FOREWORD:

The writer has already adverted to the prime necessity for unity of gauge throughout Australia, and has adduced reasons.* Public opinion is crystallising, and the question is becoming, not, shall there be a uniform gauge? but, which shall be the gauge?

The problem is largely an engineering one. Doubtless, each engineer of the necessary preliminary special training and experience has formed a very definite opinion on the matter, at least where it impinges on his own sphere; for an absence of opinion would connote an absence of serious investigation on his part. But, however definite his own views may be, the problem and the difficulty is to state them in terms which shall carry conviction to others.

The question is in the balance. There is no evidence that all the weights are on the scale, or that they are—speaking technically—just. There is every cause for the discussion which this paper is intended to evoke; for there are members of this Institute who hold the highest positions in railway administration, who may hesitate to commit themselves to questions of policy, but they may, it is hoped, draw upon the store of their data in the discussion of purely technical issues.

PREMISES:

I.—Unification of Australian railway gauge is an ultimate economical, and an immediate defence, necessity.

II.—Present action must profoundly, and almost unalterably, dominate the future of Australian transport.

III.—All gauges are arbitrary, and their efficiency is dependent upon conditions which may, and do, alter.


IV.—Since the 4ft. 8½in. gauge came into general use, more than half a century ago, the change of conditions has been profound.

V.—Manifestly the change is in the direction of an ever-increasing intensification of the services required.

Admitting the premises, the solution is contained in the answers to the questions:

Is the gauge selected half a century ago, and adequate to the then requirements of Britain, adequate now to meet the requirements of larger countries?

Will it remain adequate?

POSSIBILITIES OF THE FUTURE:

The Australian mainland has an area of 2,948,366 square miles, a population of 4,188,000, and a railway system of 16,756 miles.

Fig. 1

RELATIVE AREAS, POPULATION AND RAILWAYS OF AUSTRALIA AND THE UNITED STATES.

AUSTRALIA.

The diagram shows the area and railway mileage of Australia in 1909-10, and of the United States in 1854.

The black bands denote the relative populations at the same dates.
THE GAUGE OF AUSTRALIAN RAILWAYS

Fig. 2.

UNITED STATES.

The diagram shows the area, railways (in 1909) and population (1910) of the United States to the scale of Fig. 1.

NOTE:
The side of a square equal in area to Australia is 1717 miles.
The side of a square equal in area to United States is 1724 miles.

miles, i.e., 14,990 miles of Government, and 1,760 miles of private roads. The area (2,974,159 square miles) of the United States is almost identical, and it most nearly parallels the Australian conditions. In 1854 the American railway mileage was equal to that of Australia to-day. Its population was about 26,000,000. Now, as a result of its possession of 238,356 miles of line (1909), its population exceeds 91,000,000. (Figs. 1 and 2.)

Possibilities such as these, developments such as these, should be clearly in the minds of those who approach the discussion of railway gauge for this continent.

For Australia's development is but beginning, and in these experiences of other lands we can see ourselves at a later date; and wisdom of choice is dependent in but a lesser degree upon knowledge of our present needs and limitations; it is dependent
in a greater degree upon acquaintance with the existing facts of more developed states; it is dependent in the greatest degree upon a true interpretation of what those states would choose were they unhindered by irrevocable decisions descended from the immature beginnings of railway policy.

**Genesis of Gauges:**

Trace the origin of one of these decisions. By far the greatest portion of the world’s mileage is of the 4ft. 8½in. type* There are few wider gauges. Virtually none of the heaviest and fastest traffic is attempted on narrower gauges. But the apparent deliberate perpetuation of the choice is but an automatic continuation of that which is in other lands—but not here—unalterable. The origin was not a manifestation of fundamental law; it was wholly fortuitous. The stone ways laid in some of the older English roads probably owed their spacing to the distance apart of the wheels of the Roman chariots. The first collieries to use rails of wood spaced them similarly. Later the wood was armed with strips, or “plates,” of iron narrower than the original wooden rail. Over these lines the first locomotives ran. The first railways duplicated that tyre spacing, and the 4ft. 8½in. gauge was born.

The only serious rival of the 4ft. 8½in., or “narrow,” gauge was the 7ft., or “broad” gauge. The Great Western was of the latter type; others of the same width were projected. At once it was recognised that there must be uniformity, and the “battle of the gauges” ensued.

Then there were no data which could, in any sense, guide the engineer of the new transportation. The contestants were guided only by the light of the then simple traffic conditions and were in entire ignorance of lengths of haul greater than those possible in Britain. The “narrow” gauge was victorious, but by a narrow margin only. Even then it was considered that the greater advantages of the broader gauge would almost justify its greater cost.

* But in several of these countries where the area is great, and where recent choice has been possible, wider gauges have been adopted; for instance, Russian and Russo-Asiatic lines 5ft. 3in. and 5ft., Indian trunk lines 5ft. 6in., Argentine, 5ft. 9in.
Had the contest been between the "narrow" gauge and lines of 5ft. 3in., 5ft. 6in., or even 6ft. gauge, it is almost certain that the "narrow," or 4ft. 8½in., gauge, would have been defeated in Britain.

Thus the 4ft. 8½in., is by no means sacrosanct, nor is it founded upon immutable law, and the fact that it was chosen as suited to the requirements of the early days, is *prima facie* proof that reconsideration of the choice should be made, where reconsideration is possible.

In the "fifties," far-seeing advisers of the colonies, who had a near acquaintance with the merits of the gauge controversy, decided upon the broader "Irish," or 5ft. 3in., gauge.* The colonies of New South Wales, Victoria, and South Australia endorsed the choice, and made it the standard—in New South Wales by Act of Parliament. Possibly an even wider gauge might have been recommended had rolling stock of wider gauge been a market article.

Victoria and South Australia abode loyally by the contract, and commenced construction. Then New South Wales changed its policy, its engineer, and its gauge, and the unique opportunity for obtaining uniformity was wilfully thrown away. Since then various other gauges have been introduced on the plea of their suitability for cheap pioneer development. That claim—temporal expediency—is the only valid reason for their introduction.

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* The most complete published compilation of the facts is contained in a paper on "The History of the Australian Railway Gauge," by the late Professor Kemot, published in the Proceedings, for August, 1906.
The position is given in the following table:

### GAUGE AND MILEAGE OF AUSTRALIAN RAILWAYS.

<table>
<thead>
<tr>
<th>State</th>
<th>Length of the Several Gauges in Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5ft. 3in.</td>
</tr>
<tr>
<td>New Sth. Wales</td>
<td>3643</td>
</tr>
<tr>
<td>Victoria</td>
<td>3381</td>
</tr>
<tr>
<td>South Australia</td>
<td>599</td>
</tr>
<tr>
<td>West Australia</td>
<td>2144</td>
</tr>
<tr>
<td>Queensland</td>
<td>3661</td>
</tr>
<tr>
<td>Nthn. Territory</td>
<td>145</td>
</tr>
<tr>
<td>Totals</td>
<td>3983</td>
</tr>
<tr>
<td>Grand Totals</td>
<td>4079</td>
</tr>
</tbody>
</table>

**Note.—** Italicised figures refer to private lines.

**Merits of the Gauges:**

Any rectification clearly implies a change of the greater proportion of the lines of Australia. Least change would follow the adoption of the 3ft. 6in. gauge, which constitutes the greatest mileage. There are those who hold that gauge sufficing, even for transcontinental trunk lines. There are other advocates who contend for a differentiation of States, and a duality of gauges—
a doctrine opposed to the experience of the world and the future welfare of this continent.

It would be against self-apparent facts to contend that the 3ft. 6in. could handle the heavy and fast traffic which the broader gauges of New South Wales, Victoria, and South Australia must, and do, handle. And it would be against all the indications of probability to contend that, at no distant date, similar traffic will not be general.

If it is candidly conceded that the advocacy of the 3ft. 6in is a counsel of present economy and expediency; then apparent economy in first cost must be considered, as not a saving, but a deferred charge. That deferred payment would be shared by the parties to a future adjustment; therefore the true basis should be determined now, and as from now.

World-experience shows that the 3ft. 6in. must be eliminated as a national gauge for long hauls or important lines. The issue is thus narrowed to 4ft. 8\(\frac{1}{2}\)in. versus 5ft. 3in., although posterity may blame us for not seizing the opportunity to secure an even broader gauge.

Any difficulty in selection is dependent upon the similarity of the gauges—they differ by but 6\(\frac{1}{2}\) inches. Were the difference greater, the advantages and disadvantages would be accentuated, and choice would be simpler. There is no question as to the magnificent work possible on either. There is no question that in Australia the possibilities of either are very far indeed from exhaustion. Again, reliance must be placed upon the trend and limitations of thought and practice abroad.

Length of Haul.—But comparisons must be made with caution and reserve. Australia is a continent. The coast to coast distances are great. The interior can only be reached by hauls which are long. The values of primary products to be derived thence are small in proportion to their volume and weight. Their selling price is fixed by market rates abroad. Hence deviation from strict economy, not perhaps markedly detrimental in countries of relatively insignificant geographical distances, might well prove commercially fatal on the long hauls here.
CORRELATION OF AREA AND DIRECT DISTANCE FROM THE COAST IN AUSTRALIA.

NOTES:

1. The diagram is an approximation.

2. The circles denote the planimeter areas of the several zones plotted on the map of Australia.

3. The scale at the right indicates the order of variation of area in relation to constant variation of distance.

4. The broad line indicates the mean direct distance (or length of haul) from the coast of the whole area of Australia.
For instance, Britain, with every point comparatively near to a port, furnishes no parallel. The writer has computed, by graphical approximation, the relation of area served to length of haul in Australia. Figure 3 gives the results. The mean direct distance from the coast of the whole area of the continent proves to be about 219 miles. The maximum haul is measured by the distance between the oceans. *

Thus, the Australian gauge must be an economic long-distance gauge; for every ton carried should earn a return over all charges, when rated at a tariff which permits of world competition. If the products are carried at rates less than reproductive rates, then the disabilities of the transport facilities are being covered by undue charges upon those short hauls, or those valuable commodities, upon which surcharge is not so easily apparent. Or, still more important, development by rail is confined to a coastal fringe, or regions of special fertility or wealth, whilst the interior is neglected. But a national, in contradistinction to a parochial, policy of gauge must contemplate the development of the whole of the resources of Australia, as well poor land as good, as well distant as near. (Vide Fig. 3.)

Wherever such conditions arise, financial success has been sought in the direction of increasing the train weights and decreasing the relative number of trains run, in an endeavour to minimise labour costs and ensuing expenditures. The United States again furnish the nearest parallel. There freight trains have attained abnormal weight. They are drawn by locomotives twice, and even thrice, the weight of the heaviest Australian engine. All this on the 4ft. 8½in. gauge, and until we have reached a similar intensity of traffic, that gauge would suffice here.

But the Americans, pressed as we are not yet pressed, find that the gauge is reaching an economic limit, and many leading

*Average hauls for various other countries from actual traffic returns (1908) are as follows:—

<table>
<thead>
<tr>
<th>Country</th>
<th>Haul (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United Kingdom</td>
<td>25</td>
</tr>
<tr>
<td>Russia</td>
<td>152</td>
</tr>
<tr>
<td>Germany</td>
<td>62</td>
</tr>
<tr>
<td>France</td>
<td>78</td>
</tr>
<tr>
<td>Austria</td>
<td>65</td>
</tr>
<tr>
<td>Canada (Companies)</td>
<td>183</td>
</tr>
<tr>
<td>Canada (Government)</td>
<td>234</td>
</tr>
<tr>
<td>Argentine</td>
<td>63</td>
</tr>
<tr>
<td>United States</td>
<td>132</td>
</tr>
</tbody>
</table>
men voice the opinion that were choice again theirs—as it cannot now be—a wider gauge would be selected.

Costs:

The possibility of selecting one of the Australian gauges appreciably wider than the American gauge, is still ours; and the cost difference as between the selection of the wider and the perpetuation of the narrower, is not material.

Railway engineers will recognise that an approximately accurate estimate of conversion costs connotes a very great amount of complex and laborious work, work not to be undertaken except in immediate anticipation of actual change. General estimates for preliminary advisory purposes are certain to err on the side of overcharge. For each of the parties concerned will, quite naturally, strive for the inclusion of items which, if they do not leave the State concerned an actual pecuniary gainer by the transaction, will at least very fully assure that State against loss.

As an example: In 1897 a railway commission met to determine the relative costs of conversion of the 4ft. 8$\frac{1}{2}$in. to the 5ft. 3in. gauge, or vice versa, in the colonies of New South Wales, Victoria and South Australia. The mileage then involved, considered as single track, totalled 7,849, as against 9,407 now, the length to be altered being dependent, of course, upon the gauge selected. The conversion costs, including rolling stock and all charges, were estimated to be:

\[
\begin{align*}
4\text{ft. } 8\frac{1}{2}\text{in. to } 5\text{ft. } 3\text{in.} & : & £4,260,000 \\
5\text{ft. } 3\text{in. to } 4\text{ft. } 8\frac{1}{2}\text{in.} & : & £2,360,500 \\
\text{Difference} & : & £1,899,500
\end{align*}
\]

The difference was of the order of 2 per cent. upon the capital value of the property. Now, that estimate included provision for the re-sleepering of the 4ft. 8$\frac{1}{2}$in. lines, conditional upon their conversion to 5ft. 3in. The contention was that the sleepers in use would be too short for the wider gauge. But that gauge increment would have brought the rail only 3$\frac{1}{2}$in. nearer to the sleeper end. The weight bearing capacity of the sleeper would have remained unaltered, and there was no intention to increase the train weights supported. Since then, the shorter sleepers
THE GAUGE OF AUSTRALIAN RAILWAYS.

used on the 4ft. 8½in. have come into quite general use as sufficing for the 5ft. 3in.

The State introducing that proviso would have reaped a very real advantage in the complete re-sleepering of its lines. And there is little doubt that shrewd administration would have sought to reap considerable collateral advantages by securing a higher scale of ballasting, and allowances for interruption of traffic, etc. Such charges are legitimate, if considered as extra costs incurred to secure a more perfect permanent way, but they are not legitimate sequences of conversion, and they greatly complicate the purely engineering phases.

But the larger cost of conversion is connected, not with the conversion of the broader gauges, but with the conversion of the 3ft. 6in., to either. Especially is this the case when, in location, in cuttings, embankments and bridges, and in permanent works generally, short-sighted policy has ignored the possibility of a subsequent substitution of a line of greater capacity, an omission by a State which must eventually penalise the Commonwealth as a whole. The first section of the south to north transcontinental is a case in point.

In such cases the work to be accomplished in connection with conversion to either gauge, is chiefly work in common, and the points of divergence and comparative costs render it financially immaterial which gauge is selected.

In previous estimates provision has been included for the widening of certain tunnels, standing works, etc., as a sequence to the adoption of the broader gauge; but the question is, would not these alterations become ultimately a necessity, altogether apart from the question of gauge? There is no doubt that the earlier administration did not look far enough ahead in limiting the width of the right-of-way by these encroachments. Already the pinch resulting from insufficient clearance is felt, not on those sections only in which they exist, but in regard to the whole rolling stock which may at any time traverse them. There is no question as to the insistent striving after greater width of stock. It therefore becomes probable that the elision of these limiting structures will eventually be undertaken irrespective of the gauge in use.

One of the greatest advantages of wide gauge per se is that it permits the traffic to be conducted on the most economical
lines, because the width of the carrying stock can be increased without diminution of stability. Remember that increased width implies increased possible height, and that therefore the diminution of train length for a given load is a function of the squares of the gauges—that is, on a 5ft. 3in. gauge a train can be designed some 20 per cent. shorter than that required to carry the same load, with equal safety, on the 4ft. 8½in. That is the point appreciated in America, where trains, measured by thousands of feet in length, seem to be approaching their safe working limit.

The widening of limiting structures is, therefore, primarily a question of traffic, not gauge, requirements.

**Rolling Stock:**

Probably most mechanical engineers who have specialised in locomotive and rolling stock design, would assert the invaluable advantage of the added 6½ inches permitted between frames as a consequence of greater gauge. They know that it means the possibility of the use of internal cylinders, of greater grate area (at lower level) and boiler capacity, matters which concern not only the power of the engine, but the endurance of the road. The force of this contention is not at all lessened in respect to engine practice here by the fact that locomotives of far greater power are elsewhere running on 4ft. 8½in. roads.

*Converting Stock.*—Obviously, the 3ft. 6in. stock is incapable of adaptation to either of the wider gauges. It would have a further transitory use on minor branch lines until these grow so in importance as to justify change. Much of the vehicular stock of the wider gauges is, however, possible of adaptation to either.

The problem is more difficult as regards locomotives. It is understood that, as a matter of agreement between the States, some of the more recent locomotives of the 5ft. 3in. stock have been constructed on the assumption that they may be converted to 4ft. 8½in. That is an anticipation of a general change which should be made only as a result of exhaustive inquiry. In the meantime it, in principle, introduces limitations in regard to the utilisation of the wider gauge, although in practice, under present conditions of traffic intensity, they may be taken as negligible.

*Replacement of Stock.*—An argument strongly advanced in
favour of the adoption of the 4ft. 8½in. gauge is that local Government works and manufacturers might not be able to meet the sudden demand upon them, and that in that event the 4ft. 8½in. stock could readily imported from makers' stocks abroad, whilst the 5ft. 3in. would require to be specially manufactured.

The questions of fiscal policy involved are questions for the politician; but there is this underlying engineering consideration—supply of a number of locomotives from stock, or to their stock designs, by a number of makers, would be at once destructive to the very essential policy of standardisation and reduction of types. It would also eliminate the possibility of the inclusion in design of those matters which have evolved locally to meet Australian conditions. If it is intended that the engines shall be specially built abroad to special and uniform designs, the contemplated rapidity of supply must be largely discounted.

Disposal of Discarded Stock.—In the press reports of a statement recently made by Mr. Hale, M. Inst. C.E., it is shown that there would be an active demand for discarded 4ft. 8½in. stock, by lines abroad of that gauge; while 5ft. 3in. stock, especially locomotives, would, if discarded, largely be reduced to scrap values. Similarly, whichever gauge is adopted, surplus 3ft. 6in. gauge stock would find a market abroad.

But these are, after all but transition matters. They should not unduly influence judgment respecting the larger, lasting issues.

Electrification.—The difficulties or advantages of the several gauges in relation to the electrification of lines are not material. Chiefly they would refer to matters of trade expediency. In the case of the 4ft. 8½in., orders could be met from stocks abroad without change. In the case of the 5ft. 3in. the stock designs would require modification, chiefly in regard to the non-electrical undergear of the rolling stock. In either case the matter is of no moment if the manufacture be local.

Military Issues:

So far consideration has been restricted to civil issues. But efficiency for transport for defence may at any time become paramount. This is, however, not a complication as regards gauge. That gauge which will most quickly, and with most
enduring sureness, handle ordinary heavy traffic is also that most suited to military requirements.

It has been suggested—not, it is understood, by military authorities—that the 3ft. 6in. gauge would suffice, even for the great transcontinental lines. That gauge has done good military work elsewhere, but not under the conditions existing here.

The retention of the unpeopled North, and, to a lesser degree the West, may become dependent upon effective connection with the more populous Eastern and Southern States. That implies haulages from ocean terminal to ocean terminal. It implies hauls of from 1,200 to 1,500 miles through intervening almost uninhabited areas; and it implies the ability to draw stock from any part of the continent, and concentrate it at any point or section—a course which postulates uniform gauge.

There is no parallel to such work in past performances of the 3ft. 6in. Past experience negatives the supposition that its capacity would be adequate to our future necessities. The nearest parallel to our conditions exists in the Trans-Siberian railway. That line is of 5 ft. gauge, and some of its Russian and Russo-Asiatic feeders are wider; yet it is a matter of railway history how it was stressed to the utmost during the Russo-Japanese war.

As an example of the inadequacy of the narrow gauges for military use, even in small countries of short distances, it may be noted that it is reported that Japan has just passed an ordinance commanding the change of its 3ft. 6in. railway gauge to 4ft. 8\(\frac{1}{2}\)in.

It is not sporadic raiding ventures which matter. It is the possibility of attempted permanent invasion in force which must be considered. Then no narrow-gauge methods would suffice.

The choice for defence is between 4ft. 8\(\frac{1}{2}\)in. and 5ft. 3in.

It is understood that the military authorities favour 4ft. 8\(\frac{1}{2}\)in., and that upon that advice action, which might constitute that gauge the standard for all Australia, is contemplated. It is with diffidence that the writer refers to decisions when the underlying reasons have not been disclosed, but it may be assumed that no technical or civil reason unknown to the profession is in question. The military tactician must of necessity focus his attention on the immediate or near present; but the greater railway problems extend into, and dominate, the future.

So far as the writer knows, the military predilection seems to
be based upon the assumption of a quick emergency interchange of stock from abroad. It may be assumed that, so far as a general conversion is concerned, it would not be attempted, except in time of peace. In that case the civil consideration—already adverted to—not the military reasons, would apply.

In case of war emergency, importation of material would imply that effective command of the sea which would in itself render the necessity for the course problematical. For the supply of railway stock in adequate quantities implies the use, not of individual vessels, but of a fleet. And that fleet would have to traverse the distance from Britain or America, for the gauge of the Indian trunk lines is 5ft. 6in., and South Africa has not stock sufficient for its own requirements.

The 8¼in. would rather seem to confer an advantage upon an invader who had secured foothold, who found the lines, but found the rolling stock absent or destroyed. The 4ft. 8¼in. stock he might possess or obtain. In the case of 5ft. 3in. tracks, he must alter the lines or specially manufacture the stock, in either event a gain of valuable time to the defence.

**Future Considerations:**

As a result of pending conferences between the representatives of the several State Governments and of the Federal Government, and subsequently of the railway administrators and engineers, there is hope that discussion will crystallise in decision.

The new factors are Federal representation and, possibly, also, the recognition of claims to consideration of such private roads as are virtually extensions of Government lines.

Suppositionally there will be keen rivalry between the parties to obtain that which will assure them the greatest individual advantages in present and in contingent adjustments. There may be a tendency to accept that which will impose the least immediate financial burden. There may be concessions in regard to matters which are fundamental essentials, and upon which there can be no sound compromise. It is an open secret that in the past engineers have, as a matter of instruction or expediency, concurred in decisions in regard to the wisdom of which they were not fully assured.

**Conclusion:**

The writer is strongly of opinion that the merits are with the 5ft. 3in. gauge.
Without in anywise seeking to minimise those conditions which immediately affect the present generation, yet it remains that differences of cost of conversion in the present are as nothing in comparison with the larger problems of the near future, which they will dominate. Those who approach the matter, must, of necessity, think in millions, and must be prepared to sink heavy sums to save or gain greater amounts. Present expenditure is the most pressing, but intrinsically the least important issue involved.

There is, as yet, no evidence that the suggestions which have been made as to gauge, and those which have received tentative official endorsement, are based upon facts which are conclusive, or upon the exhaustive consideration such a momentous question demands.

Whatever gauge the representatives of the engineering profession may endorse, it is certain that the decision will be historic, irrevocable, and probably more far-reaching than any other supposable in Australian engineering.

DISCUSSION.

After the vote of thanks recorded in the "Proceedings" had been accorded to the author:—

The CHAIRMAN said they had been for years as a voice crying in the wilderness, in seeking to get the public to realise the importance of the question. It was a question with which the whole future of Australia was intimately bound. Any action taken within the next few years would to a large extent make or mar the future of Australia. One point struck him, and that was the question of a great war. It was the Civil War in the United States that made the United States adopt a uniform gauge. It was a very momentous point indeed.

The PRESIDENT resumed the chair.

Mr. J. T. N. ANDERSON said it might be well to explain the difference between a mile of single track and a mile of road.

The PRESIDENT said a road might be single, double, even quadruple. In the case of a double line a mile of road was equivalent to two miles of single track. The figures he had quoted were simply the distances between terminals, unless otherwise stated. In some cases, as for instance, in that of the Govern-
ment Conference as to conversion, the equivalent extended length of single lines, including the length of cross-overs and sidings, was in question.

Mr. F. W. Clements, referring to the diagrams submitted, said that for the United States looked marvellous indeed. The areas of the United States and Australia were about the same. But on comparing the populations at the times when the lines were of equal extent, it appeared that Australia was in a good position as to the extent of her railways. If we continued to build at the same rate, we would have an even denser diagram than the United States when our population equalled that of that country.

The President said that Australia's population at the present time, looked upon as railway pioneers, had done better work than probably any other people, whilst Canada followed very closely. If present population only, not development of the country, was alone in question, it might even be said that the population was over-railwayed.

Discussion adjourned.
THE PROBLEM OF THE GAUGE OF AUSTRALIAN RAILWAYS.

The discussion on the President's paper was continued.

Mr. W. Prior Hales wrote as follows from Tasmania:—I thank you very much for your letter of September 25th and the Proceedings of your Institute, also for your invitation to the meeting on 4th inst. I regret not being able to accept. Under separate cover is a copy of my paper on "Uniform Gauge with Australian Railways Gauge Map."

As being outside the circle of Australian railway politics, I claim to be free from local prejudices on the question of gauge. The main, in fact only, argument in favour of 5ft. 3in. gauge is its greater capacity, and therefore cheaper working cost. These are factors that will count for all time. The machine that is most efficient commercially would certainly be most suitable for military purposes. One argument which has been used locally in favour of 4ft. 8½in. gauge is that, in case of sudden shortage of rolling stock, it would be possible to purchase abroad. Would not such sudden shortage imply want of foresight? Also, as you point out in your paper of September 6th, such purchases would be fatal to standardisation of design. Another argument that has been submitted to the Government is that there is plenty of room for development from the existing heaviest engines in Australia (105 tons) to the 312 tons or even the projected 378 ton engines in U.S.A. This is only one instance bearing out my assertion that the rolling stock in Australia is not up to date. The traffic on many lines is now quite heavy enough to warrant very much larger engines and a large percentage of high capacity trucks. In U.S.A. the trucks have from 30 to 60 tons capacity, and a recent writer states that "the 10 ton truck was put on the scrap heap a generation ago." Australian railways have cost to date somewhere about £150,000,000. Say the extra cost of adopting 5ft. 3in. gauge in place of 4ft. 8½in. is £4,000,000. An additional expenditure of 2½ per cent. would increase the capacity of the machine by fully 10 per cent. Is this not a sound business proposition?

The President said he would reserve his further remarks for his reply, but in view of the public consideration of this question, he desired to emphasise some of the sections of his paper.

For instance, the application of the term "standard" to the 4ft. 8½in., or to any other gauge, gave it a weight which it did
DISCUSSION—AUSTRALIA’S RAILWAY GAUGE.

not possess. There was no “standard,” and there were sufficient reasons why there should not be one. In regard to the 4ft. 8\frac{1}{2}in., eliminating the United States lines, then there was a preponderance of other gauges.

There appeared to be a confusion in the lay mind in respect to the cost of converting existing systems to one gauge, and the difference of cost of new lines of slightly different gauges. Speaking to engineers, it was unnecessary to point out that these were two altogether different things.

If tunnels were too narrow, and standing works too close, all those works must be rectified, and it might be done when the conversion was effected. But it was an overtaking of the omissions and commissions of the past. It was work which must, eventually, be carried out in any case. But in new works the difference consequent upon the use of differing gauges was trivial. Land, survey, and engineering costs, embankments, cuttings, bridges, stations, and standing works generally, were the same. Until the capacity of the narrower gauge was exceeded, the costs of rails, sleepers, and ballast would also be the same, because the maximum weights incumbent upon the road-bed would be the same. When the broader gauge was worked to a greater capacity than the narrow gauge would permit, there must be a proportionate increase in the costs of sleepers and ballast. The cost would then be justified, and it would be small.

Professor H. PAYNE said the matter was of such importance that it was well that all views should be ventilated. The President had opened the question in a very clear manner, but it seemed to him that the paper had hardly expressed the whole position. In reading the paper, he noticed there were places in which there were two sides to the question, and the second side had been left out. Such, for instance, as the failure of the railway transport in Siberia. That was merely due to the fact that there was a single line, instead of a double line.

Then, as to the question whether there should be a 4ft. 8\frac{1}{2}in. or a 5ft. 3in. gauge, that seemed to him to be an unimportant point, because at the present moment the loading gauges of each of the systems in Australia were practically the same. The loading gauge must be settled before they had a departure from one gauge to another. The present 5ft. 3in., limited by its loading gauge, would carry not more than the 4ft. 8\frac{1}{2}in. could take. Supposing they did alter the loading gauge, the fact must
be faced that directly they altered the loading gauge, they must at once alter the distance between the rails, they must alter the whole of the stations, the whole of the tunnels, the whole of the bridges, because the bridges must then be looked upon from the standpoint of carrying the engines, which would be much heavier, on a gauge that would take the bigger loading gauge, and those bridges would then have to be re-modelled. It was a very serious expenditure when one considered it from that standpoint.

Of course, the argument might be used that the number of miles of rail laid down to-day was small to what it would be in fifty years. That was true, and, if the inhabitants of Australia could stand the additional expense, then by all means widen the gauge. But they should not increase the gauge without increasing the loading gauge with it. The loading gauge was the determining factor. Unless that were fixed at something bigger than at present, it was better to keep to the 4ft. 8¾in. That would carry all that the 5ft. 3in. would with its present loading gauge.

He had been somewhat emphatic in his statements because he believed he was correct in all the statements he had made. He trusted if there be a serious desire to have the broader gauge, the more important matter of the loading gauge be considered side by side with it.

The President said that the gauge of the rails determined the loading gauge. Twenty odd years ago, when actually designing stock for Australian railways, he had pointed out that the loading gauge in use was altogether too narrow to permit of the utilisation of the possibilities.

At the present time they could not here place stock as wide or as capacious on either the 5ft. 3in. or 4ft. 8¾in. as that possible elsewhere on the 4ft. 8¾in.

It was a fundamental matter, which had been fully recognised,*

* Extract from the speaker's paper, p. 133:—
"'In previous estimates provision has been included for the widening of certain tunnels, standing works, etc., as a sequence to the adoption of the broader gauge; but the question is, would not these alterations become ultimately a necessity, altogether apart from the question of gauge? There is no doubt that the earlier administration did not look far enough ahead in limiting the width of the right-of-way by these encroachments. Already the pinch resulting from insufficient clearance is felt, not on those sections only in which they exist, but in regard to the whole rolling stock which may at any time traverse them. There is no question as to the insistent striving after greater width of stock. It therefore becomes probable that the elision of these limiting structures will eventually be undertaken irrespective of the gauge in use.'"
that the loading gauge of these States must be increased whichever gauge was adopted.

Mr. 1. W. Fowler said he had read the paper with a good deal of interest, and he must say he agreed with the President's views. The author had pointed out the great advantage of the broader gauge in connection with the increased carrying capacity of the tracks. Of course, assuming that they could get a wider loading gauge they would have a much greater carrying capacity. The President had also pointed out the increased power obtainable from the locomotives. The increase of a comparatively small number of inches in the width of gauge must be of very great value indeed to the locomotive engineer, who was already cramped up to the utmost, especially with the 4ft. 8½in. gauge.

Of course the 4ft. 8½in. gauge had been adopted throughout Great Britain and other parts of the world, America especially, after conflict with the broad gauge, and it was then thought that the narrow gauge had won the day. But was that conflict between broad and narrow gauge? Was it not a conflict between two essentially distinct types of construction? They would remember that the narrow gauge of Stephenson and the early pioneers of Great Britain was essentially the cross sleeper railway; whereas the broad railway of Brunell was the longitudinal sleeper, one involving very expensive types of construction. Brunell, seemed to think that with the 2ft. gauge he could not economically get a transverse sleeper road, or else he was not fully seized of the advantages of such a road. Hence he adopted the longitudinal sleepers, with the rather expensive type of construction. With gauges under seven feet they were always able to use cross sleepers. He did not see that the battle of the gauges in Great Britain had really decided the question between the 4ft. 8½in. and 5ft. 3in. As a matter of fact he thought they would find that as regarded general construction there was very little difference between them. The President had already pointed out that the width of the cuttings and embankments was precisely the same on the 5ft. 3in. railways here and the 4ft. 8½in. ones at home. The standard length of sleepers—and that, of course, governed the width of the ballast and the width of the formation—had in Victoria been 9ft., but he understood from Mr. Kernot that the latter was now constructing a number of lines with 8ft. 6in. sleepers on the 5ft. 3in. gauge.
On looking up some literature to refresh his memory he noticed that the standard length of sleepers in Great Britain for the 4ft. 8½in. gauge was put down at 8ft. 11in. He understood the extra inch was cut off on account of some question of duty. Material under 9ft. in length was admitted duty free, or at a lesser rate of duty than that of 9ft. But the point was that here they had been able to work satisfactorily their 5ft. 3in. railway with precisely the same size sleeper as was used in Great Britain for 4ft. 8½in. Turning again to an American authority (Trotman), he noted that a considerable number of railways used 8ft. sleepers, some 8ft. 6in., and some 9ft., so that apparently they did not depart very much from the standard length adopted out here.

There was one point, however, that he would like to emphasise, and that was a point which he thought had not been taken up by others in connection with this question dealing with the question of the break of gauge. He noticed in that morning’s “Argus” a reference made by the consulting engineer for the Commonwealth to the advisability of overcoming the break of gauge by using axles with three wheels, or by having sliding wheels, or by using a third rail. He must confess that he would not have anything to do with a third wheel, nor with a wheel sliding on an axle. It appeared to him that that was not a type of construction to be used in connection with railway work. The third rail had been submitted as a possible alternative. The third rail was adopted on the Great Western railway before it was brought down to the 4ft. 8½in. gauge, apparently proving the practicability of the system. But he failed to see that it would be practicable here. The third rail, as used on the Great Western railway, provided for a 4ft. 8½in. line with one of 7 feet, but here we have to deal with two lines, the one 5ft. 3in., and the other 4ft. 8½in. Consider what that meant. They might take it that the width of a rail suitable for ordinary traffic was at least 2½ inches. The American standard rail head for 80lbs. was 2½ inches; and 100 lbs. 2⅛ inches. He could not turn up his records of the width of the Victorian standard types, but he fancied they were slightly wider. If they added 2½ inches to 4ft. 8½in. they got 4ft. 11in. That meant they would have a distance of four inches between the outer edge of the top of the 4ft. 8½in. rail and the inner edge of the 5ft. 3in. That might be quite enough clearance whilst running along on the straight, and it was possible that they might
construct a substantial road in that way if they used bull head rails, but when they remembered that they had to provide for an 80lb. rail with a 5 inch flange, or a 100lb. rail with a 5\(\frac{1}{2}\) inch flange, he thought they would find it would be practically impossible to satisfactorily secure those two rails side by side. But they could not have a railway system simply having one pair of rails running from point to point. At stations it was necessary to have sidings. He must confess that he saw great difficulty about having a pair of points in between the two rails in a space of four inches.

The question of crossovers had to be considered, but it introduced some important modifications. It was clear that they could not possibly get a crossing from the narrow gauge on the double rail side of the road, because the acuteness of the angle would be too great. With a double road like that it would be absolutely imperative for the crossings on the narrow gauge to be in the direction of the single rail. So that they could not have at a station the system of two rails side by side. Supposing they did that, he thought they would find their system of points and crossings very complicated, and they would have some very difficult problems indeed to work out in connection with interlocking. He was afraid that the whole thing would become so complicated that it must necessarily break down. It would not conduce to the safety of the line, and there would be the possibility of fearful complications and the probability of very serious accidents. So that he certainly thought they should look upon the third rail as being absolutely impracticable. For a three rail system to work there must be a greater distance between the rails than those two gauges would give.

He complimented the President on his paper, and thought he was doing a very good work in thus bringing forward the advantages of the broader gauge.

The President said Mr. Fowler had dealt with the possibility of a three-rail proposition. But they were engaged, he took it, in discussing a national system adequate to Australia's future. He assumed that Mr. Fowler would not for a moment suggest that a three-rail arrangement could be so classed.

Mr. Fowler: No, most certainly not.

Prof. H. Payne said that there was a point he had omitted to make when speaking previously. It was being assumed that
Great Britain was the sinner in using the 4ft. 8\(\frac{1}{2}\)in. gauge. He would like to draw attention to the fact that the 4ft. 8\(\frac{1}{2}\)in. gauge was used in Europe by Great Britain, Germany, Holland, Belgium, France, Denmark, Norway, Sweden, Austria, Switzerland, Italy, Hungary, Turkey, and in America by Canada, United States, Mexico, Peru, and Uruguay.

Mr. T. W. Fowler: But if they had the chance of starting over again, would they not go in for the wider gauge now?

The President said the assumption referred to by Professor Payne was certainly not contained in his (the speaker’s) paper. Whilst Professor Payne was on his feet, he would like to ask whether, in stating that they must at once alter all the bridges, it was intended to be conveyed that that was a sequence to change of gauge? Much heavier locomotives were being introduced, quite apart from gauge.

Prof. Payne: The later increase in weight has been in the direction of the increase of length of the locomotive.

The President: They had engines of about 100 tons running. Heavier locomotives were contemplated; there were engines of three times that weight in use abroad. Surely a 300-ton locomotive at the centre of the span of a long bridge was a very different matter to a 100-ton engine similarly placed. As a matter of fact, and as a question of systematic policy, the older bridges throughout Victoria—and in other States—which had been built to carry lightweight engines, were being greatly strengthened or rebuilt. Several important bridges within rifle-shot of where they sat were being so treated.

Therefore, apart altogether from any question of change of gauge, the fact remained that strengthening would be required.

Prof. Payne said, with reference to that point, everybody recognised that in the case of long bridges, strengthening must take place. Naturally, the increased intensity of the locomotive loadings necessitated strengthening if the bridges were built for lighter loading.

But the point which he made was in regard to short-span bridges—by short-span bridges he meant spans up to 100 feet. And the great majority of railway bridges came within this 100ft. span girder type. When they had a short-span bridge designed to the maximum loading stage, they had it designed once for all.
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The President: That is, a bridge not longer than the modern locomotive?

Prof. Payne: A modern locomotive and tender ran to about 100 feet.

The President: Meaning, he took it, that any bridge not 100 feet span would not require strengthening, apart from change of gauge?

Prof. Payne said he certainly did not state that no bridge would require strengthening. The statement he had made was that when the locomotive reached such a size as was compatible with the loading gauge, any further increase must be in the direction of length, and once the bridges were designed to stand that, they need not be increased in the future, because they could not get outside the loading gauge.

The President still did not think the point was clear. The point was that existing bridges were not sufficiently strong to carry proposed locomotives of the heavier weight that would follow increased load sections. That strengthening would require to be done to develop the capacity even of the 4ft. 8½in gauge. When bridges must be altered, it was a small matter whether they were altered simultaneously with the gauge or not.

Prof. Payne said that his previous statement answered that. He mentioned that if bridges were designed to carry certain traffic, they could not stand very much more than that.

The President asked, did the remarks apply to present conditions? He wished to clearly know what he must reply to.

Prof. Payne said he was not speaking about present conditions. He referred to the fact that the loading gauge would limit the maximum size of engine, and, looking to the future, every railway engineer should, from past experience of the increasing size of locomotives, build all bridges so that they would take all locomotives that were likely to be built in the future. And, when strengthening the bridges, they should not merely bring them up to the requirements of the day, but sufficiently for the heaviest load that could be carried on a given gauge.

Mr. T. W. Fowler said he could not altogether agree with Professor Payne as to that stipulation. It was probably judicious that they should, in building their railways, adopt a system which
would not require alteration, and that they should now lay the
foundation of a railway system which would carry a very heavy
traffic. But if that traffic was not coming on their railways for
many years—say, 50 years, or more—then, whilst they should lay
down a gauge which would ultimately carry that traffic, he did
not see that they were at the present time called upon to build
all their structures, and have their road bed and everything of
that kind fifty years ahead of their requirements.

The President: But you would make the gauge and the clear-
ances sufficient?

Mr. Fowler said the gauge and clearances should be ample.
But take the interest and capital charges on a system, say, fifty
years ahead of requirements, and he thought, if Professor Payne
looked at it again, he would see that so long as the basis was
laid down to allow for the future, the extra expenditure was un-
necessary at present.

The President: The question of timber bridges on pioneer
lines was a case in point.

Mr. Fowler: Yes; and on a pioneer line they would not
dream of putting down 100lb. rails, although they would design
it to allow for subsequent expansion.

Discussion adjourned.

LECTURES.

THE PETROLOGICAL AND EXPERIMENTAL ASPECTS
OF THE MAIN ROAD PROBLEM IN VICTORIA.

By Prof. Ernest W. Skeats, D.Sc., F.G.S., and
Mr. H. S. Summers, M.Sc.

Professor Skeats thanked the President for his courtesy in
forwarding to him the last two or three copies of the Proceedings,
in which Mr. Anderson's paper on the Main Road Problem
had appeared, and on which a very interesting discussion had
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THE AUSTRALIAN RAILWAY GAUGE.

The discussion on the President's paper on "The Problem of the Gauge of Australian Railways," was resumed.

Mr. F. K. Eslin said that in looking into what was attempted in the early days of the railway, he was rather struck by the fact that nearly all the problems that were engaging the attention of engineers to-day had been discussed by the engineers in the very early stages. For example, the question of gauge was discussed in the early years—1835-37, and he had found that Russia, which occupied a high position at present, and which would hold a position of very great importance in the future, had built her first railway on a 6ft. gauge.

When the second railway was contemplated, between St. Petersburg and Moscow, the question arose as to whether the 6ft. gauge should be continued, or a reduction made to 5ft. They went very exhaustively into the question and finally the engineer recommended that the 6ft. gauge was probably too wide, and that Stephenson's gauge was a little too narrow. He therefore recommended the 5ft. gauge, and that gauge had been adopted and continued ever since in Russia. When the Prussian Government came to build railways there was a strong belief expressed that it would not be advisable to have the 4ft. 8½in. gauge on account of the ease of transport it would afford to an invading foe.

As showing how differently the matter was treated there to the way in which it was considered in Australia, he mentioned that there it was referred to the Prussian State Ministry as a whole to give their opinion upon it, and that Ministry decided that in the interests of transportation and finance it would be better to adopt the gauge in vogue in Austria, viz., 4ft. 8½in. In England, about the year 1835, there were six or seven gauges, and a committee was appointed to consider the matter. Finally they adopted the 4ft. 8½in. gauge; not because it was considered the best gauge, but because it was the most convenient for the time being. It was commonly reported that Stephenson's gauge of 4ft. 8½in. was decided by the distance between the wheels of the coal wagons. But the latest research seemed to show that the gauge between the wheels was 4ft. 6in., and Stephenson found it necessary to widen it to 4ft. 8½in. That appeared to be one of those cases where research seemed to upset some traditions. Going
over to America he thought that the preponderance of the 4ft. 8\text{\small{\textfrac{3}{4}}}/\text{in.} gauge there might be ascribed to the fact that, outside the United States, nearly all the capital invested was English capital, and therefore the gauge to be adopted would be practically determined by the British engineers, and there was no doubt their inclination and training would lead them to adopt the 4ft. 8\text{\small{\textfrac{3}{4}}}/\text{in.}

Coming to the Australian railways, he thought they were dealing with continental problems, and not with the problems that would be met with in smaller countries. They had in Australia to meet difficulties that did not exist in the smaller and more closely settled countries like those in Europe. There was no doubt that wider gauge must be of advantage. One very striking example of that fact was that in one of the most progressive places of the present day—Japan—they were abandoning the 3ft. 6\text{\small{\textfrac{1}{2}}}/\text{in.} gauge in favour of the 4ft. 8\text{\small{\textfrac{3}{4}}}/\text{in.}. They were widening the gauge because they found the narrow one would not answer their purposes. Those who had had any experience at all in designing rolling stock must have found that a little more space was of great advantage, especially with regard to engines. As to the permanent way works there was no question that the wider gauge had very considerable advantages.

With reference to the proposal of the third rail, he thought it was sufficient to say that, as a railway engineer, he would condemn that straight out. Anyone who had had experience in designing points and crossings and interlocking must know that there would be terrific difficulties. Take for instance the Flinders Street station. In each direction leading away from the station they encountered a three-girder bridge, viz., the two lines of way were carried by one middle girder and two outside ones. There was very little clearance of the girders, therefore where could they put that third rail? Clearly there was only one way possible, and that was inside the other rails, 6\text{\small{\textfrac{1}{2}}}/\text{in.} away. That meant that they got so much closer to the girders, with the overhang on the opposite side of the 4ft. 8\text{\small{\textfrac{3}{4}}}/\text{in.} stock. To lay a third rail in the Melbourne Stations they would practically have to reconstruct the whole of the bridges, and most engineers would know that that would be a gigantic task.

Supposing they were running two tracks, such as they would have shortly, on the New Saltwater bridge, they would reduce the central clearance by about 6\text{\small{\textfrac{1}{2}}}/\text{in.}, and with the very wide
carriages now being used that was absolutely dangerous. A car-
riage door opening might cause a disaster there. And the same
thing applied to platforms. If they widened the space between
the footboard and the platform by the use of a third rail, it was
probable that passengers in the rush to board a crowded train,
would put their feet between the footboard and platform. To
overcome all the difficulties would be almost impossible. The
only way he could see would be to design a rail of the "bridge"
type, with a very deep slot in the middle, but that would lead to
so much trouble afterwards that he did not think it would be
practicable.

As to the matter mentioned by Mr. Fowler at the previous
meeting—the "battle of the gauges"—Mr. Fowler had stated—
and justly—that the fact that gave England the 4ft. 8½in. gauge
was the problem that had puzzled the engineering world, and had
not been solved, viz., the fact that they had no proper system of
longitudinal sleepers. In England little attention had been given
to it; there they mostly had the excellent chair system with cross
sleepers. But in other countries, where perhaps less money was
available, they had tried to introduce the longitudinal sleeper,
especially in France and Germany. And it must be said that no
quite satisfactory longitudinal sleeper had yet been introduced.
If they had been able to invent one the battle of the gauges would
probably not have resulted in favour of the 4ft. 8½in. gauge.

The President asked if Mr. Esling would care to give an
opinion on the question of the third rail in regard to safety. He
had dealt with it on the ground of mechanical inadvisability. It
might be that the rail could be made mechanically possible. Theo-
retically even the interlocking might be accomplished. But on the
basis of safety, did Mr. Esling think it would be the thing to use
if they could by any means avoid it? There was another cor-
related mode of transferring from one gauge to another; that was
the movable sleeve on the axle. One of the wheels was keyed
to a sleeve, and that sleeve was, by automatic or other means,
adjusted on the axle where a break of gauge occurred. His
own experience, gained in actual railway practice, was that there
must be no adjustment which might, or might not, be made.
There must be, for safety, absolute rigidity of connection.

Mr. Esling said he objected very strongly to the third rail.
In railway work they wanted the utmost simplicity. They did not
want complications. Even with the best of inspection and plain boxes and axles, rolling stock gave enough trouble. But if they introduced the sleeve wheel and axle it would almost certainly lead to disaster. They required absolute simplicity and rigidity in railway working.

The President said they all recognised that many of their men who were in leading positions in the railway world felt that they could not discuss a question of policy, and therefore might be unable to take part in the present proceedings. He would like an expression of opinion as to whether the discussion should be closed at that stage, subject to his right of reply, or postponed to another meeting to enable further contributions to be received.

Mr. Wm. Calder moved that the discussion be postponed to the next meeting.

Mr. T. Hill said he would second the motion with very great pleasure because he felt that events were so ripe, it might be necessary yet for the Institute to take action in the matter.

The President asked, before putting the motion, if he were to understand that the discussion at that meeting should be closed at once or was he expected to give an interim reply?

Mr. Hill said he would like to hear the President's interim reply, subject to his right to a full reply later on. An interim reply at that stage would be of great value.

Mr. W. Calder agreed, and varied his motion accordingly.

The motion was then put and carried.

The President said that there were a few historical points relating to railway policy which he might place before them. Mr. Esling had shown with what care and thought some great European Governments had approached the question of gauge selection. British legislators had been no less circumspect. Each body which had approached the question had approached it in a judicial spirit, and had exhaustively sifted all that could conduce to a just decision. There had, as yet, been no similar procedure in respect to the Australian gauge.

The first case he would quote was that of Britain in 1846. They all knew of the “battle of the gauges” and how the fight was waged, although there were then but some 1,400 miles of line in question—200 broad gauge—but it was obvious to admin-
istrators that there must be great expansion, and that, whether the best gauge could be chosen or not, there must be uniformity. But they did all that they could in the light of their then knowledge to arrive at the best.

A commission was appointed by Parliament to collect evidence and to sift it. Before that commission every man able to express a competent opinion gave that opinion, and gave it freely. Then the data were most carefully collated and analysed. The records covered upwards of 1000 quarto pages of printed matter. Thus the commission arrived at a decision which was submitted to the Privy Council. In the final minute, which he would read, it would be seen that, in balanced, dignified phrase, it was recorded that it was necessary to secure uniformity, but that it was clearly to be apprehended that that uniformity was admittedly arbitrary, that in affirming the expediency of adopting the 4ft. 8½in. the superiority of that gauge was not affirmed, and that the door was to be left open for future re-consideration.


"Minutes of the Lords of the Committee of Privy Council for Trade, on the Report of the Commission for enquiring into the gauge of Railways, 6th June, 1846... My Lords do not feel themselves competent to give an opinion on the Question alluded to by the Commissioners, of the Merits of the Four Feet Eight and a Half Inch Gauge as compared with any other amongst those that have been proposed.

In suggesting, therefore (with some exceptions to be specified), the Adoption of the Recommendation made by the Commission that 'the Four Feet Eight and a Half Inch Gauge should be declared by Legislation to be the gauge to be used in all public Railways,' 'hereafter to be constructed in Great Britain,' they do not conceive that any Declaration on this Point should be understood as positive and final. The Working of the wider Gauge established in Ireland, and the future History of Railways and other Countries, may possibly prove the Superiority of some other and intermediate gauge; whilst the Advance of Science and the Course of Experience may point out a practicable Method of altering an existing Gauge, and of easily effecting a great Operation which is now generally conceded to be so costly and so difficult as, in truth, to be impracticable.
With this Explanation, my Lords beg to recommend, that no Line shall hereafter be formed on any other than the Four Feet Eight and a Half Inch Gauge..."

They would see that the committee was exceedingly clear in enunciating that they in no wise affirmed that the 4ft. 8½in. was inherently the best even at that time, but that the selection was the most expedient at the time. That was the legislative authority for gauge width in Britain.

Then, with regard to India, it had been stated in reports appearing in the Press that the origin of the 5ft. 6in. was a matter of guessing and averaging existing widths. It was not so. All that could be done was done to assure the authoritative decision of the best gauge for India, and the 5ft. 6in. gauge was the result, as the following extracts from official papers would show:—

Extract from the report of the Consulting Engineer, Mr. W. S. Simms, C.E., to the Government of India, 29/4/1850.

"The Hon. the Court of Directors, in the despatch of 14th November, 1849, par. 3, expressed themselves as 'disposed to recommend (but not to order) the adoption of that known in England as the narrow gauge, namely, 4ft. 8½in.:' but with all due respect to the recommendation so given, I beg to state that in my judgment a wider gauge would be preferable in this country, and I would recommend the adoption of 5ft. 6in., or thereabouts, as I am not disposed to contend about an inch or two more or less, as I consider it immaterial.'"

Minute, 4/7/50, by the Earl of Dalhousie, Governor-General.

"I consider the question to be one of such moment as to deserve a careful consideration and an authoritative and conclusive decision by the highest authority connected with the Indian Empire, who alone can have access to that full information and extended experience which would make such a decision really and satisfactorily conclusive."

The Directors of the East India Company, "after very careful consideration, and in the light of the best opinion which we could obtain," ruled, 7/3/51, that "Your Honourable Court have authorised the extent of the Indian gauge to be 5ft. 6in."

There was no question of chance. The Engineer, the Governor-General, and the Directors of the East India Company considered the matter of the most vital importance. Again, that
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which was done was done after exhaustive consideration, and in
the best light of the time, and with full knowledge of the prece-
ding British inquiry.

Stephenson himself was not wholly enamoured of the 4ft.
8½in., although as a consultant, he would, quite naturally, ex-
hibit a preference for the gauge of the locomotive which he, as
a manufacturer, supplied. Babbage, in his “Passages from the
Life of a Philosopher,” thus recorded Stephenson’s views:—

“Now Mr. Stephenson, will you allow me to ask you, sup-
pose for an instant no railway whatever existed, and
yet that you were in full possession of all that large
amount of knowledge which you have gained from
long experience, under such circumstances, if you were
consulted respecting the gauge of a system of rail-
ways about to be inaugurated, would you advise the
gauge of 4ft. 8½in.?"

“Not exactly that gauge,” replied the creator of railroads;
“I would take a few inches more, but very few.”

Coming down to present times Mr. T. Hurry Riches, one of
Britain’s most trusted and honoured railway engineers, whose
career had just closed, in his 1907 Presidential Address, read be-
fore the Institution of Mechanical Engineers, London, after in-
stancing the inadequacy of the present British railway and load-
ing gauges, said:—

“For these reasons one sometimes regrets that the 4ft.
8½in. gauge was the one that ultimately triumphed in
the battle of gauges, but whilst saying this it must be
realised that the old broad gauge (7ft.) was not an
ideal one, and we are led to wish that the 5ft. 6in.
gauge had been adopted.”

He had elsewhere instanced the opinions of such great rail-
road organisers as Harriman and Hill. Their views were em-
phatically in favour of a gauge wider than 4ft. 8½in.

He had submitted those extracts to show that he had been
right when he said that the perpetuation of the 4ft. 8½in. in Britain
was a matter of arbitrary expediency; that the adoption of the
5ft. 6in. in India was deliberate, and not a matter of chance, and
that he by no means stood alone in asserting that the 4ft. 8½in.
was economically inadequate as the gauge for countries of great
area and long hauls.

He did not purpose to deal, at this stage, in detail with the
various views adduced in the discussion; that would be a matter for the general reply. Professor Payne had said:

"That there was a point he had omitted to make when speaking previously. It was being assumed that Great Britain was the sinner in using the 4ft. 8½in. gauge. He would like to draw attention to the fact that the 4ft. 8½in. gauge was used in Europe by Great Britain, Germany, Holland, Belgium, France, Denmark, Norway, Sweden, Austria, Switzerland, Italy, Hungary, Turkey, and in America by Canada, United States, Mexico, Peru and Uruguay."

That view had been elaborated by others elsewhere, and a list of some scores of states had been circulated. Therefore he would prefer to deal, not with the views of a member expressed in discussion, but with the general fundamental principle involved. He had analysed one of these lists, and whilst the totals were imposing, the inferences were fallacious; for 17 States, each with a total 4ft. 8½in. mileage of less than 1,000, were included; as also were minute States with less than 10 miles of line each.

The real bases of the scientific and commercial determination of gauge were habitable area, population, topography, and length of haul. The aggregates referred to taught nothing in that respect. If the total mileage of Australian lines (all gauges, ultimately to be uniform) were compared with the mileages of all

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**Fig 1.**

**DISTRIBUTION OF RAILWAY GAUGES.**

Mercator's projection.

Areas where 5 feet or wider gauges have been adopted for trunk lines, thus: \(\perp\perp\perp\)

Areas which are committed to 4 feet 8½ inches or narrower trunk line gauges, thus: \(\parallel\parallel\)
DISCUSSION—AUSTRALIA'S RAILWAY GAUGE. 183

other countries, it would be found that, ten years hence, it would be exceeded by the broad gauge line of two States, but would exceed the mileage of any 4ft. 8½in. system, with two, or including Canada, perhaps three, exceptions. The map (Fig. 1), and the subjoined table would show the inadequacy of the mere number of States, or total length of line, as a criterion of gauge suitability.

Countries which have Definitely Adopted a Policy of 5ft. to 5ft. 6in. Trunk Line Gauges:

<table>
<thead>
<tr>
<th>STATE.</th>
<th>AREA, SQUARE MILES</th>
<th>POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia in Europe</td>
<td>2,122,527</td>
<td>132,771,700</td>
</tr>
<tr>
<td>, Asia</td>
<td>6,525,130</td>
<td>22,661,600</td>
</tr>
<tr>
<td>British India</td>
<td>8,647,657</td>
<td>155,433,300</td>
</tr>
<tr>
<td>Argentina</td>
<td>1,097,821</td>
<td>231,855,533</td>
</tr>
<tr>
<td>Brazil*</td>
<td>3,292,991</td>
<td>21,531,100</td>
</tr>
<tr>
<td>Spain and Portugal</td>
<td>230,260</td>
<td>24,909,585</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>14,404,569</strong></td>
<td><strong>440,535,202</strong></td>
</tr>
</tbody>
</table>

Countries which are Committed to 4ft. 8½in. and Narrower Trunk Line Gauges:

<table>
<thead>
<tr>
<th>STATE.</th>
<th>AREA, SQUARE MILES</th>
<th>POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe (excepting Russia, Spain, and Portugal)</td>
<td>1,507,482</td>
<td>283,182,651</td>
</tr>
<tr>
<td>N. and Central America</td>
<td>8,554,490</td>
<td>120,529,770</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td><strong>10,061,972</strong></td>
<td><strong>403,712,421</strong></td>
</tr>
</tbody>
</table>

* Government Trunk Lines.

The ratios were thus:—
Gauge, 5ft. and over: 4ft. 8½in.
Area 14.4: 10.
Population 44: 40.
Not the mere number of States using a gauge, but their importance and parallelism of condition with Australian present and future conditions must be considered. For instance, there could be no comparison between Britain, with its small area, dense population, great internal interchange and 25 mile mean hauls, with Australian conditions, and a mean haul which must reach 220 miles.

Mexico had been claimed as a country "using" the 4ft. 8½in. But whilst Mexico had some 6,000 miles of that line, the configuration and topography of the country were such that it had also some 9,000 miles of narrow gauge roads. As a generalisation, the table and map would show that the States of great area and great present and future possibilities had adopted gauges wider than 4ft. 8½in. On the other hand, many States of lesser area or possibilities were adopting the 3ft. 6in., or the metre gauge, in preference to the 4ft. 8½in. In regard to Africa and China, there was nothing to show what the gauge would ultimately be.

If the great railway mileage of the United States (4ft. 8½in.) were excised, there could remain no doubt as to the preponderance of wider gauges in the largest States. And it must be remembered that railway organisers in the United States had most emphatically announced the inadequacy of the 4ft. 8½in. as an economic gauge under the present circumstances of traffic.

A statement had been published, elsewhere, to the effect that originally all engines had inside cylinders, but that as greater power was required, and as the 4ft. 8½in. did not permit of the use of larger inside cylinders, the Americans solved the difficulty by placing the cylinder outside, and that that practice had now become almost universal for quick and heavy traffic.

That was, he need hardly point out, quite incorrect.

He would show on the screen a view of the first English engine, Stephenson's "Rocket" (1829)—an outside cylinder engine. Next he would show America's first locomotive, the "America," also built by George Stephenson, in the same year—again an outside cylinder engine.

The next view showed the "Washington," the first engine built in America (by Wm. Norris, Philadelphia, 1836)—again an outside cylinder engine, following Stephenson's model closely.
DISCUSSION—AUSTRALIA'S RAILWAY GAUGE.

The Americans had ever since retained that type; there was no question of this being a recent American discovery, overcoming the disadvantages of the 4ft. 8½in. in respect to heavy traffic. But British and Continental engineers at a very early date abandoned it in favour of the easier running and less road-deteriorating inside cylinder type. And wherever traffic and gauge permitted the use of that type it was still the practice and tendency of those engineers to adopt it. This was a matter of the most commonplace knowledge to locomotive engineers.

The question of loading gauge was certainly not less vital than the question of rail gauge. But the width of the loading

Fig 2.

STANDARD CLEARANCES.

REFERENCES:

Minimum structures, heavy lines.
Maximum rolling stock (locos. left, cars and wagons right), thin line.
American "Mallet" engines, dotted lines.

NOTES:

1. Adopted in conference by New South Wales, Victoria, and South Australia in 1905 as the minimum structure dimensions for future, 4 feet 8½ inches and 5 feet 3 inches main lines.
2. When double lines are in question this encroachment on the minimum structures will be twice that shown.
gauge, and the ultimate capacity of the stock depended upon the width apart of the rails; although alteration of rail gauge could be effected quite independently of any change of loading gauge.

He exhibited the diagram (Fig. 2) of the standard minimum distances of all structures from the rail on main lines, adopted by the New South Wales, Victorian, and South Australian railway representatives in conference.

They would note:—

a: That stock capable of passing the structures on the main lines of any of these States could with equal ease, if the gauge were altered, pass the structures of any other State without alteration of those structures. Or, as he understood that there were encroachments within the gauge, wherever the standard was adhered to, the stock of any State could pass.

b: That the capacity of the Victorian and South Australian stock was greatly limited by the adoption of the standards of structures intended for a narrower gauge.

c: That the rolling stock and locomotives in N.S.W. had been widened to the very utmost limit of the clearance.

d: That modern American 4ft. 8½in. stock could not pass these structures.

It would be clear that, except where the older works did not conform with the common standard which had been adopted for all present and future use, the alteration of gauge, whichever gauge was adopted, would not involve an alteration of standing works. Obviously if there were encroachments those encroachments closed the lines and sections upon which they occurred, not only to the stock of other States, but to the modern stock of any State in which they existed.

He then showed views of some of the recent heavy "Mallet" American engines. These engines were of the 4ft. 8½in. gauge. They were far more powerful than any engine on the Australian 4ft 8½in. gauge. It had been implied that they would enable the traffic here on that gauge to be increased to the American intensity. That was true, provided the conditions were made similar. For these engines were built for very special traffic (as "pushers" at speeds of from 5 to 10 miles per hour).
were very few of them, for to strengthen the American roads
to carry them generally would require a capitalisation little, if
anything, less than the £1,000,000,000 J. J. Hill estimated
would be necessary to widen the gauge, or duplicate the lines,
of the United States.

Before even the smallest of these engines could run on the
N.S.W. lines it would be necessary (vide Fig. 2) not only to
strengthen the roads and bridges, but to also alter every plat-
form, and every structure conforming with the standard clear-
ances. There could be no further widening of the rolling stock
in the States named, except the clearances were increased also.

It would be seen that the loading gauge and clearances, and
rail gauge conversion were matters distinct. These structural
alterations must be made, gradually and as occasion justified,
if the gauge—either gauge—in Australia was to be the economic
equal of the 4ft. 8½in. elsewhere.

Mr. Hales (p. 141) had quoted the capital value of the Aus-
tralian lines as about £150,000,000. That was so, but not the
whole of that referred to the three States in regard to which esti-
mates of gauge conversion had been made. Mr. Hales had
pointed out that an expenditure of 2½ per cent. on this total
would give an extra capacity of 10 per cent. at least. But after
allowing for the lesser sum involved in respect to three States
only, the annual interest on the increased cost of providing for
an increased capacity of “at least 10 per cent.,” would be about
1-11 of one per cent. on the total capital involved.

Mr. T. Hill said that it was claimed that 300 ton locomotives
were run on the 4ft. 8½in. gauge of the United States. Would
the view shown refer to an engine of that weight?

The President said yes. But there were engines of 378 tons
in use on that gauge. But there were very few of them. They
were used on very special sections for very special work—not
indiscriminately over the whole system.

Mr. Hill: Where there were no tunnels?

The President was not aware that there were any tunnels
on those sections.

Mr. Hill said it had been stated that the 4ft. 8½in. gauge
would carry the 300 ton locomotive with a corresponding tractive
force. Did the President infer that they needed a wider gauge for that?

The President said that if they could pick up a 300 ton 4ft. 8½in. locomotive from the American lines and drop it upon a 4ft 8½in. Australian line it could do precisely the same work, but before it could traverse a section the lines must be relaid, the structures rebuilt, and the clearances enlarged.

Mr. Hill said he was pressing the point because it was said if 300 ton engines could do the work in America they could do it in New South Wales. Was there any question of mountain grades?

The President said these engines were working what were there called mountain grades i.e., 1 in 70. But there were grades of 1 in 50 on the main lines here, whilst the ruling grade on the proposed transcontinental was to be 1 in 70.

He would again point out that it was mechanically possible to build engines even heavier, but these locomotives were admittedly abnormal expedients to deal with abnormal traffic intensity on an inadequate gauge. They necessitated relatively high working, maintenance and freight charges; but they were the only alternative to widening the gauge or duplicating the American lines at a colossal increase in capitalisation.

Mr. C. W. Wagstaff asked if the President could give a basic unit of gauge, and how they would determine the advantage of gauge or the determining factor?

The President said it would be exceedingly difficult to answer that in a few words. He had postulated in his paper that "all gauges are arbitrary, and their efficiency is dependent upon conditions which may, and do, alter." The gauge suitable for the great flat stretches of Australia might not be the best for hilly country of low productivity. High or low value of freight, climate, topography, length of haul, area, population were all factors in determining which gauge would return the largest dividends or permit development at the least cost.

Mr. Wagstaff said what he had in mind was the traffic capacity.

The President said that fundamentally the wider the gauge, the wider and higher the rolling stock might be without re-
ducing the co-efficient of stability. The speed, and therefore the freight moved in a given time, might also be increased. As a generalisation the economic carrying capacity varied as a power greater than the square of the gauge. A 5ft. 3in. gauge would have a safe carrying limit about 20 per cent. greater than that of the 4ft. 8½in.

Mr. Hill asked whether the overhang of the rolling stock had been fully developed?

The President said not here, but in America it was probably approaching the limit, if it had not reached it.

Mr. Hill asked if the overhang were fully developed, for instance, in the case of a 5ft. and a 6ft. gauge, would the difference exceed the 1 foot difference of gauge width?

The President said assuredly. The ratio of the total rolling stock widths would be greater than the ratio of gauge widths.

Mr. T. Hill thanked the President, and trusted that the matter would be further elaborated at the next meeting.

[The following contribution from Mr. J. T. N. Anderson has been received since the date of the meeting.—Publication Committee.]

Mr. J. T. N. Anderson wrote as follows:—The writer is to be congratulated on the clear and trenchant manner in which he has made it obvious, to those who are sufficiently free from bias, that a great continent, with such broad unbroken tracts of land to develop, cannot be adequately served by a narrow gauge of railway.

He has made it clear, too, that even the 4ft. 8½in. gauge—formerly called in Great Britain, the narrow gauge—is inadequate to meet the heavy transport demands which the large areas our main lines must serve will put on them.

In considering the railway gauge problem, it may be conceded that, though not immediately thrust on us, still the military aspect may at any time become a vital one, and therefore must be considered of equal value with the commercial aspect.

It will be clearly seen that our military problem, compared with most countries’ military railway problems, is a singularly simple one, since we are only concerned with defence. And, while in European countries it is conceded that the most effective defence is the power to act on the aggressive, and consequently
that, though while for purely acting on the defensive, it is con-
ceded that a different railway gauge is a distinct, a great advan-
tage, it is yet inadmissible, because it would so much hinder any
attempt at attack aimed against a hostile neighbour.

In this respect Australia is unique. Of all the nations in the
world, she alone holds the whole of a continent island, with no
neighbour, who could possibly attack her, to share it, and all at-
tack must come from beyond the seas.

Hence, it will be seen that military tradition and military pre-
cedent are useless here, and, whereas elsewhere military canons
require conformity with the ruling gauge of neighbouring
countries, here the reverse is the case.

Thus, assume a unique gauge on the Australian lines, and
consider the position of an invading army. Unless it has, with
incredible foresight and enormous cost, prepared for the expedi-
tion hundreds of specially made locomotives and thousands of
trucks, it will find itself devoid of any railway transport facilities,
except such as it might be skillful enough, and successful enough,
to capture locally before our resourceful Australian soldiers have
been able to destroy them. Consequently, while the railways will
have their full efficiency for the defenders, they will be useless to
the attacking force.

This military question, therefore, instead of, as is usually the
case, being the determining factor for the establishment of the
4ft. 8½in. gauge, should be a powerful factor to abolish that
gauge.

Returning to the commercial aspect of the question: Few
who have not gone into it are aware that the reduction in the cost
of conveying heavy goods trains over a wider gauge is so con-
siderable, that, granted heavy goods traffic for only, say, two
months in the year, the extra capital expenditure in the wider
gauge, say 6 ft., as compared with 4ft. 8½in., will be more than
warranted.

Or, take the more moderate proposal before us, which is not
to follow the lead of the gauge reformers in the United States
and consider the 6ft. gauge, but to adopt the 5ft. 3in. gauge,
which is the standard at present in Victoria and South Australia.
The comparison will work out at a total cost per mile con-
verted of, say, £200. Against this trifling cost, the annual sav-
ing in traction on the steadier line would be at least 10 per cent.,
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or equivalent to at least 2 per cent. of the total annual costs. This, on the moderate estimate of £500 per annum per mile, works out at a return of 5 per cent. per annum on the capital invested. But such a calculation only shows one side, and the least attractive side of the advantages which will follow the alteration from a 4ft. 8½in. to 5ft. 3in. gauge. The most potent argument, and the most valuable advantage, is the greater carrying power, both for goods and passengers, of the wider gauge.

Approximately, the slight alteration in gauge will enable 25 per cent. greater loads to be hauled, without any alteration either in the length of the trains, or the size of stations or shunting yards, beyond the very trifling alteration in width of the latter.

This amazing increase is brought about by the fact that not only can broader and higher rolling stock be used, but, as has been repeatedly proved, greater speeds can be attained. The first two factors, of course, vary directly as the gauge varies, and the third, speed of running, varies in a greater ratio, being influenced, not so much by the steadier running obtainable, all other things (depth of ballast, weight of rails, etc.) being the same, as by the more powerful locomotives that can be employed.

Thus:—Let \( g_1 : g_2 \) represent the rival gauges.

- \( h = \) height of rolling stock (from "loading gauge").
- \( gw = \) width of rolling stock (from "loading gauge").
- \( s = \) speed of traction.

Then assuming the fraction,

\[
\frac{g_1}{g_2}
\]

as the ratio of the hauling capacity of the two gauges, then:

\[
\frac{g_1}{g_2} = \sum s \int h \int \left( \frac{g_1w}{g_2w} \right)
\]

It is hardly opportune in so general a discussion to go into questions of mechanical detail. But two questions of detail have been raised in the discussion of the question elsewhere, which are misleading, and consequently this Institute should enter its protest regarding them.

The first is the statement that the advantage originally claimed for the wider gauge, that it enabled larger diameters to be used in the steam cylinders, has disappeared with the rejection of the British type of inside cylinder engine. Not only does the inside
type of cylinder still survive, but there are constantly coming forward improvements in multiple cylinder types, so that it is more than probable that for high speed, if not for heavy traction, the balanced four-cylinder engine will win the premier position. The second statement was that a wider gauge involved much stronger and heavier axles. The difference in this respect is as $\sqrt[3]{g_1/g_2}$ and in the gauges under consideration it is inappreciable.

In all the aspects of the case, the advantages for country work are in favour of the wider gauge. Conservatism, which fears to embark on anything except what has the greatest weight of precedence behind it, seems the only factor which threatens to saddle this country with the gauge which has been evolved to meet the needs of a country where the interests to be served are urban, and where the bulk of the railways capital is sunk in lines in such crowded districts as Middlesex or Lancashire. And tradition, too, will tend to crush the patriotic effort to evolve the best gauge for Australia.

Discussion adjourned.
engineers to return with the rock they may submit, which will set out all the particulars of the sample, and the quarry whence it came.

Discussion closed.

THE PROBLEM OF THE GAUGE OF AUSTRALIAN RAILWAYS.

The discussion on the President’s paper was resumed.

Mr. A. C. Mountain said he was afraid that nothing approaching an impartial and just decision on that important matter could be hoped for until some assurance was given by the Commonwealth Government that the particular State which would have to undertake the alteration would not be at the loss of such alteration, because that would mean a very cruel tax on that particular State. Until that assurance was given he doubted very much if the professional officers—the men to whom they would look as experts—would be able to give an unbiased opinion as to what was the best thing to do. Whereas supposing they knew that it was a matter the cost of which would be borne by the Commonwealth, they would be free to give an opinion, even though it might be adverse to the State which employed them. They could not expect an engineer who had been engaged for a number of years by a State to immediately say that the gauge adopted by that State should be abandoned, and the gauge adopted by another State taken up. All that would be removed if it were explicitly stated that the expense of the alteration would be a national one, instead of being left in uncertainty. It was essential that they should get the best expert opinion in the matter, as it affected not only the present but the prospects and prosperity of the whole country. Therefore it would be foolish to start without getting an unbiased opinion.

The President, in replying to the discussion, said it was within his knowledge that it had been put forward that a condition precedent to the adoption of any particular gauge should be the laying of the foundation for the subsequent adjustment of the cost of that gauge. That course had not met with the approval of the powers that be. But such a course would be necessary to secure an impartial and a just decision from Departmental officers.
As to the general discussion he had not much to reply to. Mr. Hales, Mr. Anderson, Mr. Fowler, and Mr. Esling had agreed with him in full; as to the relatively small cost involved in making the alteration from the narrow to the wider gauge; as to the increased capacity attained by making the alteration; as to the great disadvantage of using the third rail. He could not place too much emphasis on the fact that there was grave unsafety in the use of the third rail. He would prefer to see all the disadvantages of a temporarily disorganised traffic rather than the use of the third rail. If the proposal were adopted to carry the heavy ordinary traffic and the express traffic in that manner there was every probability of a great disaster.

Professor Payne had dissented from him in some points, but he did not think he dissented in regard to fundamentals. He could not see eye to eye with the Professor when he laid it down that the increment in weight of locomotives was proportionate to the increment in length. It had not been so in the past, and there were no data known to him indicating that it would be so in the future. During the last few years locomotives had increased from 70ft. to 120ft. in length, but the tonnage had increased from 100 tons to 400 tons. That was a great discrepancy between increasing weight and length ratios. Until it was assured that the cross section available had been fully utilised it could not be said that the weight of the locomotive would increase only in proportion to its length. The bearing on bridge construction was obvious. He could not agree, either, with the assumption that they should at the beginning make the bridges on all lines of sufficient strength to carry any locomotive that might be constructed thereafter. He did not know of any country which could financially afford to do that. He would not say that any country should—as a matter of sound economics—adopt that policy even if capital offered. It would be impossible under pioneer conditions.

Weight had been placed by several speakers (in the Institute and elsewhere) on the fact that in America 400-tons engines were in traffic. He did not think that was a valid argument as to the capacity of the 4ft. 8½in. gauge. There were not 60 of those engines under construction and in use—not one engine in 1000 of those in use in the United States alone. They were as yet experimental, and whether those engines would be the type of the future
was very problematical indeed. They were used on very special and relatively short sections, and for very special work. He could not find that any of them had attained a speed of more than 15 miles an hour, and most of them were in use as "pushers" at only five to ten miles an hour. They could not draw general conclusions as to the enormously enhanced capacity of a gauge for general purposes from the fact that such engines as those existed. Professor Payne, too, had introduced a subject that others had elaborated, thus,—

"The President had opened the question in a very clear manner, but it seemed to him that the paper had hardly expressed the whole position. In reading the paper he noticed there were places in which there were two sides to the question, and the second side had been left out. Such, for instance, as the failure of the railway transport in Siberia. That was merely due to the fact that there was a single line, instead of a double line."

Naturally he had not dealt with the subject exhaustively. It would not be possible to do so in a small paper. But if he had not dealt with it exhaustively he had dealt with it to the best of his ability, and fairly. It could have been elaborated in discussion, but he did not think that any attempt had been made to supply the essentials assumed to be omitted, and he did not think there had been any definite advantage shown for the 4ft. 8½in. gauge which the 5ft. 3in. gauge did not possess in a greater degree.

He had not stated that the railway transport "failed" in Siberia. It had not failed. It was one of the redeeming administrative records in the Russo-Japanese war. He thought the parallel that he drew was the true one. In Australia, with the exception of a few hundred miles, the whole of their railways were single line tracks. The Siberian railway was a single line track. The transcontinental railways in Australia were to be single line tracks, and the prime intent was military. He was, in the clause quoted, specifically dealing with the military capacity, and he was comparing single line with single line traffic through almost uninhabited country, and with the only example of similar use, conditions and traffic, and he drew conclusions as to the military capacity, not only of the 4ft. 8½in., but of the suggested 3½ft. 6in. trunk lines also. He held that the comparison was just, and that it was no answer to say that if doubled the Trans-Siberian railway would become more effective.

It was one of the chief advantages of the 5ft. 3in. gauge that it had a capacity one-fifth greater than the 4ft. 8½in.
gauge. That one-fifth greater capacity meant that they might defer the time when they would have to duplicate the single lines, perhaps to an indefinitely remote period. And they must remember that the duplicating of a single line meant in a general way doubling the invested capital on that track, and that that capital was doubled, or increased, without any immediate traffic return therefrom. Perhaps the traffic might never increase 20 per cent., but upon the sufficient increase of traffic the net revenue depended. Everything that would tend towards postponing the time when the duplication of the lines would be a necessity was a marked advantage as far as Australia was concerned. He did not think he could convey his views better than by quoting himself in regard to the relation of economy and capacity.

"It is insisted that the ability of a gauge to permit of the haulage of heavy loads, and high speeds, is the proof conclusive of the adequacy of that gauge. The mechanical possibility of accomplishing all this is a matter of common knowledge. But mechanical possibility is a very different thing from commercial efficiency—and that is the issue.

Mechanical engineers know that they can attain these former objects readily on a narrow gauge, even when the economic capacity of such gauge has been far exceeded. But they know that it is at the cost of decreased safety and increased running and maintenance charges, and that it implies heavy additional capitalization consequent upon the strengthening of the roads, etc.

Administrators know that they cannot meet these increased charges unless they maintain high rates. They know that the primary products carried over long distances cannot bear high rates. Therefore when the economic capacity of a gauge is reached, or approximated, the carrying of such products—and, incidentally, developmental work—is discouraged. That discrimination is one of the charges made against railway trusts elsewhere; it would be even more inimical here."

It was one of the chief charges against the American Trusts that they differentiated. Charging the higher rates enabled them to run the heavy locomotives, so often alluded to; running heavy locomotives enabled them to avoid or postpone the heavy cost of general duplication or gauge alteration, but the farmers relatively suffered, because they could not ship their produce at a price permitting world competition at rates fully remunerative to the producer.

That really was the crux of the question—20 per cent. additional capacity. It had been answered (elsewhere) that the undeveloped potentialities of the 4ft. 8½in. were so enormous that no other gauge need be considered. He would quote an example:

* Federal Parliamentary Papers, numbers 49 and 51, Nov. 1911.
DISCUSSION—AUSTRALIA'S RAILWAY GAUGE.

—Starting on the basis of a single line with stations five miles apart, it was stated that if the line were doubled (a matter which, in fact, they wished to avoid) and if they used automatic signals one mile apart (which had not been proved or adopted as possible in general practice), and if they increased the weight of the locomotives to 378 tons (for which there was no general authority), then it would be capable of carrying 160 times the present amount of traffic over a 4ft. 8\(\frac{3}{4}\)in. single line. That had been presented to the Senate in detail, for its guidance, and had been seriously considered, and, apparently, accepted.

Mr. G. A. Turner asked who was responsible for that statement.

The President said it was a paper* that had been presented to the House, through the Home Affairs Office. It was placed on the table of the House, and had been printed and published, and bore the signature of the Government officers.

Analysing the Statement:

Starting with a single line with stations five miles apart, first the line was doubled, and it was stated that with the doubling of the line the capacity would be also increased at least eight times and that that was a conservative estimate. Then by proceeding another stage—the line now doubled—but now with sections (or stations) each mile, instead of one each five miles, and with automatic signals, the capacity would be increased again five-fold.

Taking that system, on which it had been assumed that locomotives of not more than 105 tons had been used, and substituting locomotives of 378 tons, it was stated that once more the traffic could be multiplied by more than 3\(\frac{1}{3}\), making a total increment specifically stated as of "160 times" the traffic of the original line. It did not take much to break those figures down. It was a very simple matter to run over the original track two trains each way per hour, or four trains in all; 160 multiplied by four thus meant an allegation that 640 trains an hour could be run over the proposed 4ft. 8\(\frac{3}{4}\)in. double line.

Mr. F. W. Temple said that the final multiplication (by 3\(\frac{1}{3}\)) gave a total of 140, not 160.

The President said he was quoting. Obviously the fact was as put by Mr. Temple. It might be a matter of clerical inadver-

tence, but all the steps were clear, as also was the meaning. Taking the figure as it stood—adopting 140 could not alter the result appreciably—and assuming that the trains were of the same length, that would give 640 trains per hour—about one each 5\(\frac{1}{2}\) seconds.

Mr. A. C. Mountain said the trains hauled by these heavier engines would be much longer.

The President said it could be assumed that the trains would be much longer, but that would not save the situation. To assume the four trains it was now possible to run per hour to possess an aggregate length of half a mile was by no means an excessive estimate. Multiply that half-a-mile by 160, and it followed that, to carry the same traffic, 80 miles of trucks per hour would be required. It followed, that before traffic could be increased in the ratio that was claimed, it would be necessary to send 40 miles of trucks over one road and receive 40 miles on the other each hour. Unless the speed of the trains exceeded 40 miles an hour the trains would exceed the whole length of the available road.

In connection with the great question of the Australian gauge there was no body but a body of expert engineers capable of saying what should be taken into consideration in the matter. No lay jury, however conscientious they might be, however able they might be, could have the intuitive knowledge necessary for the detection of fallacy in those matters, and no body but a selected body of engineers was capable of saying technically what the gauge for Australia should be.

Mr. J. T. N. Anderson had supported his point that the gauge should differ from the military gauge of other countries for military reasons. The gauge of China had been referred to. It was not determined yet. There was as yet no uniformity of plan. What gauge would be decided on for that Empire no man could predict. Japan—a small State—had altered to 4ft. 8\(\frac{1}{2}\)in., and proposed that it should be the gauge for Korea also. Assuming that Korea, China, and Siam adopted the 4ft. 8\(\frac{1}{2}\)in., and connected, the whole Eastern East would be brought within some few days' cruiser sail of Australia. He could not speak with military authority, but it seemed injudicious to make our gauge such that
our lines would, almost, become virtual continuations of those of States which might become dangerously hostile.

There was another point, that of the loading gauge. He thought that he might say that all who had taken part in the discussion were of opinion that the loading gauge was equally vital with the rail gauge. He exhibited the official diagram upon which the diagram of clearances already published in the “Proceedings” was based. He would point out that in adopting those clearances the limitations that came down to us from the past were perpetuated, and in adopting the correlated loading gauge they had deliberately put on one side the advantage they might have had from the wider stock possible on the 5ft. 3in. Whatever gauge was adopted, it would still be necessary to increase that loading gauge and those clearances to permit of the realisation of the full capacity of even the lower gauge.

The stock had gradually attained its full dimension, possible under those arbitrary limits. But the American stock was very much wider, and before they could in Australia run stock on the 4ft. 8½in. gauge equal to the stock running on the same gauge elsewhere they would have to alter every station, if not all the tunnels and bridges. They would have to incur expenditure which apparently their administrators had not begun to apprehend. And it was not fair to call that a charge against the 4ft. 8½in. or 5ft. 3in. gauge. The engineers of the past made what they believed to be ample allowance for the future; but that allowance was now found to be insufficient, and there was no doubt it would have to be increased in the near future.

He would again accentuate most emphatically the position, that in deciding that the 4ft. 8½in. gauge should be the gauge of the transcontinental line, and thus virtually deciding that it should be the gauge of Australia, the gauge question had not been the issue that had been tried. The point had been the consideration of the least money cost of conversion of the Eastern and Western States lines. Unfortunately the question of gauge had been associated with questions of lesser economics, and it had been decided, not on its merits, but because it was desired to pass, in short time, a Bill to construct a certain connecting railway.

The first consideration should have been the allocation of cost;
then the purely engineering question of the best gauge per se, not for to-day or for to-morrow only, but for generations hence, should have been decided by the engineer, or by a conference in which the engineer predominated. That had not been done. What the ultimate result would be he knew not.

The discussion was declared closed.

THE PETROLOGICAL AND GEOLOGICAL TESTING OF ROAD METALS.

The President declared the discussion on the paper by Professor E. W. Skeats and Mr. H. S. Summers open, and said there were several of the leading municipal engineers of Victoria present; he trusted they would have something to say on that question, largely a new phase so far as Victoria was concerned—the microscopic examination of rocks used in road construction.

Mr. WM. Calder said he had very much appreciated the very valuable addition to the literature on road-making that had been supplied by Professor Skeats and Mr. Summers. They were pleased to know that the University was shortly to become equipped with apparatus for the practical testing of road stones. So far that had only been done to a very limited extent. Some twelve months ago Professor Payne was good enough to test for him some bluestone from the Footscray quarry, in 2½ inch cubes. Those tests were very satisfactory, and showed that the rock compared well with some of the best basalts in use in Great Britain. So far there had been no facilities for testing for abrasion and several of the other important tests, but they were pleased to know those facilities would be available very soon.

He noticed Professor Skeats had mentioned that the French roads were the best in the world. He thought British engineers might take exception to that statement. Personally his knowledge of French roads was confined to those roads immediately on the outskirts of Paris, but he doubted if they were better than the roads he saw in Great Britain. After the Road Congress, the English engineers, after having been to France, and having seen the roads there, came to the conclusion that they had not a great deal to learn, at least as regarded the actual condition of the roads and the maintenance of the surfaces. He believed, on the
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