THE ROLES OF STANDARDS AND PROJECT SIZE IN ROAD INVESTMENT APPRAISAL

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ABSTRACT: This paper examines the roles of standards and project size in road investment strategies. It is argued that a critical examination of design standards for rural roads is essential in an environment of limited road funds. The economies to be derived from staging of road works in terms of both their size and quality (standard) are also canvassed. The final section of the paper questions the trend to higher standards when current infrastructure is unable to be adequately maintained. The views expressed in this paper are the author's and do not necessarily represent those of the Department.

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ROAD INVESTMENT APPRAISAL

INTRODUCTION

In Australia, one is currently faced with an economic environment where demands for road infrastructure, and its maintenance, outweigh the funds and resources available to supply those demands. It therefore behoves planners, designers and policy makers to continually assess proposed projects far more critically.

This paper examines a number of current practices in the light of this predicament. In the spirit of the theme of this forum, a number of myths relating to road investment decisions are postulated together with some indication of how these may be resolved. The paper makes no pretence at being a comprehensive guide for road investment analysis. The field has been quite adequately examined elsewhere. (Heggie 1972, Both and Bayley 1976). However, there has been scant attention paid, in Australia,(1) to both the principles and practices of assessing standards and staging proposals in road investment analyses. This paper examines how analyses of standards and staging may assist the road planner facing a limited budget.

The subject is treated by firstly examining standards and their role in investment appraisals. A number of considerations for staging arise from this discussion and these are dealt with in the final section of the paper.

THE ROLE OF STANDARDS IN ROAD INVESTMENT APPRAISALS

The word 'standards' can apply to a number of different situations. Commonly, the term is used in connection with design standards. However standards may also be derived to assess deficient sections of road and, in turn, to assist in determining which projects may be warranted in terms of those deficiencies. In many instances, the design standards are also used as assessment standards. The effects of varying standards in determining a range of "warranted" projects has been partially investigated elsewhere (Rahmann 1976). The appeal of this approach is that it does not presume a priori standards as being inviolate. In other words, the standards themselves deserve appraisal. Unfortunately, this approach is often neglected as noted by Heggie (1972).

"The engineering standards and the design features of the project ... are rarely evaluated in economic terms. They are simply decided by intuition".

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1 However, some work appears to have carried out overseas (Schimpeler et al 1976, March et al 1973).

Perhaps intuition is too strong a word. However upon investigating the current Australian road standards one is faced with the nagging impression that, at best, there is little or no accountability for some recommendations.

Often, design standards are considered to represent objectives for road investment. In other words, they are surrogates for the unstated objectives of accessibility, levels of service, safety and the like. They are usually readily comprehended by politicians and non experts and, as such, take on a quasi political constraint role. Consequently standards tend to be regarded as being above separate analyses.

The relationship between standards and road investment objectives is well canvassed by Harrison (1974). He comments on standards as follows:-

> "Standards are therefore reached by a process of intuitive balancing of the benefits and the costs of having the standard at a particular level, as opposed to another one".

Therein lie two of the basic tenets of this paper. Firstly the bases of the adoption of standards (and/or objectives) need to be explicit and publicly available. Secondly, standards need to be viewed in the light of their costs and benefits. That is they form additional variables in the evaluation appraisal.

Whilst it is acknowledged that economic criteria may not be the sole issue in determining investment priorities, such criteria are important insofar as they demonstrate the economic implications of adopting some other determinants for investment. Similarly, critical economic appraisals of standards assist the decision maker, (and the public) to assess the marginal worth of higher or lower standards.

Public accountability is mentioned at various times in this paper in a different context to its conventional practice with respect to road investment policies. It is usually thought of in terms of public involvement in road location studies and the obvious externalities of noise and visual intrusion which arise from new roadworks. However, there are equally important facets which relate to the "less visible" aspects. The standard of a particular road, for example, is one such item. If they are openly assessed during investment appraisals the public may then be made aware of their implications.

ROAD INVESTMENT APPRAISAL

There are two avenues of approach to testing the effects of various levels of design standards for investment appraisal or priority assessment. These are:-

- an ex ante approach of testing a variety of standards in the deficiency assessment or project selection phase, or

- an ex post approach of selecting deficient projects against some universal standard and subsequently analysing the effects of variations in standards in determining warrants for the inclusion of projects in a particular programme.

The former approach has the draw back of excluding projects which, whilst they may not be deficient in terms of some lower standard, may well have superior reasons for earlier investment. The second approach means that a large number of projects, totally unrelated to any budget constraint, need to be examined before a feasible set of projects may be obtained.

The Bases of Design Standards

Myth - Design Standards are truisms and above critical examination

The justifications for the adoption of standards are usually rather oblique statements relating to safety and other issues. For example, the NAASRA guide to the design policy for rural roads (NAASRA 1973) states that a road,

> "is designed primarily for the safe, efficient and convenient use of traffic".

Unfortunately, the designer is given very little information on how the design standards affect, and are affected by, these criteria.(1) Whilst the technical aspects are fairly well canvassed in the NAASRA policy, the designer or planner is given little assistance in assessing the consequences of changing initial standards. For example, the NAASRA standards relating to pavement widths indicate that the absolute (and desirable) minimum widths of a single carriageway for a duplicated facility should be 7.4 m in both instances. With the trend towards wide and often sealed shoulders on duplicated facilities one might legitimately question whether or not 7.3 m (as an example) may not be adequate.

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1 There are of course mathematical relationships which are presented by which items such as the centripetal forces (discomfort) acting on the occupants of vehicles during cornering may be directly related to the radius of the curve for various speeds of travel etc.

Indeed, prior to metrication the standard was 24 feet. Apparently, on converting this value to metres the NAASRA policy makers opted for 7.4 m (or 24 feet 3½ inches) rather than 7.3 m (or 23 feet 11½ inches). The author is unable to find any justification for this increase.(1) In excess of 1.5 million square metres of pavement could be saved over the National Highway System(2) alone, if the conversions from 24 feet, 22 feet and 20 feet had been made to be 7.3 m, 6.7 m and 6.1 m (in lieu of the current values of 7.4 m, 6.8 m and 6.2 m). Or in terms of road length, this would have provided enough pavement and sealing materials for nearly 230 km of 6.8 m wide road.

Whilst it is acknowledged that this simplistic trade-off may not be directly realisable to this extent, it does indicate the magnitude of the effect of incremental upgradings of standards.

The foregoing raises the question of the detail of the original research findings. If one traces the history of standards for lane widths, one is immediately faced with rather obtuse references. The NAASRA guide for rural road policy cites a paper by Vey and Ferreri (1968) which is a study of urban traffic on two bridges across the Delaware river. One bridge contained 8 lanes of 9 feet 8¾ inch (2.97 m) width and the other bridge had 7 lanes of 11 feet 3 inch (3.43 m). The bridge with the wider but smaller number of lanes had a better capacity performance and lane regimentation than the smaller lane width bridge. There are no indications of how the sampling was carried out, whether or not the upstream and downstream conditions for each bridge were similar or if the grades on the two bridges were the same. In short, it is not the sort of study upon which one would usually base a set of uniform standards(3). The position becomes hazier if one delves back into the American standards (AASHO 1954) upon which the NAASRA policy is based. Early studies (Taragin 1944) are cited to justify lane widths of 12 feet (3.65 m). These studies examined the vehicular behaviour on two lane rural roads in 1944. One would need to question the relevance of such requirements to

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1 In an even more curious conversion, the old value of 20 feet was converted to 6.2 m (or more than 20 feet 4 inches) whereas 6.1 m is slightly in excess of 20 feet anyway.

2 The National Highway System is illustrated in the Figure in Appendix 1. The system represents more than 16 300 km of road in all States.

3 One may well ask if an urban study with hourly volumes in excess of 8000 vehicles is applicable for extrapolation to rural roads with volumes less than 8000 vehicles per day.

duplicated 4 lane roads with sealed shoulders of 3 m (left hand side) and 1.2 m (right hand side).[1] It appears that through time, standards applying to shoulder widths and sealing of shoulders have increased. On a duplicated facility with such wide and often full strength sealed shoulders, are 3.7 m lane widths essential? There may well be a case for some reassessment of lane widths in cases where discretionary overtaking is the only source of potential vehicular conflict.[2]

The author is not necessarily advocating a reduction in lane width standards. The question really relates to the efficacy and justification of increasingly high standards being implemented (often in an additive fashion) without any apparent initial assessment of their economic worth.[3] The problem is exacerbated in an economic environment where needs far outweigh funds.

The Relationship Between Standards and Needs

High standard roads of course cost more both to construct and to maintain. Whilst additional benefits may be derived from higher standard roads, there are inevitably alternative investment options which may well yield higher economic returns.

The disadvantages of adopting initially high standards are thus twofold. Firstly, the additional initial capital

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1 Indeed the AASHO guide notes - 'Observations ... have not been reported for multilane and divided highways, but opinion has crystallized on the desirability of the same lane widths as on main 2-lane highways' (AASHO 1954).

2 Indeed the Highway Capacity Manual (Pignataro 1973) indicates that there is only a 3 percent reduction in capacity and service volumes on a duplicated facility when a 12 foot lane is reduced to 11 feet. As capacity is not a direct concern on most Australian rural highways it would seem that it may well be worth considering some increment between 11 feet (3.6 m) and 12 feet (3.65 m) as a standard for duplicated rural roads with adequate shoulders.

3 Guerin (1967) notes that observations of substantial widenings of certain sections of rural highways in Victoria resulted in a "barely statistically significant" reduction in casualty accidents.

costs to supply high standard facilities have a real opportunity cost. Secondly, there are earlier and higher maintenance costs associated with these higher standard facilities.

The problem seems to derive from the apparent dilemma of the requirement (as set out in standard road design guides) to design a road for 20 or 30 years hence. Ideally, one would like to match the road supply in terms of capacity, safety etc. with the demand for road space. Unfortunately, road space can not be provided in a uniform monotonic fashion. Definite and large increments typically need to be provided. It is at this point where the technical and economic arguments meet. Traditionally, road authorities have been inclined to design and construct to ultimate or near ultimate standards.(1) Arguments against staggered supply or the staging of works or standards have been in terms of differential capital outlays. Obviously in money terms, it is cheaper to construct a duplicated 4 lane facility as a whole rather than, say, constructing one carriageway and then at some later date returning and constructing the second carriageway. Economies of scale make the former option more attractive from a capital cost viewpoint. However, the latter option in terms of discounted costs may be no more expensive. Indeed, it has advantages insofar as it allows one carriageway to be available to traffic earlier than would otherwise be possible. Thus, one achieves earlier user benefits - a prime consideration of any investment proposal.

In addition, it appears that road authorities have traditionally viewed one of their objectives as "providing the greatest length of road at least cost" (Pedersen 1978). Presumably, the usual objective of governments of ensuring efficient resource allocations remains, in theory at least, the prime goal of any government investment strategy. It is understandable that authorities working within strict budget controls would consider that, once certain levels of standards were achieved then, cost minimisation was the prime objective of any investment strategy. Nevertheless, the requirements for public accountability for government investment are increasing. (Public participation programmes are one manifestation of this). Consequently investment decisions are likely to require firmer public justification in future.

There are numerous debates on the subject of the economics of staging. Technical and simplistic cost minimisation arguments are usually persuasive enough to

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1 Ultimate standards refer in this instance to design year standards (typically 15 to 30 year horizons).

preclude more than a casual examination of staging alternatives. Generally, a particular project has basic economic warrants. However, it has been rare for any calculated economic warrants to be made public.(1) The trend is beginning to change (JRPG 1978) and will provide some public accountability for future investment decisions. However, on larger projects it is important to assess the staging possibilities and appropriate short and long term standards over and above the economic worth of the whole project. The following section outlines several options for staging of major road works.

STAGING OPTIONS IN ROAD INVESTMENT

Numerous situations occur in the planning of sizeable road projects for economies to be realised from staging both the standards and size of these projects. Unfortunately, there have been quite dramatic examples of massive projects being constructed as single entities without any apparent regard to their staging. The Wallan to Broadford freeway is one example where a freeway, costing in excess of $60M (in current prices) and taking some 5 years to complete, is constructed without any attempt at staging. Similarly, the F5 (Yanderra to Aylmerton) freeway in N.S.W. is being constructed at a cost of $67M and is likely to be totally completed some 4 years after commencement.

Scale Construction Options

In both cases substantial outlays of scarce capital have been committed to projects which return no benefits for 4 or more years. The alignments chosen for these routes make staging by length very difficult. The alignments of the new routes are often several kilometres away from the existing or old highway (and public scrutiny?). If realistic alignments can not be found which allow staging by length, it is still possible and, it is suggested, often warranted to construct one carriageway and allow traffic to travel on this pavement whilst the second carriageway is being constructed.

Usually a staging by width on a new alignment (i.e. construct one carriageway and then the other one) would be done by operating the first carriageway as a two-way road in parallel to the old (existing) road. This allows traffic to assign itself in such a way as to minimise travel times on the two routes. It also means that, if the new road is bypassing a town or settlement, then the through traffic in

1 These warrants are often determined after the decision to proceed. As Heggie (1972) notes - "The simple conception of economic evaluation - often an ex post justification of a 'sound' engineering project - is far too naive".

that town will be reduced earlier than if the new facility were constructed as a whole.

However, in areas where there is little development along the existing road it may be feasible to allow traffic to flow in one direction along the first new carriageway constructed and in the other direction along the old existing road. This realises higher earlier benefits than the former option of two two-way roads. Obviously, there are difficulties with access in having one-way operation. If a resident living adjacent to the old road suddenly finds he can only travel south instead of south and north, he is not likely to be pleased. If proper access can not be restored for individuals in these cases it may be worthwhile to compensate these disaffected groups in some way; perhaps as compensation for the additional time and cost involved in travelling additional miles to the new carriageway. It may even be economic to provide a track to a nearby local road. The point being that whilst there are problems they can usually (emotional issues aside) be translated into monetary terms. It is then a relatively simple matter to trade-off those costs with the earlier benefits able to be derived from having vehicles travel on one-way facilities before the full freeway project is completed. In economic terms, the base case can be considered to be the construction of the facility to full standards and its completion prior to opening to traffic. The project or alternative case may be to construct one carriageway, open it to two-way traffic, and then construct the second carriageway. In assessing the warrant for such a project the differential benefits and costs that would need to be considered are outlined in Table 1.

There will be numerous cases where staging is not warranted. However, the economic analyses of the staging option cited above are not particularly onerous. Costs and benefits may be determined with the usual degress of confidence and warrants may be derived for staging. Whilst it may be appropriate to provide guidelines for staging proposals, it needs to be recognised that each project will have its own particular characteristics which will require individual examination.

The typical arguments against staging proposals are that the technical difficulties (costs) far outweigh any benefits. It is unusual for such a statement to be substantiated by any economic justification. There are, however, many technical and safety aspects which do require careful attention.

These generally relate to additional capital outlays required for works which are to be staged. One such aspect is noted in Table 1; the geometric standards for a two-way road are different (usually higher) than those for a one-way facility. For example, sight distances, grades and lane and bridge widths differ. Accordingly, it is argued that if an

ultimate one-way carriageway is to be operated as a two-way facility, it should be so designed and constructed. This argument appears to be somewhat invalidated by some recent short term traffic management practices.(1)

TABLE 1. COSTS AND BENEFITS ATTRIBUTABLE TO STAGING DUPLICATION

Costs:

- The differential construction costs between the staged and unstaged options. These will include
  - costs for any increased standards required for the first carriageway;
  - costs of providing additional temporary access (if any);
  - costs of providing traffic control during first stage; and
  - any additional costs associated with haulage of materials etc. during the second stage.
- The increased and earlier maintenance cost of the first carriageway.
- Any compensatory payments to disaffected persons during construction of second phase.

Benefits:

- Earlier road user savings due to the opening of the first carriageway. (Including vehicle operating and time savings).
- Reduced maintenance (and perhaps reconstruction costs savings) on the existing highway due to reduced vehicle numbers on the old road as a result of opening the first carriageway.
- Accident savings realisable with reduced traffic volumes and higher standard facility in the first stage.
- Any environmental benefits such as reduced vehicular intrusion in towns on the old facility.

1 For example, during recent pavement surfacing operations on the Hume Freeway (Wallan to Broadford) traffic was temporarily switched to two-way operation on each carriageway as the alternative carriageway was surfaced. The length of each carriageway is almost 34 km. Although, this only occurred for a period of three months it does tend to suggest some of the arguments are tenuous.

Construction of duplicated facilities may also be staged by length. One alternative route (Western) for the bypass of Mittagong and Berrima[1] allows for three straightforward lengths of construction by arranging that the proposed alignment intersect the existing Hume Highway at two points. In the case of staging by length of construction, the benefits to be derived from such a staging may well serve to determine that an alignment with easy staging options may be superior to one where staging by length is not feasible.

Staging by length is akin to project divisibility. In other words, a project defined as the bypass of the length of the Hume Highway between and including Mittagong and Berrima may be redefined. The staging options[2] would allow the original project to be assessed as three projects; a bypass of Mittagong, a bypass of Berrima and a duplicated facility between the two towns. Projects of large sizes are thus legitimately divided into quite meaningful smaller projects.

One other advantage of this divisibility is that it leads to an improved investment strategy by reason of improvements in information. In the case cited above, it may be demonstrated that sequential linear staged construction is less warranted than some other combination of construction of the three stages. Thus, projects with superior economic warrants may be identified (and implemented earlier) by examining staging warrants.[3]

There are innumerable technical possibilities for the staging of rural roadworks. Many of these are practised to some degree by various road authorities.

On roads subjected to flooding, for example, it has often been deemed 'uneconomic' to ensure that design flood-waters flow beneath road structures. Accordingly, embankments and pavements are designed to accommodate water which may

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1 The Western Route is but one of four proposed alternative routes which bypass the length of Hume Highway between Aylmerton and Hoddles Cross Roads (DMR 1977).

2 It is understood that the Department of Main Roads N.S.W. are currently examining such an option.

3 The corollary, of course, is that one element of the project may have no economic warrant at all. In other words, the benefit cost ratio (say) for the total project, may be greater than any one its parts (or stages). This may suggest a deferment of that part of the total project but this decision would obviously depend on other considerations.

overtop a road from time to time. When funds or priorities permit, these areas are provided with additional waterway capacity to accommodate design requirements for flooding. Again, there are fairly straightforward means by which the disbenefits of time delays due to impassable lengths of road may be "traded off" against the marginal costs required to make roads "all weather" facilities.

STAGING OF STANDARDS

The abovementioned design requirements for flooding leads back into the question of standards. The staging of roadworks may be tackled by either staging pre-determined standard roads by length or by staging the standards of a road. The latter option offers more possibilities. Two of these have already been discussed:- incremental upgrading by the number of carriageways and the staged reduction of flood susceptibility.

There are, however, those standards which really don't lend themselves to staging. The design speed of a road, for example, is one such item. This item has a bearing on the radii of both horizontal and vertical curves of a road and, as such, proves most difficult to increment at a later date.

Nevertheless, lane and shoulder widths, the number of carriageways, the number and siting of grade separations (overpasses of one road over another) and access to a particular road may all be viewed as technically able to be staged.

The ultimate design standards for the National Highway System (DOT 1976) have been notified to the relevant State Road Authorities by the Federal Minister for Transport. These standards incorporate differential standards for each of the highways comprising the National Highway network. They are intended as ultimate standards and, accordingly, allowance is made for the staged introduction of these ultimate standards by providing that, if "economic, environmental or other factors suggest" (DOT 1976) that lower standards are applicable, the Minister may so approve proposals to these interim lower standards. However, it is noted that any staging proposal should allow for the economic improvement to the ultimate standard.

Accordingly, there are numerous examples of where National Highway design standards have been staged.(1)

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1 An example is the bypass of Ulverstone (Tasmania) which has been designed as a duplicated facility but constructed, initially, as a single carriageway two-way road.

THE RELATIONSHIP BETWEEN STANDARDS AND FUTURE MAINTENANCE

As mentioned in an earlier section of this paper, high standard roads require larger maintenance expenditure than those constructed to lower standards.(1) Consequently, in constructing a system of roads, such as the National Highway system, the trade-off between the levels (and quality) of construction activity and the requirements for maintenance must be considered.

It is implicitly assumed that any investment which is deemed warranted (either in economic or financial terms) will be able to be maintained during its remaining life. Financial or budgetary constraints are invoked in deciding appropriate capital investment strategies. However, the same future budgetary constraints are not applied to the likely levels of future maintenance liabilities.

Historical Road Investments

Myth : All investments must be maintained.

There is evidence that past road investment strategies are becoming increasingly difficult to maintain. Indeed, one needs only to look at past investments in rail infrastructure to see how users will not always meet the costs of operating and maintaining transport facilities. In the case of rail networks, branch lines and services have been scrapped (Bland 1972) where they are no longer viable.

It is acknowledged, that at present road users show a willingness to pay (in notional terms at least) (BTE 1977) for the road infrastructure which they use and the level of its maintenance. However, the increasing difficulty of governments to allocate funds for the adequate maintenance of all roads suggests that road investment strategies (past and present) need to be reassessed in terms of the overall funding problem. For example, in 1977/78, the Victorian Country Roads Board reported (CRB 1978) that they were only able to reconstruct (i.e. provide capital maintenance) some 25 to 33 percent of rural roads requiring "imperative" reconstruction. Only some 80 percent of deserving maintenance works of rural roads could be carried out in the same period. The Board's report also notes that there are "between 2500 and 3000" bridges of timber construction which are subject to deterioration from a number of causes. The cost of replacing these bridges is reported to be approximately $180 million. These problems are not peculiar to Victoria; similar shortcomings may be found on most road systems in Australia.

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1 The strength and quality of pavement and structures is obviously excluded from this discussion. Standards refer to geometric and access standards.

These problems are symptomatic of one or more of the following causes:

- they may demonstrate an historical misallocation of resources at the time of investment;
- they may be due to significant changes in traffic patterns, technology or funding over time; or
- they represent an inappropriate balance of capital and maintenance expenditure.

The first two symptoms suggest that the facility, or at least its initial standard, may be unwarranted in current times.(1) Consequently, some sealed roads, for example, would be more appropriately converted to unsealed roads. This would require a fairly "brave" decision by one or other levels of government. Nevertheless, similar decisions have been taken with respect to railway closures (Bland, 1972). Such a decision is an acknowledgement that times have changed. A growth area in the early part of this century may no longer warrant the level of infrastructure afforded to it 50 years ago. Economic warrants do not have infinite temporal stability and the inability to maintain an investment may be a signal for its reassessment.

The third symptom relates to the previous discussions. Decisions to invest need to account for present and future maintenance requirements. Obviously, the Country Roads Board places a higher priority on certain new investments than it does in fully maintaining past capital investments. However, if funding levels remain constant or decline in real terms over time, the maintenance backlog can only increase unless a reallocation of funds between capital and maintenance categories is effected.

Current Investment Strategies

With the current trend to provide higher standard roading facilities (e.g. duplicated roads, total access control, larger road reserves) the future maintenance requirement must increase. It is legitimate to question, therefore, the quality and amount of current investment in the light of the maintenance legacy already facing road authorities.

Economic measures (such as benefit cost ratios, net present value etc.) of the worth of project do not take account of the ability to fund either its construction or

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1 It may also suggest that governments are not allocating sufficient funds for roads.

its operation. Predicting future demands for travel, and willingness to pay for travel is impossible. It is essential, therefore, that the quanta of investment are geared as closely as possible to the demand and willingness to pay for such investments.

This paper has examined several avenues for such an approach. It is hoped that a more critical appraisal of the trade-offs between the costs of early high quality road investments and the benefits to be obtained from staging those investments will be apparent.

APPENDIX ONE - THE NATIONAL HIGHWAY SYSTEM

In 1972 the Commonwealth Government initiated a Commonwealth/State Study to investigate the possibility of a system of National Highways funded separately from other road categories. The subsequent report noted that there were certain roads in Australia which because of their function and relative importance could be classified as "National Highways" and afforded particular attention. The former Bureau of Roads in its Report on Roads in Australia 1973 also recommended that the Commonwealth should assist in the development of such a system.

The National Roads Act 1974 gave effect to this concept. The legislation provided that for the three financial years 1974/75 to 1976/77 all approved construction and maintenance works on declared National Roads were eligible for 100 percent funding by the Commonwealth. Subsequent legislation, the States Grants (Roads) Act, has the same provision for the triennium 1977/78 to 1980/81.

The declared National Highways system under the current legislation, comprises the major links between adjacent mainland capital cities, with extensions in the Territories, as well as the highways between Brisbane and Cairns and Hobart and Burnie. The system is some 16 300 km in length and serves the nation's major centres of population, trade, commerce, mining and recreation.

The links which comprise the system are shown on the map in Figure I.

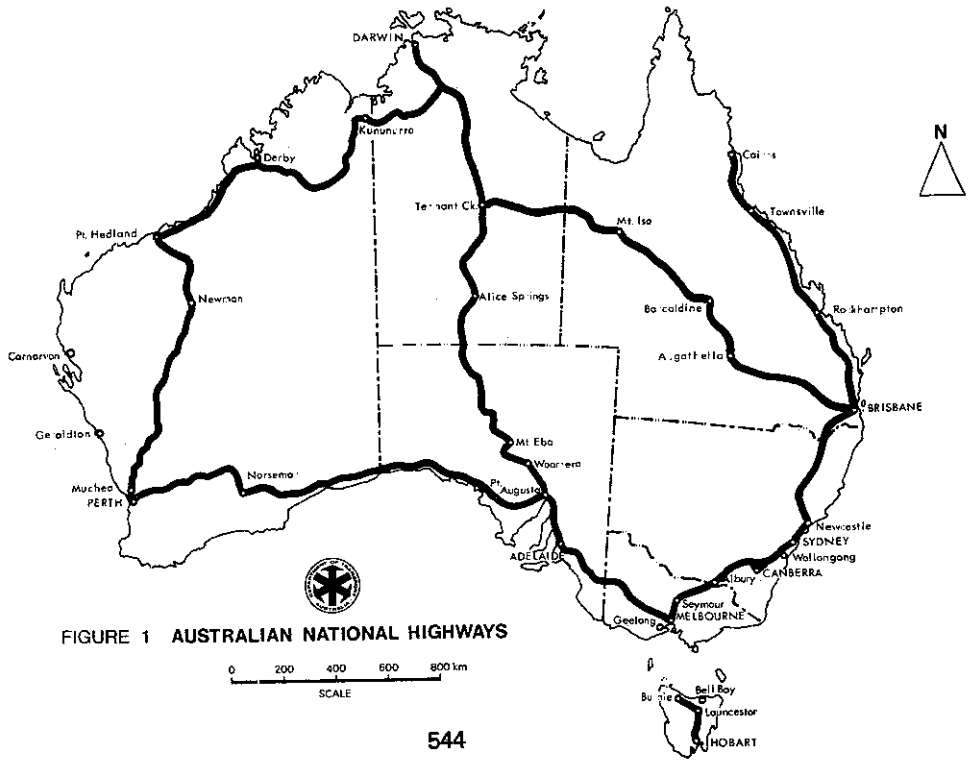

FIGURE 1 **AUSTRALIAN NATIONAL HIGHWAYS**

REFERENCES

American Association of State Highway Officials (AASHO) (1954), "A Policy on Geometric Design of Rural Highways", Washington.

Bland H.A. (1972), "Report of the Board of Inquiry into the Victorian Land Transport System", Melbourne.

Both, G.J. and Bayley, C. (1976), "Evaluation Procedures for Rural Roads and Structure Projects", Proceedings - Eighth ARRB Conference, Vol. 8, Pt. 6, Melbourne.

Bureau of Transport Economics (BTE) (1977), "Cost Recovery in Australian Transport 1974/75", AGPS, Canberra.

Country Roads Board of Victoria (CRB) (1978), "Country Roads Board Annual Report 1977/78", Melbourne, p. 4.

Department of Main Roads (NSW) (DMR) (1977), "South Western Freeway - Alternative Routes Under Investigation in the Mittagong - Moss Vale - Berrima Area", Sydney.

Department of Transport (DOT) (1976), "Consolidated Set of Design Standards for National Highways in Australia", Canberra, p.2.

Guerin N.S. (1969) "Traffic Accidents - Effects of Highway Design", Traffic Engineering Practice, Ed. Clark N. and Pretty R.L., Melbourne, p.3-10.

Harrison A.J. (1974), "The Economics of Transport Appraisal" Halstead, London, p.250 ff.

Heggie I.G. (1972), "Transport Engineering Economics", McGraw Hill, London.

Joint Road Planning Group (JRPG) (1978), "Outer Ring Study - Diamond Creek to Ringwood", JRPG Bulletin No. 3, Melbourne.

March R.C. and Beresford R. (1973), "Phased Development of Rural Highways", Proceedings - Institution of Engineers Conference on Road Engineering, Kuala Lumpur.

National Association Australian State Road Authorities (NAASRA) (1973), "Policy for Geometric Design of Rural Roads" (Metric Units), Sydney.

Pedersen T.A. (1978), "Low Cost Road Construction", Proceedings 2nd REAAA Conference, Manila 1978 (Paper quoted in West Australian 21 November 1978 p.48).

Pignataro L.J. (1973), "Traffic Engineering Theory and Practice", Prentice-Hill, New Jersey, p.187.

Rahmann W.M. (1976), "Program Allocation by Simulation - An Alternative to Cost Benefit Analysis", Proceedings - Eighth ARRB Conference, Vol. 8, Pt. 6, Melbourne.

Schimpeler C.C., Jarvis J.J. and Unger V.E. (1976), "Optimum Staging of Projects in a Highway Plan", Transportation Research Board Record, 1976.

Tarragin A. (1944), "Effect of Roadway Width on Traffic Operations : Two-lane Concrete Roads", Highway Research Board Proceedings, 1944.

Vey A.H. and Ferreri M.G. (1968), "The Effect of Lane Width on Traffic Operation", Traffic Engineering, August 1968.