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DEVELOPMENT OF ASSESSMENT TECHNIQUES AND TOOLS FOR RURAL ACCESSIBILITY

FINAL REPORT

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ABSTRACT

Current approaches to national road network planning generally focus on links and corridors in themselves and do not allow the assessment of each link as a component of the network as a whole. They do not provide any means to assess the quality of the network or the value of changes to it. This document describes a study done by Davidson Transport Consulting for Austroads to demonstrate the effectiveness of accessibility based techniques for national network planning. Further, it reviews the matter of devising accessibility based network performance measures which can help assess networks in terms of specific policies. (e.g. for particular economic, social or regional development outcomes).

Accessibility of one place to all other places is a function of the size and distribution of the other places and of the cost of getting to them. It thus combines in a single statement one point's view of the land use pattern and the transport network that serves it. Any change in either will change the value of accessibility at every point. Accessibility can be shown to be a measure of the expected utility that people enjoy from the pattern of activities available to them, reduced by the level of transport costs. In addition, changes in accessibility reflect changes in consumer surplus.

This document describes how the basic accessibility measure can be used to construct a wide variety of performance indicators that can be targeted to particular policy objectives. It then describes the national road network model constructed to test the techniques and shows the basic accessibility profiles developed using the model. Two performance indicator plots are given, one showing the degree to which the network approaches an idealised network, where every location is directly connected, and one showing the effectiveness of the network in serving a particular location.

The network model is used to test and evaluate four hypothetical road projects - two small national highway improvements in Victoria, and two large national projects – the Pacific Motorway Upgrading and the proposed Outback Highway between Cairns and Perth. This model is used to assess and compare the overall benefit of each of these projects and the footprints of benefits, allowing the relative benefits received by each state as a result of these projects to be shown.

Finally, the accessibility technique is used to explore the reliability of access for remote communities. This is done through a case study in Northern Queensland where road flooding regularly isolates communities. Maps showing the impact of a variety of flooded conditions are provided, and the overall impact of flooding is presented. A hypothetical project aimed at reducing road flooding is examined, and its impact compared with other types of road projects.

Contents

List of Figures

1. Introduction

1.1. Background

In December 1996, Davidson Transport Consulting (DTC) made a proposal to Austroads for the development of a network strategy evaluation method. This followed from a recognition that current approaches to network planning focus on links and corridors in themselves and do not allow the assessment of each link as a component of the network as a whole. Nor do they provide any means to assess the quality of the network or the value of changes to it. The proposal was to extend to a national level the work that DTC did for Queensland Transport on the Roma Pilot Project, and to review the matter of devising accessibility based network performance measures which can help assess networks in terms of specific polices. (e.g. for particular economic, social or regional development outcomes).The basic approach of the DTC proposal was incorporated into the project Brief issued by Austroads on the 27th of October 1997. The Brief was extended to include the development of tools to assess the role of roads in servicing remote communities. It was intended that that these could be used at a project level and eventually incorporated into the standard project evaluation procedure. Davidson Transport Consulting was awarded the contract, and this document is the final report for this project.

1.2. Objectives

The major objective of this work has been to develop and test network assessment and evaluation tools that both measure the performance of the overall network against defined criteria, and allow projects to be assessed in terms of overall network quality. The focus has been on developing techniques and useful computer tools for the assessment, and then to prove these tools by applying them to a test national network, and later to a particular remote area.

1.3. Review of the Concepts of Accessibility

In broad terms, accessibility is a way of measuring the benefits enjoyed from a set of activities given a set of costs associated with interacting with those activities. So, for example, a location will have high levels of accessibility to shopping if a wide range of quality shopping experiences are available at a low transport cost. The accessibility will be reduced if either the transport costs increase, or the quality or number of shops in the area decreases. Thus accessibility provides a unified indicator of both the transport and the land use system. In fact, by extending the definition of transport costs it is possible to produce accessibility indicators that take into account not only a variety of transport modes, but also non-travel options such as tele-shopping. In this way accessibility can be used as an integrated indicator of the performance of the whole system.

In the formulation used by DTC, accessibility indicators are based on well understood and widely accepted economic theory, and the basic equations have been independently developed by different researchers based on a number of different approaches. It is possible to show that accessibility is a valid measure of utility (based on random utility theory), and that changes in accessibility are a measure of changes in consumer surplus (based on supply and demand considerations).[1]

Accessibility based indicators provide an ideal starting point for examining a wide range of issues. Accessibility issues can obviously be considered directly. Equity can be considered by looking at the distribution of changes in accessibility broken down by any geographical or socioeconomic grouping. Since accessibility is a measure of benefit, and changes in accessibility are a measure of changes in consumer surplus, the ratio of accessibility improvements to project cost is correlated with the direct Benefit Cost Ratio (BCR) of a project or policy. Finally, the consideration of the factors that determine mode share are implicit in the calculations of multi-modal accessibility, and the basic equations that express behaviour in mode selection are identical to those that are used in the preparation of accessibility indicators.

In summary, the advantage of the accessibility approach is that it provides insight into many of the issues driving transport policy in an integrated, unified manner. **The accessibility approach can thus be used as a general basis for comparison – allowing a wide range of very different visions to be compared in a consistent manner. As far as we are aware, it is the only tool that can do this.**

Accessibility theory allows the formulation of a range of different measures that have value as indicators of different aspects of a subject transport network's performance or as means to compare alternative operations on the network. These measures arise through one or both of the two basic ways accessibility theory allows a network to be described - in terms of the utility it confers across the surface occupied by the network, and in terms of those geographic or topological qualities of the network which accessibility analysis reveals. The measures are either absolute or comparative values and may express a field value at a point (a point in a profile) or a network total.

Accessibility of one place to all other places is a function of the size and distribution of the other places and of the cost of getting to them. It thus combines in a single statement one point's view of the land use pattern and the transport network that serves it. Any change in either will change the value of accessibility at every point.

To be valuable, a measure of accessibility needs to reflect perceptions and behaviour. Transport planning models seek to reflect the same things: for this reason, accessibility modelling can easily be set up to be an adjunct to transport modelling and to use the same parameters. Indeed, there is a sense in which accessibility is a kind of inverse of trip distribution and the elements of accessibility measures closely resemble those found in trip distribution functions.

The measures described below are either simple geographical relationships which are easy to calculate in the context of accessibility modelling or are based on a particular measure of accessibility which we have developed. The critically important feature of the measure is that it is also a measure of utility and so can be used directly in evaluation. It is also the basis of other descriptive and evaluative indicators.

[1] See Section 2.4 for more details.

Accessibility needs to be set up so as to be "to" some activity that can be measured and "from" or applied to a population whose size is known.

Accessibility is always "to" some demographic or land use value or type of activity. It could be to employment or some segment of employment, population, a measure of the size of a particular type of activity such as retail floor space or primary school enrolments, or even the simple existence of an amenity such as a hospital or a service station or a particular franchise.

Accessibility at a place is enjoyed by the whole population of that place or whatever aspect to which the particular "accessibility 'to'" is relevant or important. This is a size measure. Thus accessibility could be of people to employment or to people (the elements of the measures being used for the national network analysis part of this study) or some specific measure such as accessibility of medical centres to trained medical support staff or of McDonalds stores to teenagers likely to be interested in casual employment (specific measures like this are useful for detailed analyses of which the isolated areas part of this study is an example).

The choice of definition of population to which the measure is relevant and activity to which accessibility is being determined depends very much on the purpose to which the measure is being applied. To return to the medical centre example, accessibility analysis could be used to assist its location in three ways:

1. To find a place where there is a large population whose accessibility to existing medical centres is low, so as to minimise competition or ensure need: the activity measure is medical centres, the size measure is population.
2. To find a place with high accessibility to potential clients: the activity measure is population, perhaps population in certain age groups.
3. To find a place where it will be easy to attract qualified staff: the activity measure is the population with certain qualifications.

It is generally in land use and location analyses, like the above example, that very disaggregate activity and size measures are used. In analyses focussed on the transport system, more global variables are used such as population for size and employment or population for activity. However if a purpose is to study how well the transport system serves industry or particular industries then industry-specific variables should be used.

Contrary to popular understanding, it needs to be emphasised that analyses of this type are of particular value in settled areas because of the subtlety and finesse with which alternatives can be differentiated and the footprint of benefits determined. Accessibility analysis comes into its own where the more usual gross indicators fail to differentiate. Thus this type of analysis would be at its most useful in places like Victoria and in other established areas with good and comprehensive road networks where impacts of change are likely to be small.

2. The Theoretical Basis for The Indicators[2]

2.1. Accessibility – Some Possible Definitions

Accessibility is a term that has been applied to various different characteristics of the land use and/or transport system. Accessibility is always understood to be the ease of getting to something, and the various uses of the term differ in the types of things that can be reached. At the most operational level, accessibility can refer to the physical ease with which various elements of the transport system can be reached. At this level, accessibility is primarily a design issue (see for example Ryan and McNally(1995) - "Accessibility of Neotraditional Neighbourhoods"), and often there is a focus on people with disabilities, or particular emphasis on public transport. In order to prevent confusion, many people refer to this as access rather than accessibility (for example Replogle (1992) – "Bicycle Access to Public Transportation: Learning from Abroad").

Accessibility can also be used to describe these same sorts of access issues, but at a system-wide or policy level. Tyler (1993) uses the term accessibility to refer both to the physical ease of getting onto vehicles, and also the availability of transport system as a whole:

> *"In recent years, the term accessibility has been concerned with the access to elements of the transport system (for example, to vehicles), with an emphasis on certain sectors of the population (for example, the elderly or the mobility impaired). Accessibility, however, is also a matter of accessibility to the transport system as a whole. In this context, accessibility includes not only the consideration of access to vehicles - step heights, hand rails, seating arrangements and so on – but also the consideration of transport system in terms of time and space from the perspective of the user. The term accessibility can be considered in a wider context than is often accepted, and should include matters of frequency, network design, interchange policy, safety and cost. It is important to stress that this perception of accessibility includes all the aspects of the current understanding of the term."*

This interpretation of accessibility is still concerned with obtaining access to the transport system, not to the activities that can be reached by the transport system. But the transport system is only a means to an end, and only really exists to let people reach other activities, as this is the reason they travel. It is possible to have a transport system that is highly accessible, ie. it provides a high level of access, but which does not allow people to easily reach the places to which they want to travel. The only way of measuring how well the transport system serves people's needs is to consider not only the transport system, but also the distribution of activities that can be reached by the transport system.

[2] Some of the material presented in this section first appeared in Davidson Transport Consulting's report to WA's Department of Transport on "The Development of an Accessibility Measure for the Transport Portfolio", 1998.

To avoid confusion, we will refer to the lower level meaning as access, and reserve the term accessibility for the combined land use/transport description. Much of the literature seems to adopt this practice, with only a small number of papers using the term accessibility to describe what we would call access, and only one paper using access to describe what we would call accessibility, Martinez(1995) – "Access: The transport-land use economic link".

Since 1959, there have been a number of papers published on accessibility, each with a slightly different focus, and many with alternative measures and definitions of accessibility. Although there is some variety in the measures of accessibility, there is broad agreement as to its meaning. Following is a selection of definitions or descriptions of accessibility taken from the literature.

> *"..accessibility is a measurement of the spatial distribution of activities about a point, adjusted for the ability and the desire of people or firms to overcome spatial separation." (Hansen, 1959)*
>
> *"Accessibility, according to a definition proposed by Dalvi(1978), denotes the ease with which any land-use activity can be reached from a location using a particular transport system." (Koenig, 1980)*
>
> *"..accessibility, or the ease with which locations of interest can be reached for desired interaction." (Helling, 1995)*
>
> *".. it is "some generalised measure of ease of interaction"(Harris,1966).*
>
> *"Accessibility is a characteristic which can be possessed by both a point in space, or a region (i.e. it can be point specific or integral, the latter being a summary measure of the individual accessibilities of all points in a region); which can be considered at various levels of aggregation (e.g. accessibility to a particular activity or to all activities; by one mode or all modes); which may be measured in terms of a number of different attributes (i.e. time, money and other level of service characteristics such as comfort, frequency, safety etc.); and which is perceived differently by different individuals (for example, travel time is valued more highly by some people than by others)." (Peacock, 1993)*
>
> *"Accessibility typically refers to the ease with which desired destinations may be reached and is frequently measured as a function of the available opportunities, moderated by some level of impedance." (Niemeier, 1997)*
>
> *"A powerful aspect of the accessibility concept is that it combines in a single, simple measure the relevant characteristic both of the land use and the transport system. Thus any change in either system will, in general, lead to a change in accessibility at every point within the are of the system." (Davidson,K , 1977)*
>
> *"Accessibility is concerned with the opportunity that an individual has to partake of a particular activity or set of activities. It is not concerned with behaviour, but with the opportunity, or potential that people at a particular*

location have of interacting with different types of land use." (Davidson, P and Pretty, 1990)

From these, and other papers, it is possible to distil the following properties of accessibility

- Accessibility is concerned with both the land use and the transport system, and provides an integrated way of measuring changes to either system.
- Accessibility considers the desirability of travel, not the actual travel that occurs. It is thus concerned more with the potential of travel, and accessibility can be determined for areas even when no one lives there.
- Accessibility is calculated with respect to a particular set of activities and a particular set of travel costs. Accessibility is TO an activity set and BY a transport system.
- Different individuals may experience different accessibility because their choice set may be different, their perception of the network costs may be different, and their preferences may be different.
- Accessibility may be improved by decreasing the costs of interaction, or by providing new activities. Either of these changes will have a positive (or zero) effect on accessibility.

2.2. Explanation of Terms

On the following pages, a number of different accessibility indicators will be examined and critiqued. The descriptions include the form of equations used to determine the indicators. All of the equations are based on the same type of input data, and so a consistent set of variables are used, and defined as:

A_i A Measure of the number of attractions at a particular destination. Depending on the type of accessibility measure, this could be the number of employment opportunities, the total retail floor area or the number of primary school enrolments.

P_i A measure of the size of the market in zone i. Often population is used, but for specific accessibility indicators one would use a measure of the market being considered. For example, if accessibility to primary schools is being considered, then the Pi values would reflect the number of primary school students in an area.

C_{ij} A measure of the cost of interaction between location i and j. This is usually the travel time or generalised cost (actual cost plus the cost equivalent of time).

T_{ij} A measure of the extent of interaction between locations i and j. This is usually the number of person trips between the locations on an average day, or over the year. Sometimes other measures might be used, such as the tonnes of freight being moved between the locations, or the number of shopping trips.

Three types of accessibility indicators are considered below. All of them provide an indication of accessibility, but differ in the type and unit of numbers that they generate.

- X_i An attractiveness based accessibility measure. It can be seen as measuring the effective number of attractions that can be reached. It is an increasing measure of accessibility, but has the units of attractions measure rather than the units of cost (e.g. accessibility is the equivalent of 10,000 jobs)
- Y_i A cost based accessibility measure (or a disutility measure). Low values indicate high accessibility, and the measure has units of cost (e.g. average cost is 38 minutes or $7.50/trip)
- U_i A utility based accessibility measure. High values indicate high accessibility, and the measure has units of cost, which are equivalent to the units of benefit (e.g. the benefit of living at this location is $35/day).

2.3. Early Accessibility Work – Hansen Accessibility

Accessibility type indicators have long been used as a measure of the performance of the transport system, and as a basis for explaining transport behaviour and urban form. At first very simple indicators were used, such as travel time or distance to a particular point (often the CBD in urban studies). An example of this type of indicator comes from the work of Colin Clark (1951) who found a negative exponential relationship between urban density and distance from city centre.

In 1959 Hansen proposed a more sophisticated indicator that has probably been the most widely used (and misused) accessibility indicator. In its original formulation, it used a power function

$$X_i = \Sigma_j \left(A_j / T_{ij}^n \right)$$

This form was used because transport attraction was seen as analogous of gravity, and in fact the power function used is often the inverse square of gravitational attraction.

It was later generalised to the form

$$X_i = \Sigma_j \left(A_j \, f(C_{ij}) \right)$$

where $f(C_{ij})$ is an impedance function, such as that used in the gravity component of a four-step model.

There is no theoretical justification for this approach, but it can be seen as derived from two common sense considerations (from Koenig 1980)

a) The total number of opportunities may be considered as a crude proxy for the satisfaction provided at the chosen destination: where the wider the range of choice among opportunities, the higher the probability of finding a good one for fulfilling a given trip purpose or need;

b) The impedance function $f(C_{ij})$ reflects the obvious feeling that a nearby destination should have a higher weight than a remote one. An exponential impedance, for instance, seems satisfactory as it counts as one, a destination at zero distance and as zero, a very distant destination.

The main problem with the Hansen accessibility index is that it is not a linear measure of utility. This is hinted at by examining units of the indicator – with an inverse square law the units are jobs/min^2 (assuming that accessibility to employment is being calculated based on travel time). This is not a unit of a utility measure – which would normally be stated in minutes or dollars. The strange units also show that the indicator is not very meaningful – the numbers that it generates cannot be simply understood and it is impossible to guess what sort of ranges of numbers might arise.

2.4. Theoretical Foundations

Recognising the lack of a theoretical basis for accessibility, a number of researchers have considered the problem from first principles. This effort began in the 1970's and two quite separate methodologies have yielded the same indicator.

The first approach was to consider classical economic theories of consumer surplus. This was done by Neuberger in 1971, when he considered the change in consumer surplus (the benefit that a consumer receives from a good above the price paid for it) that results from a change in the distribution of costs and activities. Based on the assumption that people choose their destination according to a standard gravity model with an exponential deterrence function, Neuberger found that the variation in consumer surplus over the whole city is equal to the variation in the value given by

$$U_{Total} = x_0 \Sigma_i P_i \ln X_i$$

Where

$$X_i = \Sigma_j A_j e^{-C_{ij}/x_0}$$

The second approach was developed in various forms by a number of researchers, and may be called the Behavioural Utility Approach or Random Utility Approach. This approach is based on two prime assumptions (from Koenig, 1980)

a) People associate a cardinal utility with each of the alternatives they are facing (for example: with each available destination, travel mode, route ..) and take the choice with the maximum utility to them as individuals; and

b) It is not possible for a planner to evaluate all of the factors affecting the utility associated with each alternative by a given individual, and an individual's perception of utility may vary. Thus the cardinal utility can be represented as the sum of a non-random component (for the predictable factors) and a random component (for the non-predictable and random factors).

By considering various distributions for the random variable, different models were developed, including the Hivex model (Koenig, 1974) and the Logit model (Domencich and McFadden, 1975). When the expected value of the maximum utility was calculated, both of these models gave the same result.

$$U_i = x_0 \ln (\Sigma_j A_j e^{-C_{ij}/x_0})$$

It can be seen that this is consistent with the result found by Neuberger, where the system surplus S is just the sum of the maximum utility of each location weighted by the number of trips produced at that location

When the units of this measure are determined, they are found to be the same as the cost units – i.e. dollars or minutes. This, along with the solid theoretical background, shows that the utility based accessibility indicator is a linear accessibility measure.

Although this is the best overall indicator of accessibility, it is sometimes difficult to understand exactly what the numbers mean. They have the usual property of any utility measure in that differences between utilities are meaningful, but the absolute values of the numbers have little meaning. In order to produce easily understandable numbers, a transformation initially developed by Patton and Clark (1970) and later generalised by K. Davidson (1977) can be applied. This transformation was initially applied to Hansen type accessibility indicators with an inverse power function, and was defined by

$$X_i = \Sigma_j \, (A_j \, f \, (C_{ij}) \,) = (\Sigma_j \, A_j) \, f \, (Y_i)$$

Where Yi is a new measure, named network disutility. It is also possible to apply this transformation to the utility accessibility measure, leading to the following equation

$$Yi = x_0 \ln(\Sigma_j \, A_j) - U_i$$

From this equation, it can be seen that isolation is a measure of the additional cost incurred because the activities are distributed and have a cost associated with reaching them. Another way of seeing it is as an answer to the question "If all of the activity in the system were located at a single point, how far away am I from that point?"

The problem with the isolation measure is that it can only be used when the total amount of activity in the system does not change. But it is very easily calculated from the utility accessibility measure, and so it is easy to use whichever of the two measures is most appropriate.

In either the utility formulation or the isolation formulation, this type of indicator has been used to consider a wide range of issues including: road investment evaluation (Koenig, 1980, Neuburger, 1971), trip rates (Koenig 1980), land use/transport interaction (K. Davidson, 1977), land prices (P. Davidson, 1990), car ownership (Queensland's ITFEM models, 1997), network planning and evaluation (Davidson and Davidson, 1995) and equity evaluation (Strategic Liaison Committee, 1994). It is also implicit in many mode choice models, in particular the hierarchical logit model which is widely used in advanced integrated transport models.

For the remainder of this paper, the use of the word "Accessibility" (with a capital) means accessibility calculated according to this utility formulation. Where a more generic meaning is sought, "accessibility" without the capital is used.

2.5. The Problems with Using Total Travel Time as an Evaluation Measure

Total travel times/costs are sometimes used as a simple accessibility measure, based on the idea that locations that are well located will be those that have low total travel time. The indicator can be determined by surveying or estimating the average travel time for all people living (or working) in a given area. An accessibility indicator for the whole system can be made by estimating the total travel time/cost of all users or the average travel time/cost. This type of indicator is used very often for the evaluation of transport options, and in fact savings in travel time are often used as a justification for transport expenditure.

The equation for the indicator is given by

$Y_i = \Sigma_j T_{ij}C_{ij}$ (for total cost)

Or

$Y_i = \Sigma_j (T_{ij}C_{ij}) / \Sigma_j (T_{ij})$ (for average cost)

This indicator is quite intuitive, but suffers from a serious problem – travel is a means to an end, not an end in itself. By measuring travel cost, we are measuring an input, not an output; we are seeing only the cost component of the traveller's decision, not the basic motivating factors. As Koenig(1980) says:

"The pathological properties of travel time (or cost) as an indicator of welfare change have been recognised for a long time (Neuberger, 1971; Poulit, 1974; Koenig, 1974; Williams, 1976). It is easy to find cases where an obvious improvement of transport conditions might paradoxically be associated with an increase in the mean or total travel time. As an example, improving transport conditions (by reducing travel time) between a city centre and a suburban centre may lead to some inhabitants of that suburban centre to give up a nearby shopping destination in their suburb, and prefer shopping in the more attractive city centre, even with a higher travel time."

"It might be said that the planner is put in the position of an accountant who has to estimate the profit made from goods, of which he knows the cost but not the selling price." (Koenig, 1975)

Another example of the problems with this approach can be seen from a study of new river crossings in Brisbane in 1986 (as part of the Brisbane Traffic Study). A transport model was used to evaluate a range of possible bridge locations, including one which opened up an area that had, until then, been poorly served. The model showed that the people in this area were taking advantage of the bridge to gain access to improved shopping and recreational locations. When the total system travel time was examined, it was found that their increased travel meant that the overall cost of travel from that area had increased. But it was clear that the accessibility of the area had actually increased. The additional travel cost was more than offset by the benefits of being able to access the more attractive locations.

A final example can be seen by considering the effect of adding a new regional shopping centre to an area that previously had only small local shops. The distance that people travel to reach the new shopping centre is obviously higher than the distance they travel to use their local shops. Thus if they shift some of their shopping to the new regional centre, their travel time for shopping will increase. But again it is clear that their accessibility has actually increased, and they are travelling further to gain access to a wider range of choices

3. Accessibility-based Transport Network Indicators

3.1. Introduction

Starting with the basic concepts of accessibility described earlier, it is possible to construct a variety of indicators, each of which gives a different perspective on some aspect of the land use/transport system. Some of the possible indicators are presented below.

It should be noted that all of these accessibility indicators are focussed on analysing the land use/transport system from the users point of view. They do not include externalities because accessibility is based on models of user behaviour, and by definition externalities are not considered in people's transport choices. The travel cost estimates included in the model should be based on all of the costs that users perceive, and thus could include some allowance for safety, and perhaps environmental impacts. It would be possible to calculate accessibility values based on the full social cost of people's travel, but then the model would be assuming that people make their choices to maximise the social good. This may be true to some degree, but the usual assumption is that people make choices to maximise their own benefits.

The consideration of user benefits should be combined with a consideration of the other impacts of transport/land use options, including social, environmental, financial, and transport agency issues.

3.2. Presentation Methods

All of the indicators below that give a value for each zone can be shown in two ways

- contours of equal value of the indicator
- a coloured thematic plot, where each zone is coloured based on its indicator value

The contour plots can be more revealing, but they are much more difficult to produce, as they must be manually drawn. (Software does exist to produce contours automatically, but they are generally based on assumptions that work well for landscapes but not as well for accessibility contours which can have significant discontinuities and strange boundary conditions). This report uses thematic plots for the presentation of the indicators. Whichever way they are drawn, the plots can be considered as a landscape, with mountains of high indicator values and valleys of low indicator values. The topographic features of the plot are more easily seen on a contour map.

3.3. The accessibility field or profile

Accessibility has a specific value at every point in a designated region covered by a transport network and the land-use pattern it serves. Any change to any part of either the transport network or the land use pattern will change the value of accessibility at every point. This profile of accessibility values therefore has the characteristics of the physics notion of a field (e.g. it is quite closely analogous to a gravitational field or a magnetic field) and can be analysed using similar approaches.

3.3.1. Indicator 1: Plot of Accessibility (or Plot of Network Disutility)

The first indicator of network performance is simply the plot of the Accessibility field strength. To an experienced observer the plots provide a very useful qualitative picture of the land-use/transport-network system. For example:

- Broadly, population centres show as peaks, corridors as ridges, barriers or areas between routes as valleys, and areas where a new route would always make a big difference as "cliffs."
- This "cliff" effect at some barriers is particularly relevant when looking for new bridge sites across rivers: the bigger the difference between Accessibility values on each side, the greater the impact a new crossing would have on the side with lower value (this does not necessarily mean a bridge there would give the greatest overall improvement to accessibility - there are better indicators for that and they are introduced below).
- Travel tends to be perpendicular to contour lines.
- Areas of equal Accessibility tend to have similar development densities.
- Areas of influence of centres can be seen easily with the boundary between them the point of lowest Accessibility. This can be observed for competing small centres and competing large centres.

It is also possible to plot network disutility, rather than accessibility. The plot will look exactly the same, except that the values are reversed and offset by a constant factor (see Section 2.4 for a discussion of this). Disutility plots can be more useful because the numbers are easier to interpret – they correspond to travel costs. All of the discussion about the topography of the map are still valid, except that the landscape has been inverted so that hills have become valleys etc.

3.3.2. Indicator 2: Total Accessibility and Average Accessibility

This is calculated by multiplying the accessibility at each point by the population at that point and adding. Average Accessibility is determined by dividing the Total Accessibility by the total population. When using a utility approach to accessibility, total Accessibility is the location utility of the system.

Average Accessibility can be used to compare the effectiveness of different networks or the same network over time. A greater average value indicates improvement.

3.3.3. Indicator 3: Change in the Accessibility field or profile

A change in the Accessibility field is brought about by a change in the transport network or the land use system or both and this indicator, because it represents change in utility, shows the footprint of the distribution of the benefits and dis-benefits.

Knowing the footprint of the benefits and dis-benefits of various magnitudes is extremely useful when assessing the effects of a proposal to undertake work which will change the network, and may also be used to assess the relative merits of competing proposals. Because it shows the footprint of benefits, this indicator can be used to assess the distributional effects and equity or social justice implications of a proposal or program. These are particularly important where the project or program is in pursuit of, or needs to be signed off regarding government policy of a distributional nature, for example one that favoured regional development.

3.3.4. Indicator 4: Change in Total Accessibility – Benefit Footprints

Change in Total Accessibility is measured by either subtracting Total Accessibility of the existing network from that for the proposal or by summing the product of the change in Accessibility at a point by the population at that point.

A simple efficiency way to choose between alternative proposals or network development programs is to compare the change in total Accessibility which each produces.

This indicator can be determined in nominated partial ways to evaluate how well it meets any government distributional policies. For example the policy may be to concentrate infrastructure benefits in a particular depressed or disadvantaged area: the relative impact of proposals on that area can readily be assessed if this indicator is calculated for both the subject area and the balance area for each proposal.

3.3.5. Indicator 5: Change in Total Accessibility per unit cost

Calculate this by dividing Change in Total Accessibility by the total cost of the proposal or program. It is valuable where proposals or programs of different total cost are being evaluated.

If the stage is reached where money values can be put on the locational utility measured by Accessibility, this value simply becomes the Benefit Cost Ratio for the proposal.

In any case, the most efficient proposal or program is the one with greatest Accessibility gains per dollar, or the most efficient program is the one composed of the set of projects which sum to the program allocation and which produce the greatest sum of accessibility gains.

If there are significant differences in the economic lives of projects, or the sequencing of benefits, then further analysis would be required on a “whole of life” basis.

3.4. Network Effectiveness

If the above indicators are being used to assess the quality of alternative changes to the network and its relationships with land use, Network Effectiveness indicators attempt to address the overall quality of the network in its geographical context.

No transport network can serve all travel desires perfectly but the amount by which it fails to do so can be a useful way to study an existing network and to identify fundamental areas of weakness. So the Network Effectiveness indicators seek to make various comparisons between a network as it is and a geographically perfect network.

A geographically perfect network is defined as one in which any trip can be made on a straight, flat smooth route at 100km/h unimpeded by other traffic. For analysis purposes a perfect network is constructed by assuming a perfectly straight (in geographic terms, a great circle line) route between each pair of zone centroids and that the cost of travel along that notional route is determined by assuming flat smooth unimpeded travel at 100km/h. Provided zone centroids have geographic coordinates, the determination of inter-zonal trip costs for such a network is straightforward.

3.4.1. Indicator 6: Plot of Network Quality

The ratio of Accessibility by the existing network to Accessibility by the perfect network calculated at each point and plotted as a field with contours of equal value of the ratio, or as a thematic plot.

This shows how well the network actually serves each point compared to how well it would be conceptually possible to serve that point. In making this comparison, the point’s actual location is taken as a given as is its geographical relationship to every other point. By using Accessibility as the basis for comparison, the size of each point is also taken into account as a given weighted according to established travel behaviour. So the actual quality of the transport network is isolated as the only variable. Of course there could be good reason for poor network quality in some areas, for example where there are significant areas covered by rugged mountains or where major barriers affect the directness of linkages. In other areas there will be no such reason.

The plot will show which areas are relatively well served by the network and which are relatively poorly served. Any consistent regional trend to poor quality that is not explained by the difficulty of the topography should suggest a need for a network review in the region with a view to improving linkages.

A goal of road authorities could be to develop the road network in such a way as to make the network quality as uniform as possible (i.e. a flat landscape in the plot). The effect of different infrastructure development program options or alternative link inclusion options on this indicator would give valuable choice-making guidance.

3.4.2. Indicator 7: Average Network Quality

Summing the product of population and the network quality ratio and dividing by total population will give an average value of network quality. This could be done for the whole network or for sub-areas of it - such as States or metropolitan and non-metropolitan regions.

The average value for the network is perhaps the most fundamental performance indicator for the transport network and can be plotted over time as a true indicator of whether the network is improving in its quality of service to the changing land use and population distribution pattern.

The average value for sub-areas can be used for policy development and to assess performance against policy goals. For example, the Commonwealth Government would presumably be interested to ensure that the difference in average between States was as low as possible. Commonwealth and State Governments may wish to develop policies regarding particular regions if low values of the indicator were recorded in them.

3.4.3. Indicators 8 & 9: Activity-Specific Network Quality Distribution and Averages

To the extent zone-by-zone activity data can be identified or developed, it would be possible to develop Network Quality indicators for particular activities, such as particular industries.

One network cannot serve different types of activities equally well if they are differently distributed. It may be necessary to make choices between different types of activities (say, for example, serving the tourist industry against serving the manufacturing industry because both have different patterns of activity destination). This indicator would enable the current situation to be assessed and the effect of alternative programs on each identified activity to be determined.

Note that changes in Accessibility are indicators in themselves. With the above Network Effectiveness indicators, changes will be scalar to changes in Accessibility so separate indicators are not necessary. It is the profile and values between regions which are important here.

3.4.4. Indicator 10: Plot of Network Directness

A Network Directness map may be constructed for any chosen point by simply calculating for each other point the ratio of the travel cost from the subject point via the network to the travel cost via the ideal network, and then plotting the values.

Network directness maps are useful to demonstrate how well the network serves each significant point and to identify whether there are any regions significant to that point which the network serves badly. It will generally be found that networks provide metropolitan areas with good links to all regions but provide very patchy service to other centres. The need for new or upgraded cross-links may be revealed by such analysis.

3.4.5. Indicator 11: Volume Normalising Factor

When trying to decide on routes which are of comparable significance in a strategic sense, it is easy to allow traffic volume to overwhelm the consideration and to over-represent busy roads in developed areas at the expense of highly strategic routes in isolated areas.

High accessibility is associated with high development density and typically high volumes. Conversely, low accessibility is associated with isolation, low density and low traffic volumes. The most highly strategic route in an isolated area may have traffic volumes far lower than the most insignificant collector street in a high-density area.

It has been found that dividing actual volumes by Hansen's accessibility produced normalised volumes which were effectively identical over the whole lengths of major highways running between high density and isolated areas. A similar relationship is confidently expected to be found with some function of the utility-based Accessibility and this is being explored.

Use of volume normalising factors is valuable in determining a large-scale strategic network in that it allows roads in widely different types of regions to be compared in terms of normalised traffic volume as one determinant of strategic significance.

4. The National Accessibility Model

4.1. Background

As part of this project, Davidson Transport Consulting has developed a computer representation of Australia's road network. This network is designed to include all of the roads that are significant for non-local travel, and thus includes all of the National and State Networks, and many significant local roads. The network includes data on travel speeds provided by each of the Australian road authorities. There is some variation in the speed data included in the model, as some states were only able to provide posted speed and other states could not provide any speed data at all. There is undoubtedly scope for refinement of the data in the network, but we believe that the data quality is sufficient to allow the techniques to be demonstrated and to provide insight into the effects of network changes.

It should be noted that the speed data for non-urban areas in Western Australia was not available when the network was being constructed, and so the network currently assumes all roads in WA have speeds of 100km/h. This will make WA appear better than it is and will perhaps reduce the impact of projects such as the Cairns-Perth "Outback Highway" option. However, the results for the rest of the country will be largely unaffected.

For this initial analysis of the national road network, both the activity and size variable will be population. Using it as the size variable is common in all types of general analysis but using it as the activity variable needs to be justified. Here it is justified on the grounds that it is a reasonable surrogate for all types of attractive activity in towns or regions where the study area is large and where local travel is not a significant component. It s particularly justified in that it is the only variable readily available in a consistent form across the whole of Australia. Population data is available down to the Collector's District level and is commonly aggregated at the SLA (statistical local area) level which is a convenient starting point for zone definition for a national network. Acceptable predictions of population are also available at the SLA level.

At this stage of the analysis, the surrogate used for travel cost will simply be travel time. For later projects it may be possible to substitute some better measure that relates to link quality, depending on availability and consistency of data.

4.2. Plot of Accessibility Field (Indicator 1)

Figure 1 shows the profile of accessibility described above as Indicator 1. The plot shows network disutility rather than accessibility, but as discussed in Section 3.3.1 the two plots are almost identical (as long as the colour ranges are chosen consistently).

4.3. Plot of Network Quality (Indicator 6)

Figure 2 shows the plot of Network Quality. As discussed in Section 3.4.1 this indicator measures how close the network is to an ideal network, expressed as a percentage. The higher the number, the better the network is, with a value of 100%

meaning that the network serves the areas needs as well as is possible given that it is in that location.

The plot shows that generally the network serves the needs of capital cities quite well, but that outside the cities the quality varies significantly. Most of Victoria is very good, with the exception being those areas affected by the Snowy Mountains. Tasmania and New South Wales have greater areas of low quality away from the large urban centres. Queensland has a well served coastal area, but with a significant drop in quality in the southwest corner of the state. The Northern Territory is well served in the north, and South Australia is well served in the southeast corner of the state. Almost the entire coast area of Western Australia has a very high level of network quality, but the eastern regions of the state are not so well served.

4.4. Plot of Network Directness (Indicator 10)

Figure 3 shows the Network Directness measure for Adelaide's CBD.

Figure 1 : Base Network Disutility

Figure 2 : Network Effectiveness

Figure 3 : Network Directness (Adelaide)

4.5. Use of Accessibility to Explore the Effect of Two Simple Network Changes

4.5.1. Description of Options

In order to test the ability of the accessibility approach in evaluating road network changes, two similar network improvements were proposed. The two changes were chosen so as to represent projects of similar cost, and consisted of a reduction in the travel time along two sections of road. The two sections of road selected for analysis were

- The Goulburn Valley Highway, North of Shepparton through to Cobram (total length 56.5 km)
- The Western Highway Southeast of Horsham through to Stawell (total length 54.9km)

Each of these sections of road had their travel time reduced in turn by 20%, a reduction in travel time of about 6 minutes. Figures 4 and 5 show the resulting footprints of the benefits. The benefits show the increase in accessibility at each location as a result of the road improvement. If the options had included some worsening of conditions, the plots would show some locations with a negative benefit, but for this analysis both options are simple improvements.

4.5.2. Benefit Footprints (Indicator 4)

The benefit footprints reveal that the options serve very different areas. The Goulburn Valley Highway improvement leads to improvements of accessibility within Victoria, but an even more significant improvement in NSW. The areas affected even reach up into Queensland, with very minor improvements as far North as Carpentaria (although at this distance, the network disutility is reduced by only half a second). It is interesting to note that the option has more effect in Southern Queensland than it does in Northwestern Victoria, which is largely unaffected.

The Western Highway improvement has most effect in far Western Victoria, and it extends into the Southern areas of South Australia. The rest of Victoria is largely unaffected, and none of the other states receive any benefit at all (apart from a very small improvement in the Northern Territory just north of its border with SA and one area in WA).

Figure 4 : Benefit Footprint (Goulbourn Valley Hwy, Shepparton)

Figure 5 : Benefit Footprint (Western Hwy, SE of Horsham)

From a comparison of the benefit footprints, it appears that the Goulburn Valley Highway option has a more significant impact, and affects a wider area than the Western Highway Option. By weighting the accessibility improvement in each area by the population of that area, it is possible to make a precise evaluation of the total influence of each option. In addition, it is possible to perform this analysis on a state-by-state basis to determine the extent to which each state benefits from the options. The results of these calculations are shown in the table below.

The use of population as a weighting factor for accessibility seems reasonable, but it is also possible to weight by other attributes. For instance, if we were concerned with the effect that a particular option might have on certain industries, we could weight the accessibility change to that industry by the total size of that industry in each area. Alternatively, equity issues could be explored by finding the distribution of total benefits broken down by income. If we were trying to determine the total potential of accessibility improvements, we might weight the changes by area. This is also shown in the table below.

	Goulburn Valley Highway North of Shepparton			**Western Highway Southeast of Horsham**			
	Total Benefit (Change in Total System Cost)	Distribution of Benefits Between States	Reduction in State's Total System Cost	Total Benefit (Change in Total System Cost)	Distribution of Benefits Between States	Reduction in State's Total System Cost	Total System Cost (hours x persons)
NSW	171,710	43%	0.0086%	-	0%	0.0000%	33,230,379
VIC	195,716	48%	0.0143%	38,322	34%	0.0028%	22,739,710
QLD	32,211	8%	0.0018%	-	0%	0.0000%	29,501,922
SA	182	0%	0.0000%	72,597	65%	0.0105%	11,513,608
WA	-	0%	0.0000%	16	0%	0.0000%	16,703,468
TAS	409	0%	0.0001%	110	0%	0.0000%	6,021,441
NT	-	0%	0.0000%	793	1%	0.0004%	3,519,443
ACT	3,779	1%	0.0034%	-	0%	0.0000%	1,857,450
	404,006	100%	0.0054%	111,838	100%	0.0015%	125,087,421

Accessibility Changes Weighted by Area

	Goulburn Valley Highway North of Shepparton			**Western Highway Southeast of Horsham**			
	Total Benefit (Change in Total System Cost)	Distribution of Benefits Between States	Reduction in State's Total System Cost	Total Benefit (Change in Total System Cost)	Distribution of Benefits Between States	Reduction in State's Total System Cost	Total System Cost (hours x sq km)
NSW	70,343	72%	0.0171%	-	0%	0.0000%	6,875,770
VIC	11,367	12%	0.0123%	3,482	8%	0.0038%	1,536,268
QLD	15,598	16%	0.0009%	-	0%	0.0000%	27,487,822
SA	152	0%	0.0000%	25,466	61%	0.0024%	17,633,986
WA	-	0%	0.0000%	1,798	4%	0.0001%	50,515,761
TAS	143	0%	0.0003%	13	0%	0.0000%	941,858
NT	-	0%	0.0000%	11,238	27%	0.0007%	28,570,862
ACT	24	0%	0.0026%	-	0%	0.0000%	15,863
	97,627	100%	0.0012%	41,997	100%	0.0005%	133,578,188

A number of interesting conclusions can be drawn from these tables. Firstly, the conclusion drawn from the maps is confirmed – the Goulburn Valley Highway option leads to a much greater increase in accessibility than the Western Highway option. A comparison of the total benefits shows that the first option is almost four times as effective as the second, and would reduce Australia's total transport burden by 0.015%.[3] (It should be noted that the numbers in the table are proper linear measure of the benefit of accessibility changes and the total cost of travel, but the values of the numbers are not directly meaningful at this stage. It would be possible to make them more meaningful by scaling the total system cost to a more meaningful measure – such as the total annual travelling cost. However, even if this were done, it should be remembered that the measures reflect changes in the utility of travel, not changes in travelling cost. This is a fairly subtle distinction, and is explained more thoroughly in 2.5 - The Problems with Using Total Travel Time as an Evaluation Measure.)

An examination of the distribution of benefits by state shows that the two options have quite different beneficiaries. Almost half of the benefit of the first option is received by people living in Victoria, with New South Wales receiving 43%, Queensland receiving 8% and the remainder split between Tasmania and the ACT. The second option is most significant in South Australia, which receives two thirds of the benefit, with most of the remainder going to Victoria.

It is interesting to note that even though both of the options are within Victoria, the majority of benefits are received outside of Victoria. If the interstate benefits were excluded from the evaluation, a different conclusion could result. This is not the case here, as even within Victoria the first option is significantly better.

When the benefits are weighted by area, a different picture emerges. NSW receives 72% of the benefit of the Shepparton option, and Queensland now receives more of the benefit than Victoria –16% as opposed to 12%. This indicates that the option has more potential for improving conditions in NSW and Queensland than Victoria, it just doesn't have much population in the areas affected. The same is true for the second option, where more land is improved in NT than in Victoria, but in areas with little population.

The analysis also shows that even within a mature, well-developed network, changes can have far reaching effects. Without the use of the accessibility analysis described here, it is difficult to see how these effects could be evaluated.

[3] The column "Reduction in State's Total System Cost" is calculated by dividing the Total Benefit of the option by the Total System Cost.

4.6. Use of Accessibility to Explore Two Major Road Proposals

One of the major roles for a National Accessibility Model is to allow the testing of National projects. As a further demonstration of the effectiveness of the technique, two major projects have been evaluated – the upgrading of the Pacific Highway and the so called "Outback Highway" option, improving the connection between Cairns and Perth. Figures 6 and 7 show the benefit profiles of these options, and the following table shows the results on a state by state basis.

Accessibility Changes Weighted by Population

	Cairns to Perth (via Winton, Alice Springs, Uluru,Leonora)			Pacific Motorway 110 kph along entire route			
	Total Benefit (Change in Total System Cost)	Distribution of Benefits Between States	Reduction in State's Total System Cost	Total Benefit (Change in Total System Cost)	Distribution of Benefits Between States	Reduction in State's Total System Cost	Total System Cost (hours)
NSW	8,544	0%	0.0004%	73,292,988	70%	3.6760%	33,230,379
VIC	17,214	1%	0.0013%	963,025	1%	0.0706%	22,739,710
QLD	1,049,717	54%	0.0593%	28,789,390	28%	1.6264%	29,501,922
SA	57,149	3%	0.0083%	121,345	0%	0.0176%	11,513,608
WA	541,051	28%	0.0540%	-	0%	0.0000%	16,703,468
TAS	405	0%	0.0001%	16,891	0%	0.0047%	6,021,441
NT	271,877	14%	0.1287%	748	0%	0.0004%	3,519,443
ACT	-	0%	0.0000%	1,100,952	1%	0.9879%	1,857,450
	1,945,956	100%	0.0259%	104,285,339	100%	1.3895%	125,087,421

From this analysis we can see that the Pacific Motorway shows total benefits about 65 times as great as the Outback Highway. In simple cost-benefit terms, if the Pacific Motorway cost less than 65 times as much as the Outback Highway, it would produce a better economic result. However, the benefits would be very differently distributed and this difference in benefit distribution would be likely to be relevant in a full evaluation.

It should be noted that these evaluations are based on very simple representations of these options – in both cases it is assumed that the speed along the entire route will be brought up to 110 kph (except in those areas of NT where the speed is currently higher than 100). This may not be achievable for the Pacific Motorway option. The results are also dependent on the current travel speeds entered into the model. There is currently some inconsistency between speed estimates in different states, and this may skew the results to some degree (giving more benefit in those states that currently underestimate speeds).

Figure 6 : Benefit Footprint (Outback Highway)

Figure 7 : Benefit Footprint (Pacific Motorway Upgrade)

5. Development of Reliability Evaluation Model

5.1. Introduction

5.1.1. Objectives

In recent times there has been a move away from a standards approach to road investment towards a much more explicit calculation of benefits and costs. But it has been recognised that the standard economic approaches set forth in the typical Cost Benefit Analysis often ignore or undervalue the social benefits of road investment, particularly in remote areas. These social benefits were indirectly included in the ideas of minimum standards and community service obligations. Now that these have been replaced by the new analytical framework, there is a need for their assessment somewhere within this framework.

The steering group for this project identified reliability of access as a critical issue for remote communities, particularly in areas where roads are made impassable quite frequently due to flooding. The major objective of this subproject has been to develop and test procedures for evaluating the effects of road reliability that take into account the critical nature of some rural roads to the communities they serve. The goal has been to develop a procedure that allows the testing of projects that improve the reliability of access of rural communities within a consistent project evaluation framework.

5.1.2. Outline of Procedure

There have been five tasks involved in this subproject

- Selection of a particular area for testing
- Collection and coding of road reliability data for the area
- Preparation of an evaluation procedure
- Calculation of current reliability indicators
- Example of the evaluation of a particular road reliability project

Each of these tasks will be addressed in the following sections.

5.2. Methodology

This portion of the Rural Accessibility project was always intended to build on the accessibility evaluation methods described in Section 4. These methods allow the development of integrated performance indicators that take into account transport and land use. These indicators give an overall measure at each location of the benefits that people enjoy from the other locations with which they interact. Given a particular road network and a particular distribution of population and employment, accessibility can be used to find out the overall attractiveness of each location. And by changing either the road network or the demographic system, accessibility can be used to find out the effect of any land use or transport option.

The way in which the accessibility theory can be used to evaluate changes to road reliability can be understood if a particular flooding event is viewed as a road network option, and then evaluated using the techniques developed earlier. Thus a major flood can be analysed by determining which roads would be excluded from the network due to flooding and calculating the new accessibility distribution. By comparing the accessibility in each location under the flooded condition with the accessibility under normal conditions the effect of the flood can be determined.

In reality there are a huge variety of flooding events that occur, with different sets of roads made impassable in various combinations that arise because of rainfall patterns, catchments, topography and road surfacing. The detail and complexity of these events was obviously beyond the scope of this project, and so a simplified set of flooding events was used. But conceptually, there is no problem with broadening the approach implemented for this project to a much better representation of flooding conditions, as long as for each flooding condition two things can be identified

- the roads that would be affected by the flood, and
- the expected number of days per year that the flood condition would apply (this takes into account both the probability of flooding, and the expected duration of road access problems)

The total effect of flooding can be found by taking an average of the accessibility under each condition, weighted by the probability of that condition applying on a given day.

5.3. Selection of a Particular Area for Testing

In selecting the candidate area for testing the evaluation procedure, the following characteristics were identified as useful.

- A large number of roads with reliability problems
- A range of community types, including some remote, isolated communities.
- Readily available data, and good contact with the organisations holding the data

Through a consideration of these factors and discussion with the steering committee, the area chosen to test the new procedure was North Queensland, specifically the areas covered by Queensland Main Roads' Districts 10 and 11 (North Western and Peninsula).

5.4. Collection and coding of road reliability data for the area

As mentioned above, the full detail of flooding patterns was beyond the scope of this work, and probably requires data that is not readily available. So a simplified representation of flooding was used. Three flooding events were considered, and the roads that are made impassable under these events were identified. Following advice from the Main Roads Districts, the flooding events focussed on regular floods, and did not include floods that occur less frequently than once per year. The effects of these floods may be significant, but the more common problems were given priority because they are generally more amenable to specific road reliability improvement projects.

The assumption was made that roads that were excluded due to a minor flood were also excluded from all other more serious floods. This gave a road classification system with the following codes

1 Roads that are impassable only in severe flooding conditions (Rarely cause problems)

2 Roads that are impassable in annual floods (Usually cut at least once during each wet season)

3 Roads that are impassable even in fairly common low-level flooding (Cut multiple times each wet season).

4 Unsurfaced roads that are impassable after moderate rain.

The four events that were considered were

- Base unflooded condition - all road type included
- Annual floods (at least one per wet season) – exclude type 2,3 and 4 roads
- Fairly common low-level floods (multiple per wet season) – exclude type 3 and 4 roads
- Moderate rain – exclude type 4 roads

A request was sent to both of the Main Roads Districts in the study area (North Western and Peninsula) for maps that classified the roads according to the categories listed above. This data was coded into the National Network Model prepared in Sub-Project 1. The assistance provided by K.L.Williamson and Mark Agnew of North Western District and David Hamilton of Peninsula District was appreciated.

5.5. Preparation of evaluation procedure

The evaluation procedure was implemented using the same Cyrus software that was used for Sub-Project 1. The calculations were very similar, in that each flooding condition was treated as a separate road network option and accessibility profiles were calculated using the standard equations.

The biggest problem was how to model transport costs under a flooded condition. It seemed unreasonable to treat floods as though they absolutely isolate communities, as generally there are other options, such as boats and planes. In fact the way in which communities operate under flooded conditions is very complex, and the impacts on businesses and individuals can very significantly. Particularly in areas where flooding is common, some people may arrange things so that they may not be very badly affected by some road closures, whereas other people will lose access to crucial activities. Some businesses, particularly those with perishable or time-critical goods or services will be very sensitive to floods, and their loss of accessibility may be very expensive. An ideal system would take these factors into account, varying the options available to people and their perception of the costs that would be incurred.

If information on the varied patterns of response to flooding were available then they could be included in the model, but for this project a simplified scheme was used. It was assumed that roads that were flooded were still available, but the cost of using them was increased ten-fold. This is a simplified way of dealing with the other non-road based options, including the option of deferring travel until the flood has cleared. The increase in cost will ensure that when there are other road routes available, they will almost always be used, and when no road routes are available the total transport cost will always be very significant. This simple scheme also means that extensive flooding will lead to much higher costs than local flooding, as more of the route will be on the flooded roads, with their very high user cost.

This simplified model certainly does not reflect the reality of people's response to flooding particularly well, but it demonstrates how a model of flooded situations could be prepared and gives a starting point for the calculations.

5.6. Calculation of current reliability indicators

The accessibility indicators for flooding conditions were calculated and compared with the base (unflooded) situation. Figures 10, 11 and 12 show the loss in accessibility due to flooding under the three flooding events. The maps show the percentage increase in network disutility under the three scenarios, where network disutility is as defined in Section 2.4.

It should be noted that the footprints of effects extend further afield than the study area (particularly into the Northern Territory) because flooded roads in the study area have an effect on accessibility in other locations. However, the impacts of roads that flood outside the study area have not been included in this model.

Figure 9 shows the overall effect that flooding has on accessibility. This is calculated by taking a weighted average of the other accessibility profiles. The expected annual duration of each of the different flood events was estimated, and the composite accessibility was calculated according to the following equation.

$A_{composite} = (A_1 \text{ x } D_1 + A_2 \text{ x } D_2 + A_3 \text{ x } D_3 \ldots) / [365.25 - \Sigma(D_n)]$

Where

An = the accessibility value for flooding event n

Dn = the expected number of days per year for which event n will be active

The following D values were assumed

$D_{\text{annual flood}} = 3$

$D_{\text{common flood}} = 10$

$D_{\text{moderate rain}} = 40$

It should be noted that these are not based on any empirical data but have simply been assumed in order to demonstrate the procedure. It would be easy to modify these values to reflect better information, or for policy reasons. For example, if the policy was to value more highly the effects of widespread flooding, then the D value for this event could be increased.

Figure 8 : Flooding Impact (Major Flood)

Figure 9 : Flooding Impact (Medium Flood)

Figure 10 : Flooding Impact (Minor Flood)

Figure 11 : Flooding Impact (Annual Weighted Average)

5.7. Example of the evaluation of a particular road reliability project

In order to demonstrate how the procedures described above could be used in project evaluation, a simple road reliability project was postulated and tested. The option that was tested was one that improved the reliability of the Gulf Developmental Road. This road currently floods quite frequently (road flooding type 3) and is the only access road for a large area. As a test of the procedure, it was postulated that this road could be improved so that it only flooded about once a year (road flooding type 2). This change was made in the model, and the accessibility recalculated for the three flooding events. (In fact this option only changes the accessibility profile of the "fairly common, low level flood" event, but for generality, the model recalculates all accessibility profiles.) The composite accessibility was then calculated, and the change from the base composite accessibility profile was plotted. The results of these calculations are shown in Figure 8, which plots the increase in accessibility that results from the reliability improvement option. This plot is similar to the ones in the report of Sub-Project 1 that show the benefit of road network speed improvements, and in fact it is possible to perform all of the evaluation analyses that were presented in that report.

In particular, it is possible to calculate the overall population-weighted user benefit of the change, and disaggregate this benefit in any way. The following table shows the total benefit of the option, and the breakdown of the benefits by Main Roads' District.

District	Total Benefit of Accessibility Improvement (in minutes)	Distribution of Benefits between Districts
North Western (District 10)	3,830	9%
Peninsula (District 11)	31,924	76%
Other	6,080	15%
TOTAL	**41,834**	**100%**

It should be noted that the benefit values shown in the table are directly comparable with the benefit values shown in the previous report, thus it is possible to compare reliability options with other road improvement options, such as new roads or road speed/quality improvements. Thus we can say that given the assumptions that we have made, the upgrading of the reliability of Gulf Developmental Road has half the effect of improving the section of the Western Highway near Horsham in Victoria, described in the last report, as it had a total benefit of 112,000. The Outback Highway, as modelled in Section 4.6, would give 46 times the benefit, with a total benefit of 1,945,956 and the Pacific Motorway would lead to 2500 times more accessibility benefit than the reliability improvement of the Gulf Developmental Road.

Figure 12 : Benefit Footprint (Gulf Developmental Road)

All of these calculations are based on simplified representations of each of the options and depend on the simplifying assumptions made in both parts of this Project, and so these results should only be taken as indicative of the sort of outputs that the accessibility analysis can produce. However, it can be seen that the techniques described are very powerful in that they allow the direct comparison of very different projects in different areas, within a single unifying framework.

6. Possible Further Developments

6.1. Conclusions from the Current Project

The examples presented above, and in particular the evaluation of two simple road network changes within Victoria and two major National projects, demonstrate the particular contribution that accessibility analysis can make to national network evaluation.

Accessibility analysis provides a rigorous and consistent way of

- determining those areas that are well served or poorly served
- measuring the quality of the road network in each area in a way that adjusts for the inherent location of each area
- prioritising network options and performing benefit/cost evaluation
- examining the distribution of benefits and disbenefits between states, industry groups and any other type of market segmentation that is appropriate
- addressing network options, land use changes and policy issues within a single framework and evaluation any combination of these
- calculating the contribution that each road makes to national accessibility profiles and thus determining an effective performance-based road hierarchy
- exploring network changes even within areas where the network is mature and well developed

It should be noted that all of the analysis was done without the use of traffic volumes or road quality information. The fact that meaningful results can be obtained with only basic network data shows the usefulness of the method. If full road condition data (including surface type, roughness, terrain and flow/capacity) were coded and fed into a user cost model then changes to these variables could also be considered.

6.2. Data Requirements

There are four basic categories of data required for accessibility analysis

1. Transport Cost – data required to calculate costs of travel, including description of the relevant transport networks, user costs etc.
2. Market Size – a measure of the size of a given market, broken down by some suitable zoning system
3. Attractor Size – for any particular market a measure of the size of attractors for that market broken down by some suitable zoning system
4. Behavioural – parameters for a model of the way in which people make their modal choices, their willingness to travel etc. or observed data that could be used to calibrate these parameters.

This project was about proving a methodology and hence fairly “basic” data was used.

1. Transport Cost - a network of nationally significant roads, with length and average speed coded for each road
2. Market Size – Population by SLA
3. Attractor Size – Population by SLA
4. Behavioural – Model parameter x0 estimated based on previous experience in urban modelling and tested to ensure sensible results.

The current model was developed to demonstrate the usefulness of the approach, and there was concern at the outset that the project could be impeded by difficulties and delays in obtaining data. For this reason, it was decided that the model would be based on whatever data was available from each state and that only minimal effort would be spent on validating the data and ensuring its consistency. There was a high degree of co-operation from Austroads member organisation, but it was obvious once the data had been compiled that there exists significant variation in the approaches to estimating road speeds. Whilst the inconsistencies that are apparent at state borders reduce the reliability of the model, it was found that very useful results can still be found using the unmodified data. However, it would be very desirable to have consistent National road data. This would be done with co-operation with the various Austroads members.

Even though it has been shown that not a lot of data is needed to get meaningful results, it would be necessary to improve the available data set before the accessibility methodology and model could be used in “real” situations.

Before the various Austroads members could use this model, there needs to be a clear understanding of what its data needs are and the effort associated in collecting that data. Indeed, if there were to be a national model some core, standardised set of data would have to be agreed upon by the states and territories.

6.3. Multi-Modal Issues

The extension of the existing National Accessibility Model to include other modes would require three new components

1. A representation of the infrastructure and/or service structure of the other modes
2. A representation of the costs incurred by users of the system, taking into account the particular needs of certain users (eg. Special needs of large freight vehicles)
3. A mode choice model

Multi-modal passenger models have been widely used in urban modelling and the basic theory of choice is the same. The choice is based on a probabilistic comparison of the costs of each of the alternatives. Once developed, the model would be compared against the observed mode shares.

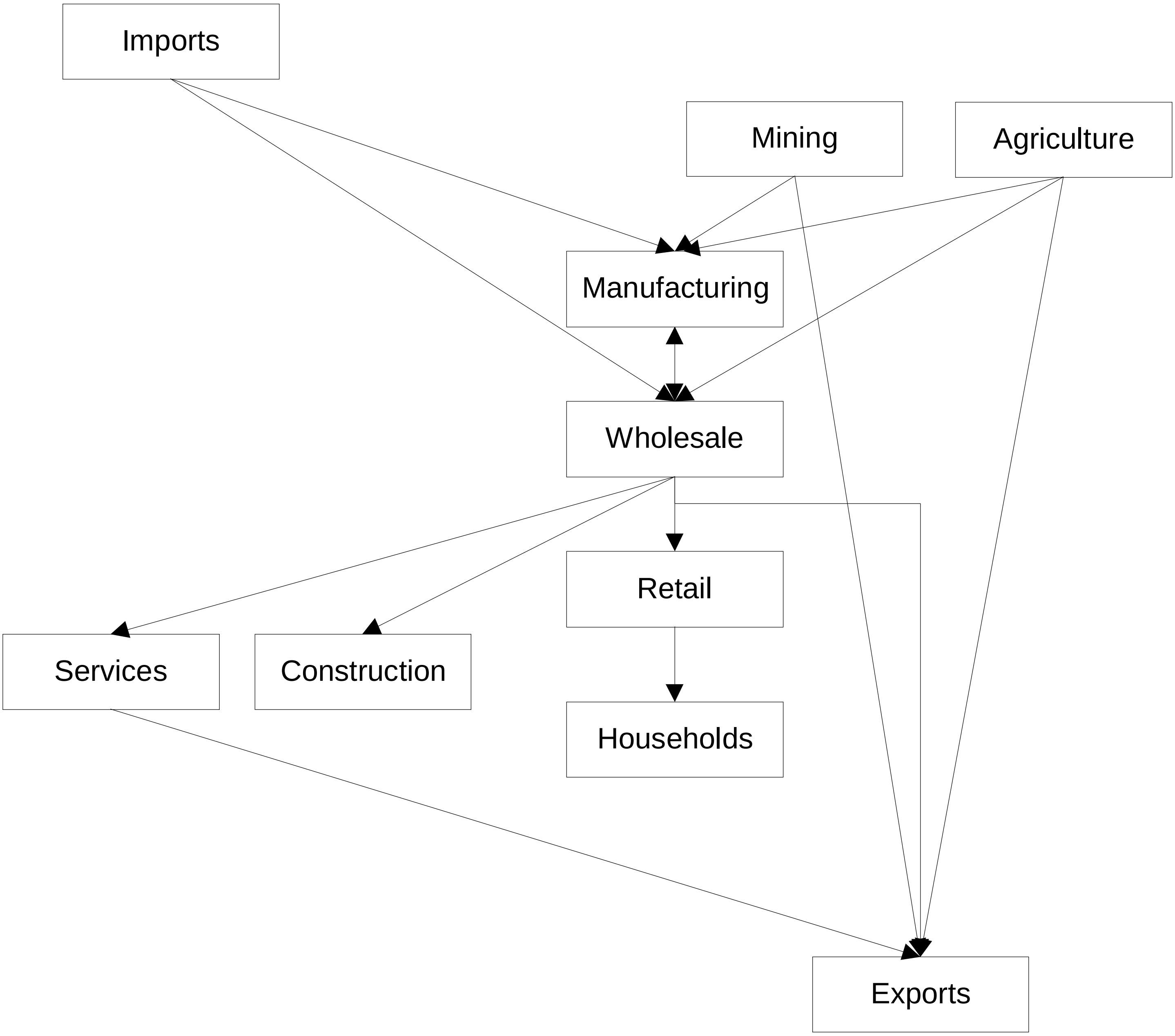
The steering committee felt that the model should be expanded to be multi-modal if it is to be truly of value to Austroads member organisations. The multi-modal aspects to be explored should cover both road-rail and road-air, and possibly road-sea.

6.4. Freight

In many ways, the movement of commodities is fundamentally more complex than the movement of people. To start with, there is a wide variety of participants in the process – shippers, arrangers, carriers, recipients and disposers of shipments. Also, there is a wide variety of types of cargo, each with different physical and economic constraints. These cargo types are from a wide variety of different industries and companies, with different operational styles and preferences. To top it all off, the whole system operates in an international economy, where suppliers and markets change, and new approaches, such as Just-In-Time manufacturing or Internet order and delivery systems are rapidly adopted by companies wishing to remain competitive.

The comprehensive modelling of the whole freight system is obviously an extremely difficult task, and accurate long-range forecasting is impossible. Fortunately for most transport planning evaluation, full details of freight operation are not required. We would propose that a simplified representation of the freight task would be used. One possible approach is seen in Figure 13, where the broad categories of freight movement are identified.

Figure 13 : Likely Commodity Flows Through the Australian Economy



The basic driving forces behind each of these broad categories would be identified (eg. Area of irrigated land, international trans-shipment points, manufacturing employees etc). These driving forces would all be indicators of the size of producers and markets. In addition, the transport cost parameters would be identified for each of these categories that would reflect the particular transport constraints of that movement. This would included the factors that influence mode choice and the trade-off that businesses make between increased travel cost and increased choice or market access.

Ideally, observed freight data would be used to develop and calibrate these parameters, but in the absence of data a combination of judgement and overseas data could be used. In any case, the driving behavioural assumptions would be clearly stated and easily changed.

It is understood that Austroads is investigating the possibility of improving the range and quality of freight data that it holds, and we encourage this process and would seek to incorporate any applicable information. In the absence of local data, it may be possible to use results gleaned from an analysis of data from the United States. The advantage of US data is that it is very comprehensive and freely available, unlike Australian data that can be prohibitively expensive.

6.5. Risk Analysis

Any long term planning or evaluation should not depend on a particular prediction of the future, but should be robust enough to be appropriate under a wide range of conditions. An assessment of the sensitivity of any of the indicators could be done by performing the analysis under a range of possible futures. If it is possible to make some assessment of the probability of each future scenario, then all of the analysis could report outcomes as probability distributions.

There is also a risk that inaccuracies in the model may lead to the wrong conclusions. This risk is particularly significant given the limited availability of data in rural areas, and the difficulty of ensuring consistency across the whole of Australia. For this reason, it would be useful if any future analysis were based on multiple runs of the model, with the basic network and land use parameters perturbed slightly each time. The level of perturbation could be based on the level of confidence in the data. The final results could be based on the average of each run, or could in fact be presented as a distribution, allowing probabilistic statements to be made (eg. Option A has an 80% chance of leading to greater benefits than Option B, with a 20% chance of the benefit being twice as big).

6.6. Evaluation of Policy, including Economic and Regional Development

One of the key advantages of an integrated evaluation tool, such as the one described in this document, is that a wide range of issues can be considered in a unified framework. Accessibility is an overall indicator of the land use system and the transport system and can be customised to focus on particular industries or market segments. This makes it an starting point for the investigation of transport's impact on economic and regional development.

From its earliest days, accessibility has been used as a means to understand development patterns – particularly in urban areas. As early as 1951, distance to city centre (a simple urban accessibility measure) was related to urban density. Others have developed similar relationships, notably Ken Davidson in 1977 who developed a relationship between urban density and centrality (a modified form of the utility based accessibility used in this project). Davidson proposed an equilibrium density that exists at a given level of accessibility, and postulated that development was likely to occur in those areas where the existing density was lower than the equilibrium density. Further, by looking at those areas whose accessibility increases as a result of any proposed change to the system, one can identify those areas that are likely to develop.

As far as we are aware, no such relationships have been developed in rural areas, or at a National level. However, it is reasonable to suppose that similar relationships would exist, and could be used to explore the impacts of any road network changes on regional development.

It should be noted that even without formal relationships between development and accessibility change, accessibility analysis could make a significant contribution to the evaluation of projects against higher level policy objectives. It would do this through its ability to develop performance indicators focussed on particular market segments and based on the requirements and opportunities of that market.

For example, we might want to test the performance of a road program against a policy of improving the potential of mineral reserves. This could be done by identifying the size and distribution of economically extractable mineral reserves across the state and determine the accessibility of these reserves to markets (including overseas markets through the inclusion of ports). By producing an indicator of accessibility weighted by size of mineral reserve, we would have a single value that can be used to compare different programs against the policy objective. As far as we are aware, accessibility provides the only integrated basis for this type of analysis.

6.7. Future Directions

The following points were agreed to by the Steering Committee as the desired future actions coming out of this project –

- It was agreed that this project’s accessibility model provides a very appropriate tool for evaluating rural road networks, perhaps better than BCA.
- The assertion was made that this model should be maintained at a national level
- There is benefit in having a follow-on project that would provide a more detailed and realistic demonstration of the accessibility model. Four or five case studies (one from each participating state or territory) would be used, with some form of concluding “Austroads” overview and review of results. Amongst other things, these case studies could demonstrate the impact of variations in data between states and territories.
- An estimate should be prepared of the cost and effort involved in developing and maintaining a national model.

- Steps should be taken to agree to a minimal national data set for this model.
- This model should be expanded to be multi-modal in nature.
- This model should be examined to determine its scope for assessing the economic and regional development impacts of transport infrastructure.

We believe that accessibility analysis, and in particular the National Accessibility Model prepared for this project could be of great use to Austroads and its member organisations, both for project and program evaluation, and for the evaluation of wider policy questions. This project has brought the model to the point where its effectiveness and use have been demonstrated, although to date all of the options tested have been hypothetical. There are still significant administrative issues that need to be resolved, concerning data, model development and maintenance, but we agree with the steering committee that the next step should be to use the model for more realistic and detailed analysis of real projects.

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