Secretary by Mr. Woods:—

TONGOI RAILWAY, CHILI.

Gauge 3 feet 6 inches.

Including extension of 10¼ miles now being made is 41¼ miles in length.

Forms outlet to the rich copper mines of Tamaya. The extension commences at the foot of a range of hills, and to avoid deep ravines it winds much, and has curves of 187 feet radius. There are from twenty-five to thirty curves of small radius.

The maximum gradient on the extension is 1 in 19, and there are many steep gradients.

Rails.—42 lbs. per yard, in lengths of 18 feet to 20 feet, fish-jointed, flanged, and laid on transverse sleepers of wood.

Wagons.—Platform wagons 7 feet 6 inches by 5 feet 10 inches outside; sides, 13 inches deep, one side falls; wheel centres, 5 feet.

1st Class & 2nd Class Carriages.—16 feet by 6 feet outside; longitudinal seats for twelve passengers.

Engine.—Six-wheeled coupled tank engines. Cylinders (inside) 12 inches by 17 inches; wheels, 30 inches, leading and trailing, fitted with Caillet's translation apparatus; wheel base, 10 feet 9 inches; grate, 2 feet 8 inches by 2 feet 2 inches.

CARRIZAL RAILWAY, CHILI.

Gauge 4 feet 2 inches.

			Feet.
Length of old line	18 miles . .	Rises	734
Do. extension	4½ „ . . .	„	826
	22½ miles.	Total rise	1,560

Average gradient over first 18 miles	1 in 129.
Maximum do. over do.	1 in 88.
Average gradient over extension	1 in 28.
Maximum ditto ditto	1 in 25.

Curves.—373 feet radius and upwards.

Rails.—44 lbs. per yard, in 21-feet lengths, fished-flanged.

Sleepers.—Ten to each pair of rails. Dimensions 8 ft. × 6½ in. × 4 in.

Wagons.—Some are on 8 wheels, and weigh 6,000 lbs.

Some are on 4 do. do. 2,500 „

100 tons for weight of wagons, represent 63 tons cargo, or net load.

considerable experience in making light roads, especially in the United States of America, and had tried various kinds of flat and edge rails of variable weights. In a country like Australia, cheap railways were essential, involving curves of short radius, and steep gradients; but, looking at the nature of the traffic, he did not think this description of gauge suitable for English railways, excepting in cases like the Festiniog line; and even there he believed a gauge of 4 feet 8½ inches might have been adopted with advantage, as the cost would not have been much greater, and the disadvantages of so narrow a gauge were considerable. With regard to the question of light and heavy engines, they had been gradually increased in weight from 10 tons up to 30 and 40 tons, to meet the enormous increase of traffic on the main lines, but with such heavy engines the wear and tear of the rails was excessive, and he should prefer dividing the weight of the trains. He had been told, by the late Mr. George Stephenson, that the loose wheel on the axle was the plan first adopted on colliery tramways; it was, however, difficult to keep grit and dirt out of the bearings. He had great experience in constructing engines with bogie frames; in fact, the bogie in its present form, was the invention of Mr. David Matthews and himself, and he had introduced, thirty years ago, engines fitted with bogies on the Patterson and New York Railway. Mr. W. Adams had recently effected some improvements, which enabled engines to traverse the sharpest curves of the North London Railway at great speed, the accommodation being in every way satisfactory, from the peculiar arrangement of the centre pin. He saw no particular objection to Mr. Fairlie's engine, though he thought it had better be divided; there was nothing new in the arrangement of the driving-axles. He thought that much credit was due to Mr. Fox, for having called the attention of young Engineers, not to what had been done in England, but to what could be done abroad, where in all probability their talents must be applied for the future. The suggestion had been made to throw a portion of the weight of the tender on the engine; this had been his own practice in America, where he had placed the driving-wheels at the back of the furnace, in a manner similar to that subsequently patented in this country.

Mr. F. W. SHEILDS thought the material point which had been

Engines.—Six-wheeled coupled tank engines. Cylinders (inside), 12 in. × 17 in.; wheels, 30 in., leading and trailing, fitted with Caillet's translation apparatus; weight in working order, 14½ to 15 tons; tank 500 gallons.

The engines will take a gross load of 125 tons, representing 79 tons of cargo, up the first 18 miles, at an average speed of 9 miles per hour, and they will take a gross load of 52 tons, representing 32 tons of cargo up the 4½ miles extension, at about 5 miles per hour.

raised was as to the cost of light railways in comparison with those ordinarily in use in this country. He agreed that the permanent way, stations, and other matters, must remain pretty much alike on either system; and he considered the only way to account for the great economy in the cost of the Queensland railways must have consisted in the reduction of earthworks and masonry, caused by the adoption of sharp curves and steep gradients throughout the line. If curves of 5 chains radius and gradients of 1 in 50 were used, a large amount of cutting and embankment would of course be saved: in fact, by that means the earthworks would be reduced to a minimum. Taking the cost of earthworks at 20 per cent., and the bridges at 15 to 20 per cent. of the whole expenditure, there would be a margin of 35 to 40 per cent. on which a great saving could be made; and in earthworks alone he dare say three-fourths of the ordinary cost would be saved. In short, the reduction of the gauge admitted of the curves being decreased, and that seemed to him the chief point in which this system was productive of economy. With regard to the advantages of this system in Australia, as compared with England, he would say a few words. He had laid out lines in Australia, and had found a remarkable difference in the two countries. Australia was a new country, with few other lines of communication of any kind; whereas in England provision must be made at every step for passing other railways, roads, canals, &c., either over or under the line, involving cuttings, embankments, and other heavy works, which could not be obviated by the adoption of any curves or gradients whatever. In Australia, therefore, the benefit of the economy resulting from the use of sharper curves, allowable on the system under discussion, could be fully realised; and it seemed to him that this system could be applied with greater advantage in Australia than in England. It occurred to him also to remark, that in his own experience in Australia he made it a rule to use the materials of the country as far as he could; still he had no doubt the Author was justified in sending many things from England for the reason, that whereas the wages of workmen and other expenses were at one time moderate, they had since increased enormously. Mechanics' wages had, he understood, risen to 10*s.*, 15*s.*, and even at times 20*s.* per day; and, if that state of things prevailed, it made a serious difference in the cost of work done on the spot, and justified a considerable modification of the former practice. The timber of Australia was amongst the best in the world. He had never seen any woods which exceeded in strength and durability those of New South Wales; and he should be inclined to use them in construction as far as possible. He would suggest that Mr. Fox should be asked what was the average amount of earthwork per mile on the Southern and Western Railway of Queensland, in order to enable an estimate to be made, how far its low cost per mile was due to the circumstances he had endeavoured to explain.

Mr. F. J. BRAMWELL had only one observation to make, and that was in reference to the locomotive used on the Queensland Railways. It had been said that the sole advantage of such a double-ended or compound engine was, that one set of men attended to that which was in fact two engines. Mr. Bramwell had a recollection of a Paper read at this Institution, in which there was a description of the arrangement of engines used for working the steep incline on the line leading from Genoa to the interior (the Giovi incline),[1] and which engines were, he believed, designed by the late Mr. R. Stephenson, or under his advice. Two separate engines were used to draw the train, but they were coupled up foot-plate to foot-plate, so that one driver and one fire-man were sufficient for the two. He had seen those engines in operation when he travelled over the incline a few years since, and they appeared to be very efficient, and undoubtedly they had the advantages attendant on the ability to work them either coupled or separate.

Mr. ABERNETHY had travelled on that line recently, and he then noticed that the engines were not placed foot-plate to foot-plate.

Mr. HEMANS could state that they were so placed for years.

Capt. H. W. TYLER said, when he was on the Giovi incline, in June, 1866, the engines were worked foot-plate to foot-plate. He thought there was one important saving which had not been referred to, but which had been effected by adopting a narrower gauge in certain localities, namely, in the avoidance of heavy works in mountainous countries. In flat countries, very little saving could be effected by reducing the gauge from 4 feet $8\frac{1}{2}$ inches to 3 feet 6 inches. But in mountainous districts, sharper curves, which worked more easily on the narrower gauge, could be better employed. By climbing round the sides of hills instead of passing through them, an enormous amount of rock cutting, of embankment, of viaduct, and even of tunnelling—costly works, which were almost prohibitory if the object were to make an inexpensive railway—might frequently be avoided. In considering the question of using light engines on railways of narrow gauge, the excellent system which it was hoped might be seen in operation on the Mont Cenis Railway in 1867, under the supervision of Mr. Brunlees, must not be forgotten; and he trusted that an opportunity might be afforded for a discussion of its merits later in the session.

Since the reading of his Paper on the Festiniog Railway,[2] he had had the pleasure of opening for passenger traffic the Talyllyn

[1] *Vide* Minutes of Proceedings Inst. C. E., vol. xv., p. 358.
[2] *Ibid.*, vol. xxiv., p. 359.

Railway, 8 miles long, from Towyn to Abergenolwyn, on a gauge of 2 feet 6 inches.

Mr. G. H. PHIPPS said, it appeared to him that, if the carriages were as wide as had been described, in order to make room for them, there could not be much saving in the cuttings.

Mr. T. E. HARRISON remarked, that this question seemed to resolve itself into how to make cheap railways in England; and he thought there were two points, which had been omitted in the discussion, which bore essentially on the cost of railways. In the first place his own experience was, with few exceptions, in all the railways he had made, extending over a period of more than thirty years, that the landowners extorted the utmost farthing they could get for their land, either by means of juries or by arbitration; and if landowners expected railway companies to make railways into their districts, under that system, he was satisfied in future years they would be mistaken. There was one case he could refer to as an honourable exception to the course which was generally pursued. The late Lord Carlisle was very anxious to get a line from Thirsk to Malton. He was a large landowner himself, and had sufficient influence in the district to induce the whole of the landowners over twenty-two miles of line, with only a few exceptions, to agree before the Act was obtained—because unless that was done there could be no confidence in mere general statements —to sell their land for £60 an acre, including severance and tenants' damages. His lordship himself took a large interest in the construction of the line, and he and the other landowners found one-half of the capital. Under those circumstances the whole cost of the line of 22 miles, including stations, was under £100,000, and it now paid about 4 per cent. The other point to be considered in connection with the cost of railways was the requirement which the Board of Trade insisted on—that, with very few exceptions, public roads should not be crossed on a level. He was satisfied the persistence of the Board of Trade in that requirement was, in many instances, quite unnecessary. In some cases a portion of country was traversed where not more than two or three carts, and very rarely indeed a carriage, passed in the day, and it involved a hard contest to get a level crossing sanctioned under any circumstances. In the case of a main line of railway, and an important road, he always advocated a bridge in preference to a level crossing; but he did not think the Board of Trade exercised a just discrimination in their general prohibition of level crossings; the nature of the line, and the objects to be obtained by it, should be more carefully considered. So long as it was the rule to have no level crossings, cheap lines of railways could never be made in this country. He had been accustomed for many years past to study the statistics of the traffic of railways. In a purely agricultural district, without either manufactures or mineral productions, the calculation of what the cost of the line ought to be, to make the traffic pay, was of a very simple kind. He was satisfied that the results of actual traffic to be produced from any line of that nature were not more than from £7 to £10 per mile per week; and he took that traffic return as the basis of what the cost of the line ought to be, which, to pay 5 per cent., and with 50 per cent. for working expenses, ought not to exceed £3,600 and £5,200 per mile, respectively. Generally speaking, in this country a mistake was made at the commencement. Instead of estimating what the country was likely to produce, and then saying, unless the line could be constructed for a certain price it would not pay 5 per cent., lines were laid out without regard to the question whether the traffic was likely to pay or not. He was satisfied, if promoters would take a more commercial view of the matter, and if the lines were constructed only at such a cost as to afford reasonable prospects of the traffic giving a fair return upon the capital, there would be found even at this time, abundance of people ready to invest their money; but when a line was made at a cost commensurate with a traffic of £20 per mile per week, whilst the actual traffic only produced £10, then, he thought, people would be acting an insane part to put their money into it.

Mr. W. B. Adams said, with regard to the general consideration of light and heavy railways, it involved chiefly the question of cost. He agreed that a line should be constructed in reference to the traffic that was to come upon it, paying 10 per cent. on the outlay, with one-half for working expenses; but if it was supposed that railways could not be made for less than £30,000 a mile, then of course it could not be expected that such lines would be provided in poor or sparsely peopled districts. If it was worth while to improve the traffic by a cheaper kind of haulage, substituting the locomotive for the horse, regard must be paid to the work to be done. With reference to the curves, one would hardly venture to say what they might ultimately be brought to. Captain Tyler had given an account of what was done on the Festiniog Railway; but an engine was now being built in Wales to go round curves, not of chains, but of feet, and of so small a radius as 17 feet 6 inches. The gauge was 3 feet, and he supposed that it was thought it would pay. With regard to the saving in width of gauge, it could only have reference to the lightness of the rails, the extent of interval between the sleepers, and the amount of earthwork. Other things being equal, a less cost made the narrow gauge desirable; but whatever the gauge was, the bodies of the carriages to run on it might be made twice the width of the gauge. If it were a question of running the general stock of a main line on light railways, he could not see any particular advantage, and all the saving then obtainable would be in the weight of iron put into the rails, and the diminished number or size of the sleepers. There must be the same strength of railway while the gauge was the same, or the heavy engines would destroy it. Now that the point of putting comparatively light engines on the light rails, with the load distributed over many wheels had been arrived at, the advantage was, the rails were not destroyed by the superincumbent weight; but if the ordinary stock of the main line were used, a large source of mischief would remain. It was an axiom of the late Mr. R. Stephenson, that more damage was done to a railway by bad rolling stock than by heavy engines. With regard to making the engine double, four cylinders in one frame, or two separate frames with two cylinders each, it was a question of convenience. He had no doubt the engine described by Mr. Fox would work well round curves. Whether it was desirable always to have the pressure the same, taking the whole weight of the engine for traction, he was not sure. It was contended that two separate engines would do quite as well in traction, with various other advantages, but if coupled by merely chain-links, a portion of power would be lost in snatches by varying speed. To make two engines work well together, they should be coupled by a universal joint. It was well known that two horses in a carriage rarely developed double the power that each horse exerted separately; and thus the double engine, not subject to this irregularity, would have the advantage. Whether it be doubled by a single frame and boiler with travelling bogies, or by a universal joint, was a question worth considering. In his own case, he generally tried to adapt the tender as a means of increased traction, making it radial to the engine, and by putting friction-wheels between the driving-wheels of the engine and the front wheels of the tender, with a simple arrangement by which the driver could couple and uncouple the wheels as might be required, according as he had a heavy train or a light one to start, or an incline to surmount. A disadvantage in many engines was, that the cylinders were placed in front of the leading-wheels. If they were large cylinders, they acted like a weighted lever on the wheels. He preferred to put the leading-wheels in front of the cylinders, making them radial, and in that case the cylinders, being supported between the driving and the leading-wheels, did not produce any injurious effect. This leverage was very mischievous in two ways, damaging the line by a kind of ploughing action, and taking weight off the hind coupled driving-wheels, to remedy which it was not an uncommon practice to load the foot-plate with a large amount of cast iron as a counterbalance to the cylinders. The double bogie engine had overhanging cylinders, but very small ones, only 11 inches in diameter, and so of comparatively little consequence. A pair of cylinders of 15½ inches in diameter would develop the same power, and with radial wheels in front would not overhang. He had no doubt in some cases the one system was as advisable as the other; and in Mr. Fox's case the engines were intended for special mountain work, and not for general purposes. If he might refer to his own plans, he remarked that Mr. Fox had adopted the spring tires, the advantage of which was, when the engine was going round a curve, the tire slid round the wheel instead of slipping on the rails. One effect of this was to give about 20 per cent. more adhesive value by an elastic fit to the rails, and another, to prevent torsion of the axle; and the tire yielded only just as much as was necessary, in fact, as a friction clutch; and the breaking of a tire under those circumstances would be almost impossible. The reason of tires breaking was generally because they were put on too tight, a system which seemed to have descended from the wheels used on ordinary roads, and when railways were constructed the same system was adopted, and the practice was still continued; but he thought the tire might, with great advantage, be loose, with the certainty that it would never burst. The practice of through bolting the tire also took away one-third of its strength, and on receiving a sudden blow, when it was in a state of greater tension in frosty weather, it broke. His own impression was, that the loose tire would remove a serious element of danger on railways, and would greatly diminish noise, jarring, and destructive wear. If loose wheels were used, they must have a boss, as long, at least, as half the diameter of the wheel; if not, the flange pressure would have a tendency to wear out the bore. Some years ago, happening to be in Mr. Hague's factory, he found there some loose wheels, which had been made for the Great Western Railway. Mr. Adams then asked Mr. Hague how long he thought they would last, when he replied, in his opinion, about a fortnight. The pressure of the flanges of the wheels, 4 feet in diameter, against a short boss of 9 inches, put the wheels to such a severe strain and wear that they had to be taken out again. He tried the principle on the Birmingham and Gloucester line with 3-feet wheels, the boss being about 15 inches. The wheels did very well for about six months, and then began to wear loose. To make loose, or independent wheels, would necessitate a better structure and more cost. The surfaces would require hardening or bushing, and more space would be taken up by the extra size and length of boss; but either the loose wheel or the loose tire must be used, if free action and diminished friction were wanted, as the great object was to get rid of the 'rolling friction.' He preferred the loose tire, either a spring tire, or a hoop tire between the tire and the wheel, as giving all the effect of a loose wheel with greatly increased safety and diminished cost. A large portion of the noise and vibration in a railway train was induced by the skidding of the wheels on the irregular pathway.

Mr. R. Peacock remarked, that the weights of the engine described in the Paper, corresponded very nearly with the leading dimensions of two tank-engines which had recently been built by his firm for the Norwegian Railway on the 3 feet 6 inches gauge. He would briefly give the dimensions of those engines. The cylinders were 11 inches in diameter, with a length of stroke of 18 inches. The leading-wheels were 2 feet in diameter, and the driving and hind wheels 3 feet 9 inches in diameter. It would thus be seen that the tractive power of the engines was not very different; but he found there was a great difference in the dimensions of the boilers, particularly as regarded the heating surfaces, and it struck him either that the Norwegian boilers must be too small or that those of Mr. Fairlie's engine must be too large: nevertheless, the former engines were reported to make steam extremely well. The boiler of the Norwegian engine was 8 feet long, 2 feet 11 inches in diameter, with one hundred and seven tubes of $1\frac{5}{8}$-ths inch diameter; the heating surface was 416 square feet in each of the Norwegian engines, against 1,000 square feet in Mr. Fairlie's engine. And although the Norwegian engines carried only 300 gallons of water, with a fuel capacity of 23 cubic feet each, nevertheless, the weight of each of those engines, in working order, was 16 tons 19 cwt., whilst that of the double engine was given as 30 tons only. He should be glad to know whether the weights given in the Paper were calculated or actual weights, as it seemed to him there must be some mistake. As to whether the double engine or engines constructed on the ordinary principle were preferable, it must be allowed that two independent engines, arranged foot-plate to foot-plate, could be made a better mechanical job than an engine built with loose independent frames, and attached to the boiler by centre pins. He contended that the cost of working two engines placed foot-plate to foot-plate would not be more than the cost of working the engine described in the Paper, inasmuch as one driver and fireman could attend to both. Another feature in favour of two independent engines was, that in the case of the break-down of one engine, it could be detached, and a fellow-engine could be put to the one remaining; and thus only half the engine-power would be laid up for repair, as against the whole engine-power in the other case. He did not consider the engine described in the Paper possessed anything like the simplicity or stability, as a mechanical structure, that two separate engines did; neither did he think it could be kept up at the same cost. As a locomotive manufacturer, he would sooner build two independent engines of equal tractive power, for the same money, than one similar to the engine described in the Paper, and he thought the two engines would be found much less costly in repairs. The weight on the leading wheels of the Norwegian engines was 4 tons 2 cwt., on the driving-wheels 6 tons 12 cwt., and on the hind wheels 6 tons 5 cwt.; but as the engines were provided with equal compensating levers between the driving and hind wheels, the weights upon these wheels would be found equal, after the engines had run a short time.

Mr. Fox, in reply upon the discussion, said it was only proposed to use Mr. Fairlie's engine on those parts of the line which had very sharp curves and severe gradients; and the reason why, after a great deal of consideration, it was decided to adopt it, instead of two engines foot-plate to foot-plate, was, that by using two engines suitable for sharp curves, the advantage of the adhesion of the weight on all the wheels could not be obtained. By Mr. Fairlie's principle, they got 3 tons on each wheel, whereas with two engines, there were two wheels of the six which had no effect upon the tractive power. In the Queensland engine there was no waste weight, all being available for the purpose of haulage. A similar engine had been at work for some months, with eight wheels instead of twelve, and on this he had made a most satisfactory trip. With reference to the inquiry as to the quantity of earthwork per mile on the Queensland line, he would state that of the total cost of that part which came out at £9,000 per mile, the proportion for excavation was about £2,500. On the part costing £6,000, the excavation was £1,050. He could not state what was the price per yard, but it was probably about 1*s.* 6*d.* for ordinary soil. With reference to what had fallen from Mr. Harrison, he would say that the question of the calculation of cost proportionate to the traffic of the line was broached by Mr. FitzGibbon directly the Government decided upon making railways in Queensland, and they began by looking at the traffic which actually existed at the time. The Appendix to the Paper, giving the calculations of Mr. FitzGibbon, the Chief Engineer, showed what the minimum traffic would be, and it was then estimated what traffic might be expected, based upon the old calculations of the first railways in England. It was estimated that the minimum traffic on the Queensland line would pay $8\frac{1}{4}$ per cent. on the capital expended, and letters from the colony stated that 8 per cent. had been realized. It seemed there was an apprehension, that he advocated break of gauge, and the introduction of the narrower gauge in England. He did no such thing, though this might, in certain cases, be desirable. His object was to lay down an important principle, the reduction of the weight on the driving-wheels, by using an increased number of wheels, and by making the rolling-loads as light as possible. He believed, with due care, railways might be made in England, through an ordinary country, for £5,000 per mile. As to the sharp curves and steep gradients, they were only used on particular parts of the line—over mountain ranges—therefore much of the saving in an ordinary country could not be attributed to sharp curves. If they had not been adopted on the Main Range, the expenditure would have been ruinous; and if the minimum radius had been 8 chains instead of 5 chains, the cost of that portion of the line would have been at least £30,000 per mile more. But that was not the general reason why these light lines had been cheaply made. It was because all the parts were properly proportioned, and made as light as they could be. In earlier days, when labour was cheap, it would no doubt have been better to use the excellent native timber, than to have sent out iron structures from this country ready to be fitted up. With reference to the loose wheel, he had only tried it as an experiment. Mr. Adams had stated, that the bearing ought to be one-half the diameter of the wheel, and that was just what it was in this case. Railways should be proportioned to their traffic, and it was important to have as light a weight on the driving-wheels as possible; as by so doing the weight of every part of the structure might be kept down.

December 4, 1866.

CHARLES HUTTON GREGORY, Vice-President, in the Chair.

The following Candidates were balloted for and duly elected:—Peter Ashcroft, John Chester Craven, William Johnstone, Thomas Martin, A.B., James Raine Rushton, and Arthur Anderson West, as Members; James Abernethy, Thornton Andrews, John Charles Ardagh, Lieut., R.E., Robert Dudley Baxter, James Blackburn, William Wingfield Bonnin, Thomas Brassey, Jun., Albert James Leppoc Cappel, George James Crosbie Dawson, George Eedes Eachus, Joseph Breedon Fryer, Thomas William Gardner, Lewis Conway Gordon, Lieut., R.E., John Thewlis Johnson, William Mercer, Charles James More, Charles Mumford, Francis George Shirecliffe Parker, Capt. 54th Regiment, Michael Patterson, William Ridley, Christer Peter Sandberg, William Brounger Taylor, James Farnham Tuson, and Edward Henry Woods, as Associates.

The discussion upon the Paper, No. 1,166, on "Light Railways," occupied the whole of the evening, to the exclusion of any other subject.
