FOREWORD:

For the second time the delivery of the presidential address falls to my lot. Again there has been difficulty in selecting a subject not already polished to sufficiency. But one of the chief objects of our constitution, the advancement of those engineering matters "which tend to develop the resources of Australia," gave a clue.

Unquestionably the factor most potent for good or ill in Australian development is an essentially engineering subject—Transport. Of the great sections constituting transport, the greatest is—Railways. And in railroading the greatest problems are not questions of a part, of a province, of a State, of the immediate present; but they concern the co-ordination of the whole, in relation to a continent, in relation to the life-period of a people.

A passing glance, a brief mention of salient facts, of the most intense needs, is all that can be attempted. The mere enumeration of the articulations which form the skeleton scheme* of this address clearly conveys that, in some forty minutes of your time, in some dozen pages of the "Proceedings," it is impossible to show how best to use that knowledge which is the past, how best to anticipate that knowledge which is the future.

Australia is emerging from the pioneer stage; the time of simply-grasped obvious procedure has passed. The time of issues of great magnitude, of great complexity, is with us. If the potentialities of Australia's boundless possibilities are to be realised—nationally, commercially—railway engineering must be raised from the minor phase of tactics and technique to its true plane, that of administrative science of the order of statesmanship. For the problems are worthy of the statesman, but the solutions are possible only to the engineer.

Should this be made in some degree clearer by that which follows, the purpose of this address will have been fulfilled.

PREFATORY:

Summarised, achievement and requirement may be measured thus:

Australia has built 16,212 miles of line: one mile for each 259 of its population: serving (actually), within 20 miles of rail, about 390,000 square miles of territory, about one mile for each 11 individuals (Plate 2).

* Vide appended synoptic table.
Britain has 23,100 miles of line within an area of 121,390 sq. miles: one lineal mile per 1,934 inhabitants: one square mile per 363 people.

As allocated, Australian railways serve a territory capable of supporting within twenty miles of the rail more than three times Britain's population (Plate 3).

Britain and the United States have one railway gauge, Australia has five.

When all Australian territory shall have been brought within twenty miles of the rail, at least 74,000 miles of lines will have been laid. For what more the future may hold; for the magnitude of the works which may crown the beginnings of to-day, look to the railways of the United States.

SECTION I.: WORLD-RELATIONS.

The lesson of world-relations is dual. It fixes the place of this land in regard to other lands. It gives a standard by which local effort may be gauged and guided.

*External Environment.*—A handful of colonists, inhabiting a great land, insular and without indigenous population, with great separating tracts of sea and land, might choose comparative isolation. With the extension of the rail the choice has vanished, and ideas must be readjusted to the exigencies of an environment which cannot be controlled.

Convention is apt to colour consideration of Australia's cosmographic relations. As an instance, the Mercator projection is excellent for the ends for which it was planned, but by its distortions of area and position it gives an exceedingly erroneous impression of the continent in regard to the outer world. Apparently separated from congested centres of activity, reached only by long detours from direct lines, the reverse is, in fact, the case.

Change the viewpoint: Instead of accepting the equator as an arbitrary base line, substitute a similar great circle cutting the meridian of Greenwich at 30 deg. N., a little to the south of England. That line is the shortest path between any two points situated in it. Follow the trail east: Beginning just south of England it passes through France, through Central Europe, tracing closely the lines along which rail systems are strengthening towards Southern Asia. It crosses Persia, traverses India, cuts diagonally through West Australia and grazes Tasmania and New Zealand. It extends across the Pacific, intersecting Panama at the canal region, thence returning direct to the starting point.

A relatively narrow belt, symmetrical about that line, contains more populous, civilised, powerful and directly-connected states than any other zone of an equal area of the earth's surface. It is, in truth, a Band of Dominance. In it the points of chief control—the chief links in the connecting lines—are held by the English-speaking, railway-building races. In that zone Australia's posi-
tion is not one of isolation; it is a focal area which must respond to every great change (Plate I).

Each link in every vital connecting chain of the world's transport has hitherto been dominated by the sea-link. The ocean-link is still the first link. It is no longer, in the old sense, the only link, and its length and time value are contracting. The era of the rail is with us.

Within half a week's quick steaming from the North there are points on which are converging the lines of concentration which are surely developing in the East—lines which tap regions of dense population and power; lines along which the epoch-making movements of the future must pulse.

Already the map of Asia, with its railway beginnings, great extensions, abrupt endings, its intervening blanks, conveys its lessons of diplomacy, is significant of the future struggle for supremacy by the methods of engineering, by a war of the rail. When all is straightened out, when the Trans-Siberian shall have come south through an awakened China, when expediency shall have justified the elimination of the Thibetan, Afghan and Persian railway deserts, when the Central European lines shall have pushed east, picking up the African connection on the way, Australia will, for good or evil, be exceedingly near to the old world and its problems of commerce and power.

Defence.—Such a train of thought leads naturally to the railway issue of major national consequence—the place of the rail in defence. Undoubtedly the mental attitude in railway matters has tacitly postulated unbroken peace.

But, with changing conditions, concepts must change. A possible enemy may not be the seeker, but may be the sought. The question of rail-born armies, with the sea as a narrow barrier or short connecting link, according to the point of view, must be a vital factor in the question of co-relation of States railway policies. The condition, partly of external, partly of local creation, can be met only by work based upon clear-cut common intent. Thus only can great areas be efficiently protected by the concentration of a small population, normally widely-diffused in a peaceful occupancy of those areas.

Unoccupied areas are in themselves defensive barriers, not to be prematurely removed until effective substitutes have been devised. The work must be wisely planned and advanced, for, once constructed, the railway is an indestructible highway, which may be used for invasion.

Availability of Resource.—The simultaneous attainment of military aims and local commercial ends may seem difficult, but the factors are not incommensurable; and, rightly understood, the underlying law is a law common to both questions—to coin a phrase, it is availability of resource.

Severally, neither area, climatic conditions, populations, nor population density, affords an adequate standard of effective
power. A country may be great in area but unpopulated; densely populated, it may yet be small; large, and densely populated, it may be deficient in transport facilities. By the extent of its utilisable territory; by the sufficiency of the population to secure complete utilisation; by the sufficiency of the transport to concentrate utilisation, the strength of a people is measured. The standard must be a compound ratio recognising area, population and transport.

Australia is singularly blessed in regard to territory. It possesses very considerable transport facilities. It is lacking in the third factor—population. In that connection, world-relations will force the more intelligent utilisation of the means which the railway engineer has already provided.

SECTION II: INTERNAL RELATIONS.

STATES SPHERES:

Boundaries.—Australian territory is allocated by State political boundaries. The frontiers chiefly follow—sometimes for many hundreds of miles—imaginary lines of longitude and latitude. They are crudely arbitrary, conforming to no natural law or condition. Artificial as these delimitations unquestionably are, they constitute very real impediments to a homogeneous system of internal transportation.

Each State is a segregated railway entity, segregated by its boundaries, segregated by gauge differences, which are a consequence of boundaries. Each State has its own political control, its own organisation, its own aims and objects, its own unchangeable rolling-stock.

Differences of Purpose.—Naturally profound differences of plan and operative mode have resulted.

Queensland’s roads penetrate inland as parallel slightly-branched trunk lines feeding a connecting coastal navigation service. Ultimately the connection will be by coastal line.

New South Wales lines fan out from Sydney, with secondary radiations from the main radii. The system effectually isolates point from point, but concentrates the trade of an immense area at the capital, through which all interchange must pass.

Melbourne is the focal point of the Victorian lines. By reason of the inherent advantages of the metropolis as a great continental port, conjoined with the smallness of the sphere assigned, the development is more intense than in any other of the States. As a consequence an intermeshing cross-reticulation supplements a radial reticulation.

The elementary lines of South Australia predetermine no definite after-system. The undeveloped wealth of the great Northern Territory awaits the coming of the rail.

The railroadisation of the one million square miles of Western Australia has hardly begun. The lines are rather developmental concessions to chance-placed mineral areas than evidences of the commencement of general systems.
Divergence of purpose, or lack of considered purpose, is of lesser moment if States are considered isolated except by capital-to-capital lines. They are of fundamental import if the States are considered as the components of a harmonious whole. Viewing the States as integral parts of an ultimate railway entity, it is clear that unless correlation of the larger efforts is sought now the condition will be chaotic later, when the accomplishment of complete intercommunication at all points is forced by natural growth.

After all, the delimitations of railway areas are but matters of official or administrative convenience. It is improbable that the larger States will remain undivided. New centres must arise. It is certain that the rail recognises no barriers save those which are physical, therefore it would be unwise to give the weight of permanencies to conventional limitations when reviewing the common factors of a complete system.

LOCATION:

Consonance with Natural Conditions.—In the light of a manifold assurance of great resources, of continued progress, and of a population increasing to many millions, all that has been done is open to revision, all Australia is yet open to the railway engineer. Sound location—all location not admittedly ephemeral—must be based upon standards which ensure, not transitory, but permanent efficiency and economy.

Only when evolved system is consonant with physical law can these ends be attained. Given consonance, then the capital and working expenses are a minimum. Assume inconsistence, that the natural conditions are departed from, that traffic is constrained from natural paths of flow and deflected to other than the pre-ordained points of concentration; then unduly high freight rates will mark initial imperfection by a permanent tax—which is an absolute economic loss—on productivity.

There is no avoiding the issue, for the underlying, ever-operative correcting force is gravitation itself. For every error of position, for each avoidable grade, for each unnecessary curve, for each inappropriate speed, a toll in perpetuity will be exacted. The nature and magnitude of revisional work sequent to phases of limited capitalisation, or limited mental grasp, are illustrated vividly in the enlightened reconstruction of many of the United States systems of lines. The Pennsylvanian system is credited with having, within a few years, expended 400,000,000 dollars to this end, with the further intention of spending 300,000,000 dollars more. Much of such expenditures is a corollary of want of foresight as well as want of capital in the past.

Climate.—The climatic conditions are favourable to railway engineering. They close no portion of the continent to railway effort; they simplify the labours of location; they render but little of the total area inherently unprofitable railway area, provided
the connection between the products and environment is duly observed.

Australia is a snowless land; thus the railway engineer is relieved from the heavy constructional and working expenses that snow accumulations entail in many other countries.* A simultaneous consequence is that in artificial conservation of rainfall run-off a substitute must be found by the irrigation engineer for the natural storage and distribution of water by slowly melting snow-fields.

Duly conserved, that wasted run-off, conjoined with warmth of climate—that manifestation of thermal energy by which all life exists and thrives—constitute national assets of incalculable value.

In many cases, in new country, the work of the irrigation engineer has this relation to the work of the railway engineer—the water can be brought to those areas suited to the rail as conveniently as the rail, to reach independently determined irrigated sites, can be taken to less suitable railway country. Gravitational water flow may thus, in effect, supersede steam haulage with its inherent costs.

Internal Frontiers.—It has been shown that spheres of railway activity are conventions not physically dictated. In part this may be traced to the general absence of suitably-placed frontier marks, such as mountain chains or rivers, immediately obvious to the lay understanding. To laymen, apparent alternatives are possible when, in fact, there is no economic alternative.

When surface conditions do not define, or contraindicate, the allocation is a simple problem in geometry. The requirement is that each point in the boundary shall be equidistant from the concentration points of the adjacent systems. A straight line bisecting at right angles another straight line joining those points is the solution. When uniformity of topography renders the comparison just, it is interesting to note the divergence between the actual and the geometric boundaries. It is no less interesting to endeavour to compute the resultant accumulated losses should slow evolution, unassisted by intelligent anticipation, be left to

* By the courtesy of the Commonwealth Meteorologist (Mr. A. H. Hunt, A.V.I.E.) the following comparison is possible:

<table>
<thead>
<tr>
<th>Isotherm</th>
<th>Australia, sq. miles</th>
<th>Canada, sq. miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over 80° F</td>
<td>422,100</td>
<td></td>
</tr>
<tr>
<td>80° to 70°</td>
<td>1,521,000</td>
<td></td>
</tr>
<tr>
<td>70 to 60°</td>
<td>927,000</td>
<td></td>
</tr>
<tr>
<td>Under 60°</td>
<td>104,500</td>
<td></td>
</tr>
<tr>
<td>Over 40°</td>
<td></td>
<td>292,300</td>
</tr>
<tr>
<td>40° to 30°</td>
<td></td>
<td>711,000</td>
</tr>
<tr>
<td>30° to 20°</td>
<td></td>
<td>1,114,600</td>
</tr>
<tr>
<td>Under 20°</td>
<td></td>
<td>1,501,918</td>
</tr>
<tr>
<td>Total Australian</td>
<td>2,074,600</td>
<td>Total Canadian</td>
</tr>
</tbody>
</table>
correct frontier alignment errors, from whatever causes those errors arise.

A study of the converging and meeting frontier lines which the geometric conditions postulate, irresistibly conveys the conclusion that inland States, without sea frontiers, must eventually evolve as a consequence of the general geographical conformation.

**Ocean Frontier.**—Australia's frontier to the world is the ocean. At that frontier all international exchange must be made—the sole idea in mind when the early railways planners drove the lines inland from the coastal settlements. The trend to concentrate traffic at maritime metropoli, without full recognition of the possibilities of inland centres and their allied cross-connections, has continued.

But, inherently, the coastal influence must always be pre-potential in the work of location. It permits the linking of terminals by an unbroken closed curve of circumnavigation. No other country of equal area possesses this island advantage. In Europe, Asia, or the Americas there is but one coast, or coasts widely separated. The matter marks a basic difference in the general system suitable for those lands and for this, and it marks a great natural advantage to the Commonwealth.

The beginnings of a connecting, closed curve of rail exist in the Eastern States; its extension is but a matter of time. In paralleling the many thousands of miles of undeveloped coast, a multiplicity of new maritime concentrating points must come into existence. Unless anticipated in position and provided for in location, these foci would exercise a grave effect upon any general scheme which fails to provide for them. Not merely a courtesy, but a close formal association of the harbour and railway engineer is foreshadowed.

**Zonal Areas.**—It is convenient to consider internal areas as zones, conforming, generally, with the coast line. A distinct connection between such bands and the meteorological conditions which make for uniformity of production can also be traced. Further, zones are an expression of the connection between length of haul and area served.

When the type reticulation is centripetal, converging inwards, with the coast and the inland terminal as the objectives, there is a limit to the length of remunerative haul. Especially is this the case when the intervening country is unsettled. Such lines can be made self-supporting extensions at an early stage only if they are locally used by a considerable population inhabiting a comparatively narrow band coterminous with the rail. That is the plea for "closer settlement." Intermediate points functioning as local terminals, or as terminals to local reticulations, also reduce the difficulty. That is the case for inland centres.

A point deserving of note, which, it is believed, has not been noted, is the effect of an undue number of junctions in pioneer
work designed to serve the greatest area by the least length of rail. For instance, assume that the Australian roads had been extended as single lines solely with pioneering in view. They would have served 650,000 square miles of country within 20 miles of rail. They actually serve about 390,000 square miles. One of the chief reasons of this great discrepancy is that each cross-junction implies the loss, in this relation, of an equivalent of 40 miles lineal, or 1,600 square miles, of such a railway band.

Calling the developmental efficiency of single, straight lines 100 per cent., the Australian lines, as a whole, have an efficiency of about 60 per cent. The amount as to which there are complete explanations, or differences of opinion, is about 40 per cent.

Topographical Determinants.—Zonal functions lie very close to the basis of general plan, but there are influences, chiefly topographical and productive, which justify or require local modifications. For instance, much present and prospective freight may be viewed as solidified rainfall. The gathering area is, broadly, the area of the water availability, and as a generalisation, the heavy freight flow is unidirectional, coastward, and is governed by the location of the river systems where these exist.

In this climate the relation of the rail to the stream is complex. Water is the prime need; it is not over-abundant without conservation, and its value is therefore enhanced. When the value of the water for irrigation uses exceeds its value as a mode of transport, and when the flow is not simultaneously available, as by locking, for both uses, then the construction of river-valley lines, with easy grades, is indicated. Most existing railways meet the streams, tap them, but do not follow them—a plan depending upon the fashion of a time anterior to recognition of the imperative necessity for the full use of all waters for irrigation.

Obviously the questions of irrigation and railway minor location are intimately connected.

Grade.—More than any other individual item, often more than all other engineering factors, grade is a determinant of first cost and working expenses. Grades of 1 in 50 and 1 in 40 on main trunk lines are an unfortunate heritage from the past to us. The lines were in new, undeveloped country, heavier grades permitted cheaper location, the traffic was virtually nil, therefore the heavy resulting rate of the working costs conveyed no immediate hint to the layman of the real costs the grades would impose as traffic grew. Apparently capital cost and its interest charges were everything; haulage costs nothing. But the relative haulage cost fixed then is operative now on the enormously greater tonnage; whilst the interest charges are, practically, a constant.

There were, usually, no physical reasons why more favourable grading should not have been attained. The reasons were reasons of transient expediency. Where they operate, such grades are multiplying haulage charges fourfold, and more than
fourfold. There is no engineering doubt that, in national development by lines destined to become main lines heavy revenue-crippling grades should be rigidly discouraged.

**Topographic Data.**—In the wider generalisations, the engineer in Australia is at a disadvantage. His contemporary abroad has to deal with settled communities, which have through the centuries found their lines of transport. He has recorded and traditional knowledge of flood-levels and other essential matters; also he has in Ordnance and similar surveys extremely accurate collated information in regard to the conditions of every possible, prospective route. Here there are no such guides. The engineer locating a railroad is dependent upon himself for the collection and estimation of his data, collected as he proceeds, and available as a result of his progress. The mode has been unavoidable, but it tends, obviously, to local narrowness.

Sufficiently-complete topographical surveys are matters which cannot be too early undertaken in order that the after engineering of surface conditions, military as well as civil, may be carried out with clear judgment.

**Surface Roads.**—The locating of a railway in new country governs largely the planning and efficiency of the whole consequential system of surface roads. It is necessary also to bear in mind that those roads may, with the increase in application of mechanical road-traction, become virtually light-line feeders to the rail; therefore that the rail must be so placed that, if possible, the main highway grades are moderate also. This provides another argument for anticipatory topographic survey.

**Gauge.**—There is no intention to here discuss the relative merits of different gauges or of particular gauges. The point is that difference of gauge absolutely precludes unfettered inter-State interchange.

In construction, given gauge uniformity, great economies would result. Instead of a multiplicity of structural designs, a sufficiently few types would be evolved; instead of many rail sections, a relatively small number would meet the case. Instead of many stocks of differing sections, and differing adjuncts, the standardisation of stocks, their reduction, and a reduction in the dead capital they represent would follow. With orders concentrated upon a lesser number of types, and those types standards, contract rates would be lowered, and the prospect of local production would be enhanced.

**Margin for the Future.**—It is economically wise, if not always immediately economical, to allow an ample margin of strength and safety for the heavier loads, and greater cross-section of loads, and the increased speed which must undoubtedly come.

Past engineers left in this respect a legacy, equivalent to a reserve of capital, to present engineers. In the light of growing
physical knowledge of the strength of materials and the relation of strength to load, it is possible for successive engineering administration to draw upon that marginal reserve. There is temptation to do so, or to too exactly adapt the provision for the day to the needs of the day. There is no formal compulsion to provide for the future, nor is it inherently unsafe to omit the provision, although a lower factor of safety requires a higher factor of skill, but it is ultimately costly not to make that provision when permanent works are in question—works which cannot afterwards be amended except at heavy cost.

Afforestation is not a function of the railway engineer; but enormous calls will be made upon the already depleted forest areas for future railway extension and sleeper and structural renewals. That the supply may be cheap and plentiful, forest conservation is an essential, and an immediate essential.

From this brief and incomplete summary of the components of the policy of location it may be gathered that the details are numerous, and far beyond matters for mere routine treatment.

It will be gleaned that prescience is the quality to be cultivated; for there is choice between national efficiency and local efficiency, between cheap construction and complete construction, between apparent economy and true economy.

TRACTION:

To one who has had experience of locomotive matters, the inducement is strong to dwell upon details of technical interest. But the perspective of traction in regard to general policy, not the details of traction, is the question now.

Unremunerative Weights. — Traction, obviously, is the application of force to the movement of mass. As corollaries, the less the unremunerative mass, the less the consequential resistances, the less will be the energy required, the lower will be the working cost.

It matters not what the immediate source, the remoter derivation, the mode of application of the energy may be, the definition is fundamentally exact, is deduced from exact law. Strength and weight of material used in excess may improperly replace skill in the design of the tractor. The ratio of dead weight to paying load in rolling-stock may be above a safe minimum. Added dead-weight of stock, concomitant of luxurious appointment may pass the limits of the remunerative. In each case—in every case—each extraneous pound upon the rail is a departure from economic principle, from the conditions which permit cheap freights. And in each case there must be added strength and capital cost of the permanent way supporting the tractor and the load.

Grades. — Inclines have already been referred to under location, but their specific relation to traction warrants further analysis. Every engineering student is seized of the gravitational fact that the tractive effort required is proportional to the incline.
On, say, a 1:100 incline the tractor must, in addition to overcoming all other resistances, exercise in overcoming grade resistances an effort sufficient to lift vertically the one-hundredth part of the entire weight of the train. On a 1:50 incline the dead-lift is one-fiftieth of the total weight, and so on pro rata. On level lines there is no lift against gravity, and the remaining resistances, which are approximately constant for all inclinations, are—in the absence of strong winds—equivalent to less than 1/300th of the total train weight at speeds not exceeding 40 miles per hour. The weight of the tractor is a constant, equally to be deducted from the heavier total load on the level, or the lighter load on the grade, when arriving at the net paying weight haulable.

Few Australian trunk lines are free from ruling grades of 1:50. In general terms such a grade reduces, on the section which it governs, tractive effect by about 85 per cent. in comparison with traction on the level. If the average speed over the section is reduced as a consequence of grade, increased rolling-stock at increased capital cost is involved. Also, there are increased costs of permanent way, consequential to the use of heavier tractors. This increased cost extends to all the sections over which those tractors must pass, and is not confined to the ruling grade only.

Grade losses, when grades are avoidable or reducible, are wastes absolute, grave in their aggregate money value. Unless under very exceptional circumstances, there should be no toleration of heavy grades in any sections which by any possibility may be destined to become future arterial lines of heavy traffic.

**Speed.**—With each combination of traffic and road there is associated an economical speed, which can be determined. It should be adhered to when possible, but in a general organisation it may be legitimate to sacrifice the fuel and smaller economies to attain larger economies or conveniences in passenger or freight service.

**Mode of Traction: The Locomotive.** —In the absence of natural sources of power the only modes of traction possible are derivatives of thermal energy.

In isolated systems, or in urban or suburban areas, the choice is between direct steam traction, and steam or gas power transformed and electrically applied. But in non-isolated systems, when differences of gauge shall have been eliminated, the larger question of interchange of rolling-stock—with its great potentialities of reduced capital investment—must arise. Concentration or diffusion of tractive effort; the prompt mobilisation of that effort at any time, at any point, in any quantity, are traffic factors of the first importance, to be met only by unit tractive elements drawn from a common reservoir. In this connection, in national issues continental in extent, the detached
self-contained locomotive has no competitor. For instance, intensity of traffic conditions is a function of seasonal change, and the time of maximum requirement varies throughout the continent. With mobile units and interchange, the flow of rolling-stock can be made to conform with the seasonal change, and the general stock can be proportionately reduced.

The locomotive is truly a product of evolution, the materialisation of the effort of tens of thousands who have striven to utilise each method of mechanics and physics, to eliminate the cause of each unforeseen failure, to mould into perfect compromise conditions not themselves coherent. The locomotive has evolved into complete accord with simultaneously evolving complementary conditions. Further improvement must be relatively slow, because minor gain does not justify departure from type; because radical alteration implies radical alteration of the whole organisation, and it must be justified on the larger economy, not as regards improvement of the tractor per se.

As engineers, we know that the locomotive is not an ideal steam-user compared with engines working under conditions which cannot obtain on the rail. But the deviations from the possible ideal are not great, and the margin for reduction in steam costs in relation to other factors is small. The gains that may be anticipated from improved traction efficiency sink into insignificance compared with the losses that follow defective location.

Standardisation.—High though the merit of local design and manufacture undoubtedly is, it should, given unification of gauge, become even higher. Fewer types would suffice; attention could be concentrated on those types; the labours of standardising minuta\textae would be justifiable, and might, as in America, be carried to high perfection. Every mechanical engineer will grant that complete standardisation of type and detail, and an avoidance of multiplicity of types, is the root economy in manufacture and running.

Fuel Reserves.—The whole future of Australian internal communication is a question of the adequacy of the coal beds. There is no question of the sufficiency of the present coal in sight to meet for hundreds of years requirements on the basis of present consumption. There is every probability that other coal measures will be found. Great though the known supplies are, they are not inexhaustible. Britain’s annual output would exhaust the one-thousand million tons of the great New South Wales basin in four years.

Traction and Location.—Tractive engineering is an application of exact mechanical and physical knowledge. Location, as precedent to construction, is largely a personal equation of complex data, and a well-considered co-ordination of the possibilities. It is seldom that the two methods of thought are found conjoined in one individual, but it is imperative that they should be coequally manifest in general policy.
Finance.—In private railway enterprise keen rivalry—or the possibilities of rivalry—compels equally keen, responsible internal criticism, until results at least equal those of competing or parallel undertakings. Read in the light of the knowledge that effort is as effective as close interested censorship can make it, a comparatively simple return giving prominence to capital invested and net return, and giving lesser prominence to intermediate processes, suffices. It is no part of a private undertaking's policy to, in fact, disclose its methods of operating.

Something more is requisite in the case of the control of national engineering interests. There is no competition. Continued responsibility is absent. Questions of general policy blend with questions of railway policy, and only the initiated can discern the intent. In so far as railways are organised engineering, in so far is it necessary that all material permitting the comparison that replaces—in a degree—competition, should be presented, and in a comparable form.

Excluding the value of lands dedicated by grant, the capital value of the Commonwealth railways was in 1908 £139,988,015. The net earnings equaled 4.22 per cent., or .58 per cent. more than interest on loans. Such figures are satisfactory from a bondholder's point of view. But they do not differentiate between engineering charges and taxation rates. Neither does a statement of the ratio of expenses to revenue earned make this clear. The ratio may be the same if economy is coupled with low rates, or if inefficiency is connected with proportionately higher rates.

The "train-mile" purports to furnish a standard. It is, in fact, but an arbitrary convention of limited application in older communities of constant condition or slow change. As an Australian standard it would be fallacious. Each increment of locomotive power gives a new value to the unit, therefore it fails conclusively in the comparison of differing periods or of differing systems. It does not discriminate between train weights or train speeds. It does not effectually discriminate between gauge differences; in fact, if gauge difference is not specifically indicated, a fictitious equality is attached to widely differing quantities. (Obviously a train-mile on a three-foot and a train-mile on a standard-gauge line are very different things.) It gives no hint as to the relation of paying load to dead load. It does not disclose the efficiency of location or traction.

The fully acknowledged "passenger-mile" or "ton-mile"—that is, one passenger, or one ton hauled one mile—is far more crucial. The resulting total cost of hauling unit weight over unit distance is a definite expression. It is the total in which all antecedent factors merge. It is a summation, in comparable form, of the effects and efficiency of location, construction, traction and administration.
In national railway issues the importance of selecting a definite, constant, comparable equivalent of the constructional and operative efficiencies is unquestionable.

Before passing to the next section, one point is well worthy of note. It is the statistical convention of differentiating between State and private railway capital. The mode presents Australia’s position for popular comparison abroad in an unjustly unfavourable light.

Australia adds its Government railway capital to “debts.”
Canada adds its private railway capital to “wealth.”

Adding Canada’s railway capital to its “debts” the total amount is £312,387,161
Adding Australia’s railway capital to its “debts” the total amount is £2,43,335,487

The usual statistical statement of debts reads thus:—

<table>
<thead>
<tr>
<th>Country</th>
<th>Total Debt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>£2,43,335,487</td>
</tr>
<tr>
<td>Canada</td>
<td>£78,104,292</td>
</tr>
</tbody>
</table>

Administration.—The greater administrative function, depending for completeness upon the unison of engineering and statesmanship, is the provision of access to the land, and provision of settlement of accessible territory. Access provided, not too quickly, else will the immediate burden be too great; not too slowly, else will the work of development be chilled, the potential capital lie dormant, perhaps to pass to others.

Canada has grasped the duality of the situation, and is profiting. Its lines are, principally, privately owned. The capital is held at centres which control the immigration streams. The climate is rigorous. But, apart from higher reasons, as a business proposition the streams of population have been diverted to those areas where, whilst advancing their own interests, the emigrants also become dividend-earning forces. The effect is reflex, once started persisting; and increasing at compound interest rate; the people creating the possibilities of further rail extension, the extension which the people create, permitting of further population.

There is in Australia no railway sodality which ensures unity of interest and endeavour in those affairs which so profoundly affect the bases of engineering design. Each State has its own railway jurisdiction, its own local management, its own limitations. It cannot be held that the units shall always remain segregated and segregating railway entities.

It is clear that there must evolve a connecting organisation, a body exercising the higher engineering functions; a body competent to judge, to suggest, with the power to ensure that the suggestion shall be a materialisation of the best available knowledge; a body competent to determine questions of engineering
economy: a body with machinery to ensure that economies are not pushed to the point when they become menaces to public safety.

The problems which the larger future holds are so transcendentally complex that there is difficulty in forming a conclusion, or group of conclusions, which shall cover all the conditions. Yet there are guiding signs. There are communities which have passed through, and left behind them, those stages in which we now are. In a railway sense those States are more mature than these. They have, in keen merciless commercial rivalry and war of interests, encountered and solved in large measure those problems of a strenuous existence which are now to be solved in Australia. Boards of Trade, Boards of Control, Interstate Commissions are amongst the products of the effort.

Evolutions are culminating under the guidance of the shrewdest intelligences striving for colossal stakes of power, wealth, reputation; stimuli operating effectively to prevent administration degenerating into routine—stimuli almost absent here. Almost without analysis salient essentials are disclosed. In the mature investment and solid progress period sequent to the tentative speculative phase, sound thorough engineering of the highest class is demanded. Because the work is to stand, because there must be no failure, the highest endowments, and the highest alone, are sought.

In that administrative engineering, and in the railway administration generally, the objective has been the organisation of a force, each unit specialised, the unit subordinate to the whole, the whole a machine—precise, prompt, impersonal and immediate in its full response to the will of the very few who direct. The few, for it is the history-old story of "the mighty individual."

So far Australia’s efforts have resulted in six machines. The attainment of the completer specialisation, the co-ordination of the parts of the six machines as a whole for the achievement of joint purpose, the crystallising of a supreme connecting controlling intent is the great work of the future, a work in which the engineer must bear a heavy part, for in his hands rest the lives of the people, the destiny of a continent.
The central dot-dash line is the produced straight-line course connecting (approximately) Britain and Panama. It is a projection of a great circle cutting meridian 10° at 35° N.

The curved dot-dash line is the Equator. The curvature indicates the nature of the distortion of Australia's true world-relation on the Mercator Chart.

The projection is cylindrical.

Lines thus ———— indicate railway arteries.
The broad red lines indicate land within 20 miles of existing railways.
The zones are lines of equidistance from the coast.
The distance between zone and zone, and zone and coast, is 100 miles.

Capitals are indicated by ringed dots; E to W they are Brisbane, Sydney, Melbourne, Adelaide, Perth.

The dot-dash lines are lines of equidistance from adjacent capitals. The triple point for Sydney, Melbourne, and Adelaide is near Cobar; the geometric borders of Queensland in reference to New South Wales, and of New South Wales in reference to Victoria, if produced, would meet near Innamincka.

The dotted lines are the political boundaries.
The red parallel lines denote in the aggregate the length of Australia's railways.

The central black square is the area equivalent to the sum of the 40 miles wide railway bands. It is equal to about 390,000 square miles.

The outer red square denotes the maximum area, about 650,000 square miles, within 20 miles of rail, which such lines could theoretically serve.

The lines are sufficient to cover Britain's area with single, straight parallel roads about 8 miles apart.
FOREWORD.

PREFATORY:

Work accomplished.

Work to be accomplished.

SECTION I.

WORLD-RELATIONS:

External Environment.
National Defence.
Avail ability.

SECTION II.

STATE SPHERES:

Natural Conditions.

Climate:

Internal Frontiers:

Ocean Frontiers.

Zonal Areas:

Topographic Determinants:

Gauge.

Margin for the Future.

Afforestation.

INTERNAL-RELATIONS:

Location.

Unremunerative Weight.

Grade.

Speed.

Mode of Traction: The Locomotive.

Standardisation.

Fuel Resources.

Traction and Location.

FINANCE AND ADMINISTRATION.
The Chairman (Vice-President Lieut.-Colonel J. Monash) said it was not the practice of the Institute to discuss in technical detail the Presidential address. At the same time it was competent and proper that the meeting should convey to the President the sense of their obligation to him for the very able address he had delivered. Personally he was greatly impressed with the address. It was a most thoughtful one, handling a vast subject on a high plane. It was full of statistical matter of great value, and would be an interesting and valuable contribution to the literary records of the Institute.

Mr. R. O. Thompson said he was sure they would all be pleased to read the address when circulated. As an Institute they should congratulate themselves that they had a President who would be able to carry on the work for another year with the same ability and courtesy that he had done for the past two years.

Mr. G. A. Turner said the amount of study and care and thought that anyone in Mr. Smith's position had to give to a subject of that description could only be realised by those who had attempted the same kind of thing. They were indebted to Mr. Smith for having devoted so much of his time to the preparation of so able an address.

Mr. G. H. Knibbs (Commonwealth Statist) said that, speaking as a visitor, he wished to add his quota of appreciation on several grounds. One was that his present position was that of critic of all things belonging to this country as it stood in relation to the affairs of other nations.

Australia was in the fortunate position of not having to settle the problem that gave considerable trouble to Europe—the nationalisation of its railways. From that point one saw how immensely national destiny was governed by railway policy. He thought that when the public of Australia understood the question, it would be seen that however necessary it might be to retain some State control of the railway systems, it would be necessary to marshal our railway effort from the standpoint of Australia as an entity, and not from the standpoint of the States in rivalry with one another.

One thing the President drew attention to was a matter with which he (the speaker) had been concerned for some time; that was the mode of getting comparisons between the railway systems and he had strongly urged through the Governments that they should check according to passenger-mile and ton-mile in order to get some solid basis of comparison. Even that comparison was not perfect, but it was better than any other existing. He hoped that at some future time it would be possible to get, perhaps not perfect statistics of railways, but an advance on existing statistics. He was glad the President had given his support to that in his address. Mr. Smith knew how qualified statistics of that kind
were, and understood that our existing data as supplied to the public were not adequate for the purpose of criticism.

He was also glad the President had drawn attention to the different way in which Canada estimated its wealth in regard to matters of that kind. It was not unknown in other branches of Canadian statistics, that the statements were somewhat on the enthusiastic side. In the long run people found this out, and made deductions where they should not be made. They were indebted to the President for what he might call the wide perception of the nature of the railway question.