AP-R194

FORECASTING DEMAND FOR BICYCLE FACILITIES

AUSTROADS

Forecasting Demand for Bicycle Facilities
First Published 2001

National Library of Australia
Cataloguing-in-Publication data:

Forecasting Demand for Bicycle Facilities
ISBN 0 85588 601 3

Austroads Project No. RUM.TM.N.501

Austroads Publication No. AP–R194/01

Project Manager
Ms Tracey O'Meara, Department of Main Roads Queensland

Author
Dr Rod Katz

Working Group
Australian Bicycle Council

Published by Austroads Incorporated
Level 9, Robell House
287 Elizabeth Street
Sydney NSW 2000 Australia
Phone: +61 2 9264 7088
Fax: +61 2 9264 1657
Email: austroads@austroads.com.au
www.austroads.com.au

FORECASTING DEMAND FOR BICYCLE FACILITIES

AUSTROADS

Sydney 2001

AUSTROADS PROFILE

Austroads is the association of Australian and New Zealand road transport and traffic authorities whose purpose is to contribute to the achievement of improved Australian and New Zealand transport related outcomes by:

- developing and promoting best practice for the safe and effective management and use of the road system
- providing professional support and advice to member organisations and national and international bodies
- acting as a common vehicle for national and international action
- fulfilling the role of the Australian Transport Council’s Road Modal Group
- undertaking performance assessment and development of Australian and New Zealand standards
- developing and managing the National Strategic Research Program for roads and their use.

Within this ambit, Austroads aims to provide strategic direction for the integrated development, management and operation of the Australian and New Zealand road system — through the promotion of national uniformity and harmony, elimination of unnecessary duplication, and the identification and application of world best practice.

AUSTROADS MEMBERSHIP

Austroads membership comprises the six State and two Territory road transport and traffic authorities and the Commonwealth Department of Transport and Regional Services in Australia, the Australian Local Government Association and Transit New Zealand. It is governed by a council consisting of the chief executive officer (or an alternative senior executive officer) of each of its eleven member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Main Roads Queensland
- Main Roads Western Australia
- Transport South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Transport and Works Northern Territory
- Department of Urban Services Australian Capital Territory
- Commonwealth Department of Transport and Regional Services
- Australian Local Government Association
- Transit New Zealand

The success of Austroads is derived from the synergies of interest and participation of member organisations and others in the road industry.

The Australian Bicycle Council (ABC) oversees the advancement of cycling in Australia, via the implementation of "Australia Cycling – The National Strategy" (Austroads, 1999). That strategy document has a **vision** of "Increased cycling for transport and recreation to enhance the well-being of all Australians" as well as a specific **goal** of doubling bicycle use by 2004.

The ABC functions as the Austroads Bicycle Reference Group, to provide advice to government on cycling matters, research needs, and emerging issues.

The ABC through Austroads has commissioned these 'Guidelines for Forecasting Demand for Bicycle Facilities'. The objective is to provide State and Territory government agencies and key stakeholder organisations with a framework for analysing available data to develop forecasts of demand for bicycle use. These are desirable for effective and efficient policy development, evaluation and implementation, particularly in view of the specific goal of doubling cycling.

This guide has been developed based on a review of the literature, both internationally and in Australia. In addition, various experts on forecasting have been contacted directly and the wider community of cycling enthusiasts has been contacted through Australian bicycle internet mailing lists.

Executive Summary

This guide arises from Australia Cycling: The National Strategy 1999-2004. That strategy is directed at increasing cycling. In order to further the objectives of the strategy it is appropriate to examine methods by which demand for cycling under different conditions can be estimated. The importance of developing sound forecasting methods has been recognised in other jurisdictions – notably the USA where a guidebook on different methods has been developed at considerable effort. This guide draws heavily on that guidebook while at the same time providing an Australian perspective on the purposes, advantages, limitations and methods of demand forecasting.

There are a number of methods that are available to those with an interest in demand modelling. These can be categorised into aggregate and disaggregate methods. Generally speaking the aggregate methods are simpler to carry out but do not have a solid theoretical basis. Without a solid theoretical grounding it is arguably more dangerous to produce forecasts.

The most basic of the aggregate methods are **comparison studies**. These compare bicycle use at one time or place with use at a later time or different place. These studies can be quite persuasive if the changes from one situation to another are very controlled. Problems arise however where other factors can affect levels of bicycle use apart from the location or the time – and they always can!

Aggregate behaviour studies are a more sophisticated form of comparison studies. They generally use some statistical tool such as regression analysis to create models of relationships between bicycle use in a particular area and one or more other variables associated with that area. The range of variables that could be selected for use in such models is very extensive, for instance bicycle ownership rates or motor vehicle rates, average income, average age, hilliness of the area etc. could all be used to form a predictive model of bicycle use. Results of such models are however generally fairly questionable – largely due to the nature of the aggregation taking place and the lack of a sound theoretical connection between most of the variables and the use of bicycles.

Maximal share models can be useful for identifying the latent demand for cycling and the nature of the major constraints on cycling. These models have had limited application because they require quite intensive data collection. Transferability of the results of these models remains a question mark.

Sketch plan methods is a term that can be used to describe a fairly ad hoc approach to modelling demand based on information that is available or readily obtained. It uses spreadsheets to manipulate data from various sources to come up with estimates of the possible effect of providing more cycling facilities in a particular location or area. These methods are likely to be particularly useful for bicycle researchers where they do not have access to the extensive modelling tools used in regional travel models.

Regional travel models are the mainstays of traditional integrated transport planning. They are extremely powerful as they can produce relatively detailed forecasts of traffic flows on routes identified in the network. They rely on a series of models of trip generation, distribution, mode choice and assignment to produce these trip tables and, from them, calculate performance measures relating to issues such as congestion, emissions, etc. The cost of developing these models is considerable and they tend to deal very badly with minority modes such as cycling. Nevertheless elements of these models can be used as the basis for bicycle demand modelling if there is adequate commitment of resources. To date in Australia this has not been particularly evident. In other countries there has been some work put into defining bicycle networks within regional travel models.

One of the most popular methods of understanding different dimensions of demand for transport at the individual or disaggregate level is the **discrete choice model** of behaviour. This has been used extensively for modelling decisions about the use of different modes, routes, products or services. This type of model assumes behaviour is based on rational choices between different alternatives, which is a fairly robust assumption across a large range of choices. However, it is not clear that it is robust when it comes to choice of travel behaviour where there are arguably a lot of other influences on choice and there is a vast number of choices that lead to the adoption of a travel pattern.

Discrete choice models have been used in a number of situations for analysis of bicycle demand. They appear to be particularly useful at the route choice level where they have had probably the most applications.

The parameters derived from discrete choice models on such issues as the relative attraction of cycling with bicycle paths versus on road can be used in regional travel models or sketch plan models or even for inclusion in GIS models (see below).

Other approaches to disaggregate behavioural modelling that are worth mentioning include structural equation modelling and activity modelling. Due to the limited applications and technical complexity of such techniques they are merely noted in this guide.

An important technological aid in developing models for bicycle use, particularly at the local level, are GISs (**geographic information systems**). These offer a flexible data base approach to managing and presenting information about the transport network and aggregate data on users. There have been some very good applications of fairly simple models that use GIS to give a good picture of the likely possible use of bicycles. The limitations of these models relate to the technical aspects of mastering the GIS software, ensuring that there is an adequate behavioural foundation in identifying likely demand and the issues of bicycle network definition.

Table of Contents

1 INTRODUCTION

1.1 Background

Australian Context: The development of these 'Guidelines for Forecasting Demand for Bicycle Facilities' has arisen from Australia Cycling, the National Strategy 1999-2004'. There are a number of Objectives within that strategy that can be served by good information about demand for cycling:

- Objective 3 is for 'Facilities that support increased cycling'. In order to know what those facilities are we need to be able to relate increases in cycling to a particular type of facility or facilities. Arguably this requires data on peoples' preferences and behavioural responses to certain types of infrastructure.
- Objective 5 is that 'The benefits of cycling are recognised by decision makers and the Australian community'. One strategy (5.3) proposed under this objective is to 'undertake research on emerging issues associated with cycling' and strategy 5.4 states that 'reliable, accurate and up-to-date information is available to assist decisions made about cycling issues'.

One activity already carried out under Objective 5, Strategy 5.2 has been the 'Guidelines for Cycling Data and Cycling Indicators' (Steer Davies and Gleave 2000). The data guidelines provide an excellent base for applying forecasting techniques. They set out available data sources on various aspects of cycling demand in major Australian cities and represent a useful foundation for forecasting.

This guide seeks to build on the base provided by the data guidelines by setting out a menu of forecasting approaches. These approaches can use much of the data described in the Guidelines for Cycling Data and Cycling Indicators to provide information desirable for meaningful evaluation of alternative policy positions.

Inspiration: This guide is inspired by a guidebook done for the Federal Highway Administration of the US (US Department of Transportation 1999) available at http://www.fhwa.dot.gov/tfhrc/safety/pubs/vol1/contents.htm . This is a very useful and comprehensive guidebook. It is intended to provide the means to address questions such as:

- How many people will use a proposed bicycle facility?
- If we improve an existing facility or network how many additional people will use it?
- What types of improvements will have the greatest impact on bicycle use?
- How will improvements in bicycle facilities affect other modes and other transport impacts on the community and the environment?

These questions are important for anyone involved in designing transport networks, allocating budgets, determining priorities and developing policy at all levels of government. These people may include:

- Local government transport coordinators, especially those responsible for developing or implementing bicycle plans or strategies;
- State government transport and roads officials; and
- Federal government officials in transport, health or environment.

This guide is particularly intended as a resource for those who have an interest in or responsibilities for bicycle matters, transport generally or the externalities associated with our transport system, for example, local and global pollution (including greenhouse gases) and health.

This guidebook does not seek to duplicate the work done on behalf of the US Federal Highway Administration (FHWA). As can be seen from the material prepared, particularly the supporting documentation at volume 2 of the US guidebook (see http://www.fhwa.dot.gov/tfhrc/safety/pubs/vol2/contents.htm, the FHWA has done a vast amount of research including an extensive worldwide literature review and expert interviews.

For those interested in an in depth knowledge of the various approaches discussed in the US guidebook it is appropriate to review volume 2 of the guidebook and the literature to which it refers. In many cases however, this will not be enough to apply the techniques discussed. For this reason this guide revisits the various methods discussed in the US text and provides an Australian interpretation and suggests examples and contacts where possible for Australian practitioners. It also refers back to the Guidelines for Cycling Data and Cycling Indicators where those Guidelines provide a useful review of available data for forecasting.

Despite the significant reliance on the US guidebook as a base, this guide is also intended to be a stand-alone reference. As such, it provides an overview of the various techniques, their uses and abuses, data issues and examples. Unlike the US guidebook, this guide does not include references to pedestrian modelling.

1.2 What constitutes a forecast?

Demand forecasts are generally made on the basis of some knowledge about existing conditions and how current levels of demand are likely to be affected by likely changes in key variables. This requires some kind of model, whether a formal mathematical model or a 'mental' model (Ortuzar and Willumsen 1990).

Models can be defined as a representation of an actual or proposed structure. Thus transport models, by their nature, attempt to simulate systems by identifying a set of relationships between a limited set of variables on which the modeller has some data.

Transport modellers hope to create a reasonably accurate representation of observed transport behaviour and, from this, deduce likely behaviour given one or more changes in conditions.

One of the modeller's basic tasks is to identify relationships between variables that can be influenced by policy and the outcomes of interest to policy makers. Some policy outcomes that may be of interest are set out below:

Cycling related outcomes of interest to policy makers

- Relief of congestion and reduction in pollution;
- The bicycle's availability as a mode of access for otherwise mobility constrained groups (especially the young);
- Cyclists' possible impact on other aspects of the network for example traffic speed, intersection volumes, inter-modal links etc.; and,
- Increased use of a health-promoting mode.

Policies likely to positively affect bicycle use that can be identified include;

- extending and enhancing the bicycle network via provision of on-road and off-road bicycle ways;
- Reducing volumes, speed or size of motorised traffic generally or on an identified bicycle network;
- End of trip facilities (secure parking / showering facilities);
- Subsidies for bicycle use / imposition of costs on motorised vehicle use;
- Integration of bicycle use with public transport (for example provision of bike parking at interchanges and provision for carriage of bicycles on trains, ferries, trams and buses) – making public transport part of the bicycle network;
- Encouragement of high density urban development; and,
- Marketing campaigns aimed at reducing use of motorised vehicles and increasing use of ‘sustainable’ modes.

Policy variables likely to negatively affect bicycle use may include;

- Proposals for registration of bicycles and other regulatory moves that increase the cost of cycling, the convenience or the social status of cycling;
- Closures of roads / areas to bicycles;
- Increasing travel times of bicycles by rearranging network features; and,
- Promoting negative safety aspects of bicycles.

Models to forecast bicycle use may include variables from these lists as well as non-policy variables such as weather, some socio-demographics and some geographical variables.

1.3 Reasons for forecasting bicycle demand

It is possible to identify a number of reasons for formal modelling of bicycle demand. These may be loosely classified as; strategic policy development, network management and network enhancement.

Strategic policy development: Models may be used to evaluate alternative policy approaches from a medium to long term strategic viewpoint. Performance indicators for the overall transport system may be calculated using strategic transport models.

An example of such an exercise was the Future Directions study for Sydney (Roads and Traffic Authority 1991). This raised the prospect of very poor performance for the Sydney transport system against a number of indicators – especially congestion and pollution under a ‘steady as she goes’ policy framework. The use of strategic models may be decisive in setting a particular policy. While the Future Directions study did not include the bicycle mode, there are a number of metropolitan transport models that have and these are discussed in section 7.

If the aims of the National Strategy are to be implemented it is important that these types of strategic models incorporate cycling. If cycling is left out of the forecasting process it will also be likely to be left out of policy and provisioning.

Strategic models are increasingly being used to develop projections regarding such crucial issues as greenhouse emissions. Examples of these are the report by Goldsmith quoted in the US guidelines and, in Australia, (McNamara 2000).

Other strategic modelling exercises attempt to estimate the maximal share for the bicycle mode in any given environment (for example Brög, Erl et al. (1983); Morgan-Thomas (1992)). These are classified as market analysis studies in the US guidelines.

Network management: In addition to assisting in policy formulation, models can be useful in managing existing networks and programs. Increasingly, traffic planners are relying on sophisticated modelling tools for evaluating particular "links" and "nodes" in the transport network. This is especially the case for larger urban centres where specialised network analysis software (eg. EMME/2 and TRIPS) is used to run complex traffic models. Based on observed traffic and feedback from users, traffic planners adjust aspects of the road system such as potential traffic volume, lane widths, traffic signal sequencing etc in the models to estimate likely consequences through the system on a relatively micro scale. There are examples of this sort of model that have been applied to cycling (Sharples 1993; MVA 1995; DHV Environment and Infrastructure (no date)), but never in Australia.

In many cases local governments and others have started using Geographical Information Systems (GIS) to keep an inventory of roads and paths and manage other local government assets. These can provide sophisticated tools for modelling where appropriate data is available (see for example Hutchinson (2000)).

In some cases, network managers may wish to identify why some aspects of the network are well used and others are not. A comparison study (see section 3 below) may be appropriate in this instance or, for more insight into the behavioural motivations for network use, a discrete choice model can be estimated (refer section 8).

Network enhancement: If a network is to be enhanced for bicycle use a model may be able to give some guidance as to which parts of the network can be improved for maximum effect and which parts of the network are currently most in need of improvement.

One of the tools used in network management and enhancement is level of service (LOS) modelling. This can be used to assess the quality of a network and where most improvement could be required.

Other tools that are useful in network enhancement decisions are the discrete choice methods discussed in later sections. These are designed to obtain information about people's preferences and likely behaviour based on the importance they ascribe to particular attributes of a system.

Relatively simple comparison models and sketch-plan models can also be used to evaluate the likely use of proposed network improvements.

1.4 Limitations of forecasts

While forecasts of demand are in some ways essential, many people are critical of models' ability to capture attitudinal factors associated with demand and hence the accuracy of forecasts produced. This is a reasonable critique but where large sums of money and resources are at stake some process is required for evaluating competing proposals. In the absence of a satisfactory alternative, modelling is desirable albeit with some regard to its limitations.

An over-reliance on the results of quantitative models can be dangerous without recognition of the possible errors that may occur. One possible consequence of forecasting errors is expenditure on a facility that does not attract the forecast patronage. This may be an inefficient use of resources and may jeopardise the possibility of building an alternate facility that would have met patronage expectations.

Dangers in forecasting are particularly acute when trying to forecast far into the future and for large areas. Changes in technology, the economy and society can have far-reaching and unanticipated effects on transport behaviour. Differences between people and places can make transferability of results very dangerous.

Despite these problems, quantitative models have the advantage that they make explicit the assumptions that go into decision making processes. It is important in modelling for all the assumptions to be spelt out so that the results can be interpreted appropriately.

Alternatives to quantitative forecasting could be simple things such as lists of pro's and con's or some of the "visioning" exercises that are increasingly being used in transport and business (Queensland Transport and Main Roads 1999; Saul 2001). These sorts of futures studies are very useful for the larger strategic issues but of less use for the more local issues of prioritising facility construction.

Specific limitations of the various modelling techniques are discussed for each type of model listed. In some cases, alternative approaches are also discussed.

1.5 Organisation of this guide

The objective in this guide is to set out a menu of modelling options that address the key issues discussed above, that is, likely usage, how to achieve maximal usage, and effects on other aspects of the transport system or the environment. The forecasting options cover a range of applications, costs, ease of use, and data requirements.

Generally the methods reviewed start with the lowest level of complexity and build to the more complex modelling techniques. A number of 'traditional' transport-modelling frameworks are catalogued at as well as some more advanced methods.

In organising this guide and implicitly the US guidebook on which it is based, a number of issues were addressed:

- Categorisation of available methods

Modelling methods may be categorised into aggregate and disaggregate methods – these are akin to taking a top down or bottom up approach. In the case of top down or aggregate approaches, grouped data is used to produce forecasts – for example bicycle use can be forecast based on existing average use and say changes in area wide aggregate car ownership. This contrasts with a disaggregate approach that takes the perspective of individuals or households – for example a person's bicycle use could be forecast based on their income, age and gender and changes to their trip profile. The individual models are then aggregated after estimation for summary

Generally speaking aggregate methods are simpler to use but are more likely to produce unreliable results. It is this sort of trade-off that the practitioner needs to make in developing or interpreting models. The most obvious forms of disaggregate models are the discrete choice models discussed at section 8.

- Criteria for deciding between methods

Choice of forecasting method will depend on the questions of particular interest, the decisions to be made, the accuracy required and the resources available.

For most practitioners relatively simple tools will be as far as they will want or be able to go. These may well be as sufficient for experienced practitioners with a good understanding of local conditions and with significant resource constraints. However it may be that there is scope for employing some more sophisticated tools where data and expertise are available. This will generally be the case in multi-modal transport models. These models, especially in Australia, are unlikely to include bicycle as a mode as a matter of course.

The more complex and, hopefully, accurate models may be necessary where parameters are required in integrated transport analyses. The traditional four-stage transport model provides the basis for most urban transport models and is capable of being adapted to include parameters from bicycle models.

A challenge facing those interested in bicycle policy is to ensure that integrated transport models do include provision for bicycles and there are appropriately validated models to produce parameters for the multi-modal models.

2 METHODS OVERVIEW

The forecasting methods reviewed in this guide are grouped into eight categories for convenience. These are:

Method	Description	Key features
1. Comparison studies	Analysis of aggregate data from two areas with an attempt to identify variables that contribute to different levels of bicycle use between areas or times.	• Relatively simple technique • Wide range of applications • Easy to misinterpret results
2. Aggregate behaviour studies	Methods that relate bicycle travel to characteristics of the local area generally through regression analysis and other multivariate statistical approaches	• Some statistical expertise required • Moderate data requirements • Can be used to identify importance of variables across different locations
3. Maximal share studies	Market analysis that attempts to identify maximal demand for cycling and likely bicycling demand are included in this category.	• Useful to identify key constraints on cycle use • Requires very detailed surveying of market
4. Sketch-plan methods	Predict use of a facility based on rules of thumb about travel behaviour.	• Relatively simple to construct predictive models • Uses secondary data and parameters from previous research • Likely to have significant errors but can run a series of "what ifs" for sensitivity analysis
5. Regional travel models	Generally based on classical four stage models relying on a sequence of estimates of trip generation, distribution, mode share and assignment	• Require considerable technical skills • Models already exist for motor vehicles and transit in most major centres • Do not deal well with bicycle demand due to the focus of the modelling systems and data used • Scope for using these models as a basis for bicycle models in the future
6. Discrete choice models	Models based on observed or stated individual choice behaviour	• Well established theoretical basis • Considerable technical skill required • Can use revealed and stated preference data • Wide range of applications (mode choice, route choice, vehicle choice etc.)
7. Other advanced behavioural modelling techniques	Path analysis and structural equation models may be used to gain an understanding of the feedback elements between endogenous variables	• Significant technical skills required • No applications yet in forecasting bicycle demand
8. GIS based approaches	Use of geographical information systems to model and present forecast demand for cycling facilities.	• Increasingly used for local planning • Some good examples in the bicycle demand area • Requires knowledge of GIS software

These groups have been set out in generally ascending order of difficulty – where difficulty is determined based on a judgement about the technical modelling skills and the data required.

In addition, there is discussion of the forecasting implications of some of the individual marketing (or 'travel blending') approaches to transport demand management.

The various modelling techniques are discussed in terms of:

- A general overview;
- Uses;
- Limitations;
- Data issues;
- Examples; and,
- Use in Australia.

3 COMPARISON STUDIES

Description: Comparison studies adopt the straightforward approach that if there is an observed level of bicycle use in one observation then it should occur in another. If it does not then it is appropriate to identify variables that account for the difference.

There are two basic types of comparison studies used in modelling bicycle demand – firstly, before and after studies and secondly studies between different facilities where on the face of it they should have the same level of patronage.

Use: Before and after studies can be used to evaluate the effectiveness of a particular type of facility or policy. These can then be used to predict the effect of the same sort of facility or policy in a different place on the assumption that the experience in one place will be repeated in another.

It is fairly common to examine several locations that have some similarities and then to try to account for the differences in bicycle use by knowledge about particular local conditions.

Some studies have also been done comparing use of similar facilities in different locations. The interpretive task here may be to identify which variables associated with the facilities may account for the differences in demand.

Use of comparison studies in Australia has been reasonably widespread. However these sorts of studies are not often published. An advantage of these sorts of studies is that they are easily understood and presented to a broad audience.

Limitations: The major limitation with comparison studies is that very few situations are compared and only a limited number of variables are examined. While it is often the case that variables are proposed to explain differences in use, it is not possible to establish whether those variables truly account for the differences and how much impact a variable actually has on the demand across only a couple of observations without a "control" group.

In comparing locations that share some characteristics it is easy to overlook differences. This is a problem with all modelling techniques but tends to be a particular problem with comparison studies.

Data Issues: Minimal data is required for these studies. Generally, count data from one facility to another is sufficient. For more sophisticated comparison studies it is possible to adjust counts by reference to census figures.

Examples: Two studies at a local level, are cited in the US guidebook. The first of these was a study where an existing bicycle/pedestrian facility and its surrounding population are compared with a proposed facility and its surrounding population to estimate potential usage levels on the proposed facility(Lewis and Kirk 1997).

The second study cited in the US guidebook was actually an Australian study (Wigan, Richardson et al. 1998) which compared the characteristics of two existing off-road bike paths with quite different levels of patronage. This was a relatively sophisticated comparison study using GIS databases to compare population characteristics peripheral to the two trails.

Other Australian examples relate to the travel behaviour modification programs implemented in Perth and Adelaide (Department of Transport Western Australia (2000); Tisato and Robinson (1999)). In these analyses, use of different modes of transport is compared for a study group before and after the travel behaviour modification trial is conducted. The resulting travel behaviour change is extrapolated from the study area to establish cost/benefit parameters for more widespread implementation of programs. In the South Australian case (Tisato and Robinson 1999) the net benefits of implementing a 'travel blending' program across Adelaide were estimated based on a benefit / cost ratio of 5.7 achieved in the study area.

4 AGGREGATE BEHAVIOUR STUDIES

Overview: The aggregate behaviour studies are similar to the comparison studies in some ways – they may often use similar data but use more data points. Use of a greater number of data points allows use of various statistical techniques to evaluate the data.

These studies use data that is believed to have a strong relationship to levels of cycling in different regions, cities, towns, suburbs or census districts. They then seek to relate that data to other variables that may be correlated with different levels of demand. Regression analysis or some other multi-variate statistical technique is used to model relationships between variables.

Use: Aggregate behaviour studies can be used to predict mode split across various geographical regions. This could be used for focussing efforts on areas where potential is greatest.

They can also be used to provide parameters of demand for cycling for inclusion in regional travel models – see below.

Aggregate demand models have not been widely used in Australia. This is perhaps surprising given the availability of census data that would be suitable for modelling bicycle demand – at least for the journey to work – at the aggregate level. Possible reasons for the lack of use in Australia are the questions about the technique itself (see limitations below) and the non-inclusion of bicycles in many regional travel models where the parameters from aggregate demand models could be applied.

Limitations: The data used is at the aggregate level and the correlation identified between many variables may be spurious. Data that correlates well with demand for bicycle use is not readily available compared with say data on ‘motor vehicle ownership’, which correlates well with demand for motor vehicle use. Ownership of bicycles does not seem to be a particularly good predictor of demand for cycling in Australian cities.

Some familiarity with regression analysis and other statistical concepts is required for useful application of these methods.

Data issues: Some data used for these studies is obtainable from census and geographic data. Census data that may be relevant include car ownership, income, and average age. Of particular use in Australia are the journey to work figures from the census – see Milthorpe (1993) – these can be used to obtain the percentage of commute trips by bicycle cross tabulated with gender, local government area and other variables on the census.

More difficult to obtain and code is information about topographical features such as ‘hilliness’ although such variables may be derived from geographical studies and geographical information systems (GIS).

Examples: One example of a bicycle use forecast from and aggregate behaviour model is that of Waldman (1977) who compared similar sized cities in Britain by cycling rates and geographical features. He used a regression model to estimate parameters for ‘hillyness’ as an explanatory variable for bicycle use. Cities that had low bicycle use and flat terrain were hypothesised to be those cities where the level of cycling safety was particularly low – of course there could have been other factors involved relating to socio-demographics, urban design or cultural issues.

Surprisingly studies of this type are not evident in Australia. Conceivably, regression models of bicycle use could be developed based on the data identified in the Data Guidelines publication (Steer Davies and Gleave 2000) but to date no significant studies have come to our attention. Possibly this is due to the large degree of variation in bicycle use within groups – for instance there is no local area in the Sydney statistical district that stands out in its use of bicycles and there is a vast degree of variation within different areas in peoples’ travel behaviour generally.

5 MAXIMAL SHARE STUDIES

Overview: The classic studies of this type are those of Brög (1982). These take a hierarchical elimination approach to understanding transport demand. The Brög *et al* studies identify "situational constraints" that prevent people from using bicycles and classify them into different types that roughly relate to the ease with which it would be possible to get people to change modes.

Situational Groups per (Brög 1982)

Group	Description
I. and II.	Objective conditions prevent use of bicycle or there are constraints which can only be changed with great difficulty
III.	Constrained by lack of information
IV.	Constrained by poor perception of mode
V.	Constrained by negative attitude
VI.	Subjectively possible but do not use it

The better studies of this type use comprehensive household interview surveys to understand which group an individual falls into. More rudimentary examples may use proxies or rules of thumb for determining group membership.

Use: Maximal share analysis can be used to identify "latent" demand for cycling. This is a question of considerable interest when presenting a case for additional funding of bicycle facilities or programs.

Sophisticated versions of these studies can be used to understand where the major constraints on bicycle use lie and possibly the sorts of measures or societal changes that would be needed to overcome those constraints.

Limitations: Classification of individuals into situational groups is not as straightforward as it may seem. While some constraints and grouping criteria may be readily observable, other criteria may not be as clear cut. For example, non-cyclists perception of cycling or a cycle route may not be particularly useful if they have never thought about cycling or how they would make a trip by bicycle from a particular origin to a particular destination.

The nature of the data is such that it is strongly influenced by interviewers and the nature of the interview.

Large-scale application of these sorts of techniques could be very expensive.

It is difficult to transfer the results of these sorts of models to other environments.

Data issues: Generally these sorts of models rely on special purpose data collection. It may be possible to integrate these sorts of studies into the behaviour modification programs ('Individualised Marketing' and 'travel blending') that are currently being implemented in a number of centres in Australia. Indeed some of these behavioural change programs may be perceived as the descendants of the hierarchical elimination models of the early 1980's.

Alternatives: These models share some of the qualities of activity models which have long been advanced as a desirable approach to understanding travel behaviour.

Market research type studies have been done in Australian cities which share some of the in depth attitudinal and household interrogation techniques of the Brög work (see for example Spectrum Research 1987; Datacol 1992; Market and Communications Research 1998; Market and Communications Research 1999). These sorts of studies do not apply the hierarchical elimination framework but do provide insights into major factors constraining increased demand for bicycle use.

An alternative framework is the rational decision making framework discussed in section 8. Proponents of the situational group approach are likely to argue that utility maximisation is not a good behavioural assumption for determining transport behaviour.

Examples: The early example of Brög (1982) provides an illustration of the outputs available from this sort of model. As shown in figure 1 below, the objective constraints on use of bicycle for commute trips were firstly an assumption that bicycle commute trips be less than 15km. Other objective constraints accounted for 11% of respondents. Constraints on bicycle use eliminated a further 37%, negative perceptions of routes 6%, perceptions of bicycle use 8%, and subjective unwillingness a further 8%. This left a possible 30% of trips shorter than 15km as being capable of being made by bicycle with relatively minor changes in people's decisions.

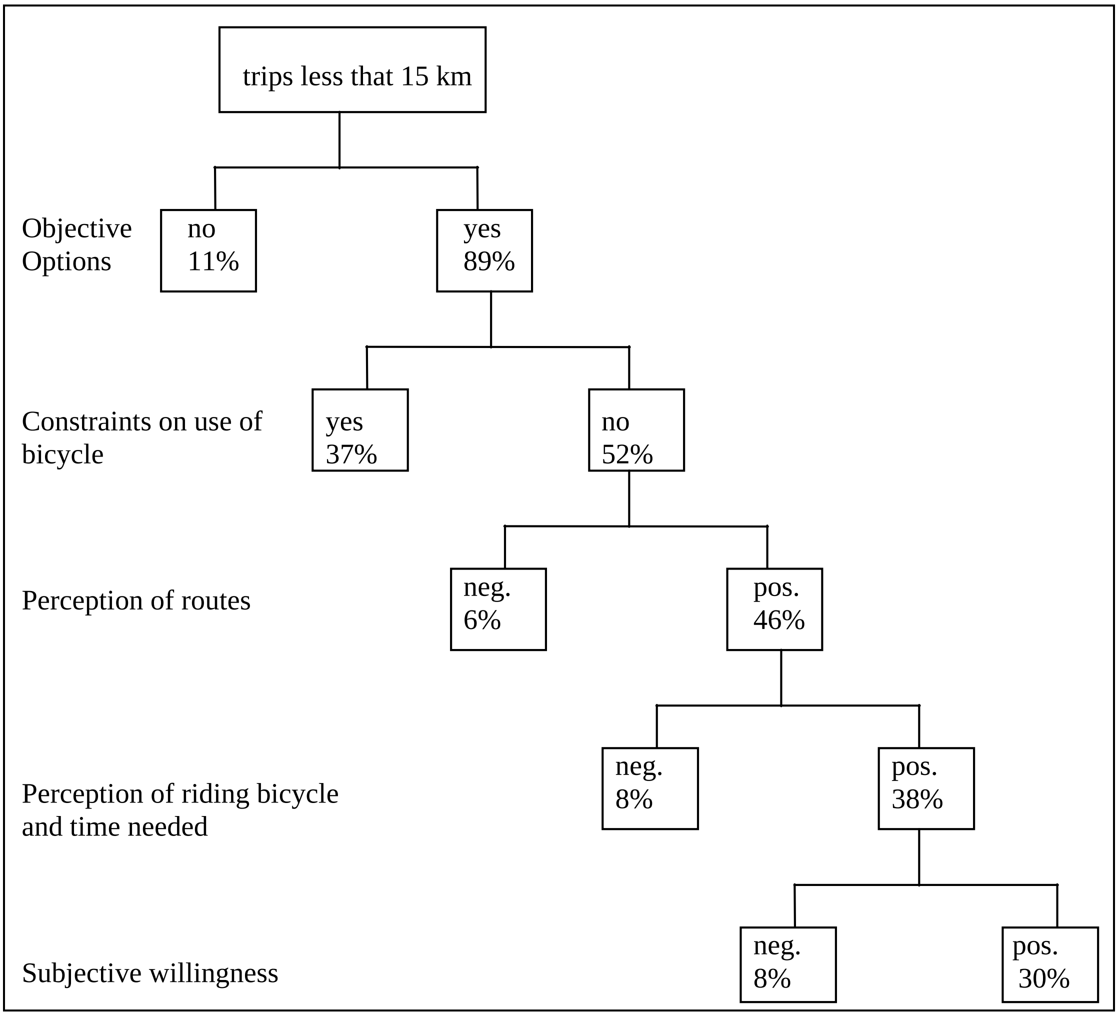

Figure 1 — Results from Brög (1982)

An Australian example of this type of approach is that of Morgan-Thomas (1992). This used a hierarchical elimination model to predict possible travel to Griffith University in Brisbane. The marked difference between that study and the illustration in figure 1 was at the level of perception of routes where in Brisbane 38% were negative towards the route and 11% positive compared with 6% and 46% respectively in the German study. The final maximal share among the respondents to the Brisbane survey was 9%. It should be noted that this is amongst university students who might be considered positively disposed towards bicycle use relative to the general population.

6 SKETCH PLAN METHODS

Overview: Sketch plan methods are the term given in the US guidelines to rough models linking data from various sources. These can be used to estimate the likely effect of different facilities or policies. Sketch plan models are generally done on spreadsheets using parameters from other studies to estimate the likely consequences of expenditure.

For estimates of demand for a particular facility, the concept of the ‘travel shed’ (Goldsmith 1997) is used to define the potential demand zone. This is then multiplied by the commute population, the bicycle commute rate and scaled up by estimates of non-work trips and the likely mode change as a result of a improved facilities.

Use: These sorts of models are particularly useful in answering questions such as the likely impact of a facility on greenhouse emissions, parking or some other impact of bicycle use.

One advantage of using spreadsheet models is that it is easy to run a number of different scenarios. ‘Best’ case, ‘median’ and ‘worst’ case scenarios can be run. Of course they are also fairly cheap to construct using secondary data sources.

Limitations: The accuracy of sketch plan methods is questionable given the parameters are generally derived from previous studies that do not necessarily have transferable results. Alternatively they may be based on the modeller’s estimates.

The ‘travel shed’ concept is not clearly defined and requires the modeller to have a good knowledge of local conditions and elements such as geographical barriers or other network severance.

Unlike the more sophisticated traffic models discussed later it does not cope as easily with the notions of the likelihood that someone will use a particular facility based on distance from it etc.

Data issues: These methods use available data in the area. A good knowledge of available data and local conditions is required.

Alternatives: Comprehensive network models as discussed below, comparison models or aggregate behaviour models.

Examples: There are two examples of this type of approach that illustrate its potential. Both of these relate to estimation of bicycle provision on greenhouse gas abatement reflecting the topicality of greenhouse concerns.

The first example is at the city wide level (see Katz (2000)). This study used a figure for *elasticity of demand for cycling with respect to the proportion of a trip served by designated bicycle facility* of 0.6 (Katz 1996). Based on this elasticity figure it was assumed that an increase of 25% in the cycleway proportion of all possible trips in Sydney would increase the numbers of cycle commuters by approximately 15% over existing levels. This would see average bicycle commuter numbers in the greater Sydney region increase from approximately 13 400 (Australian Bureau of Statistics 1996) to 15 410. In addition to the commute trips there are approximately 7000 trips in the greater Sydney area that are made by bicycle on a daily basis for non-work purposes based on HTS figures. It is likely that the elasticity response to cycleways for these non-work trips is at least as high as for the work trips. In this case, an additional thousand non-work bicycle trips would be made. A total of approximately 3000 additional bicycle trips per day would thus be the result of increasing the average proportion of trips served by cycleways by 25%. These demand figures are used to extrapolate the potential emissions savings from reducing motorised vkt and then to work out a cost per tonne of CO2 equivalent emissions saved.

The second example is that used in the US guidelines (Goldsmith 1997). This developed emission reduction figures based on the following steps:

- A 0.8-km buffer was used to create a corridor-specific travel shed
- To estimate commuter bicycle trips, first multiply the percentage of residents who commute on a daily basis (60 percent in Seattle) by the population of the travel shed. With the commuting population number, multiply it by the bicycle commute rate. This calculation gives existing estimated bicycle commute trips.
- An estimate for potential bicycle commuters is determined through survey data that reveals that percentage of residents who at one point bicycle commuted. This was used to obtain the percent of potential new bicycle commuters (Seattle used 8 percent). This number is then multiplied by the number of commuters in the travel shed and then by the number of commuters who said that they would switch to bicycling if safer facilities were provided (26 percent in Seattle). The equation is as follows:

  # new bicycle commuters = # CBD (central business district) commuters * percent potential bicycle commuters * percent ride on safe facilities
- Non-work trip estimates: These were based on national and city wide estimates of non-work trips relative to commute trips (approx 2:1)
- The proportion of work and non-work trips that would have been motorized vehicular trips (as opposed to public transport or walk diversions) – conservatively assumed at 50%.
- The average length of these diverted trips. Commuting distances are estimated using census journey-to-work data. For utilitarian non-work trip distances, the commuting distance was divided in half.

Going through these steps the author derived estimates of motor vehicle kilometres diverted as a result of the bicycle facility and using standard emission factors was able to estimate the greenhouse gas abatement effect of the facility.

7 REGIONAL TRAVEL MODELS

Overview: Regional transport models are the mainstays of integrated urban transport planning. Traditionally they have been carried out in a four-stage process of Trip generation, Trip distribution, Mode split and Network assignment. A common structure for these sorts of models is shown in figure 2.

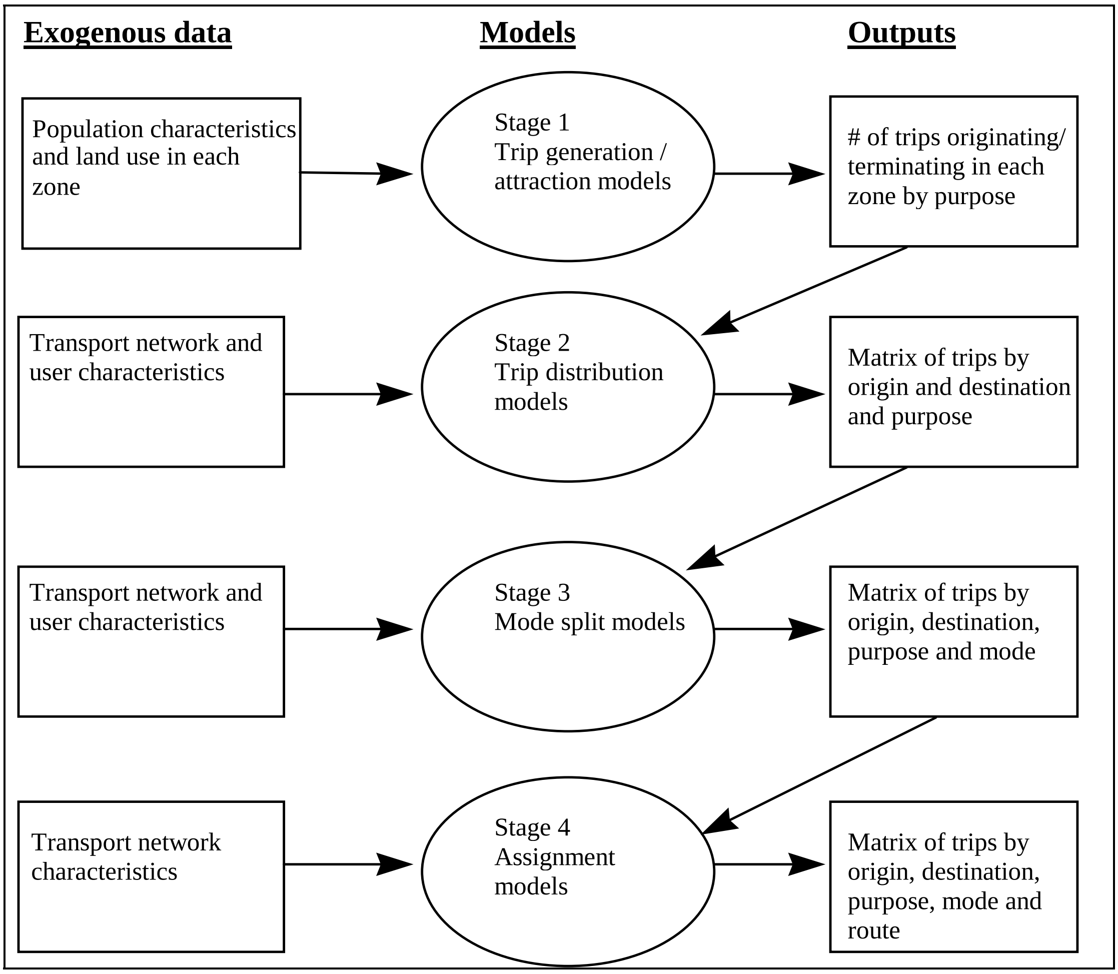

Figure 2 — The classic four stage transport model (after Nash 1982)

Uses These models are used in major international and Australian cities. They provide for the medium to long term planning of the transport network. They allow planners to examine traffic volumes, speeds and delays throughout the network. Using various assumptions, they can project the network's performance into the future at a relatively fine zonal level. They can also be used to examine network performance on a number of criteria such as emissions.

One of the principle uses of these models is to develop trip tables showing origin and destination pairs now and at some future point. These trip tables are then used for evaluating the quality of links (where links may be roads, public transport services or bicycle facilities) connecting these origins and destinations.

Being such a powerful integrated planning tool, great reliance tends to be placed on these models in evaluating proposed changes to the transport network. Unfortunately, it is difficult to incorporate bicycle use into these models where they have been developed with a primary view towards modelling motor vehicles and public transport or where levels of bicycle use are so low that they tend to fall out in the calibration process.

Even where bicycle networks and flows are not modelled directly, the regional travel models can provide useful information. Often the results of regional travel models, (eg. Traffic volumes and speeds on particular links) would be useful for sketch-plan modelling of a bicycle network. They may be used to represent demand on particular desire lines. Rule of thumb diversion factors from aggregate market share and forecast market share can be used to identify latent bicycle demand on those lines.

Limitations: Much has been written about the limitations of the traditional four stage model (see for example Atkins (1987)). Criticisms arise from the tendency to produce and interpret models, particularly in a growth climate, to suggest that more road construction is necessary to meet predicted increases in demand for private motor vehicle transport. This flows from the structure of the models that generally restrict feedback between the urban form and network characteristics, user characteristics and trip generation characteristics that could limit private motor vehicle transport demand under certain constraints.

Restrictions on feedback between elements are necessary to make the models tractable. The precise form of the restrictions is as much a question of judgement as science. In the past, the judgement has been that the appropriate form for a model was to predict increases in private motor vehicle as accurately as possible given limited policy intervention to actively manage transport demand.

The models generally are focussed purely on 'utilitarian' travel, particularly work trips. Given the increasing proportion of non-work trips, the models have become increasingly nipped and tucked to fit observed travel patterns. Such non-work trips may be especially important for bicycle travel demand.

Data issues: Data requirements for these sorts of models are extensive. Depending on the final structure of the model, they require information from:

- socio-demographic studies, including population figures, employment growth figures, vehicle ownership and access figures;
- detailed information on workplace and residential location;
- detailed information about the behavioural factors determining peoples' residential location choice, travel time choice, route choice, mode choice and other factors affecting their transport behaviour; and,
- a well specified model of the physical transport network and transport service overlay including the ability to factor in features such as differential tolls and parking charges, public transport trip times, fares and frequencies and, of particular importance for this guide, bicycle network features.

All metropolitan models compromise in one or more areas, again to make the models tractable. One of the most common compromises in Australian models is to exclude bicycles.

Inclusion of the bicycle in regional transport models requires firstly a conscious decision to include them in the model specifications and secondly data on the physical network and appropriate parameters for inclusion in one or more model sequences.

Alternatives: Alternatives to including bicycle demand in regional models include running separate models representing each stage of the regional modelling process and to link these via sketch-plan models. This can provide an integrated planning perspective for forecasting demand for alternative modes on alternative routes.

If the primary interest is in facility evaluation, a practical alternative may be in GIS based modelling as discussed below.

Examples

Australia: Regional travel models have recently been updated in Sydney and Melbourne. Perth is in the process of an extensive review of its strategic planning models. Brisbane and Adelaide are running similar regional travel models. Both are looking at their data requirements for enhancing their models.

Relevant contacts are Frank Milthorpe (Transport Data Centre, NSW Department of Transport) and Edward Chung (Victorian Department of Infrastructure), Steve Piotrowski (WA Department of Transport), Lindsay Oxlad (Transport SA) and Edmund Chandra (Main Roads, Queensland).

The Melbourne model is run on a network modelled using TRIPS software. It has recently been updated with a focus on improving the public transport modelling capability. It is also being re-calibrated to reflect changes resulting from the toll road developments in Melbourne. It relies on employment and population forecasts to derive trip generation figures and uses data from the Victorian Activity and Travel Survey (VATS – see Bicycle Data Guidelines (Steer Davies and Gleave 2000)), screen-line traffic counts, and patronage data from public transport franchisees to develop trip distribution models and calibrate the mode choice and network assignment. There is no attempt to capture bicycles in the model at this stage.

The Sydney Transport Model (STM) represents a major new modelling effort. Home to work trip tables are now available for four time periods and seven modes from 1996 to 2026. Non-work trip tables are expected to be available by the end of 2001.

While the STM is essentially a traditional four-step model, it uses a market analysis stage prior to trip generation to divide the market into 128 different segments. These market segments are tracked through the whole modelling process. A major innovation for the model is the motor vehicle ownership and access and licence holding sub models. Results are not yet available in the form of a publication.

Bicycles were included as an alternative mode in formulating the model system however they fall out in the estimation due to the low existing levels of bicycle use in Sydney. A bicycle network is not specified in the network modelling software (EMME/2) for Sydney. This would need to be done if the regional travel model was to provide major insights into bicycle demand and this is not currently seen as being practicable.

The models rely on the Sydney Household Travel Survey data (see Data Guidelines for more information) for much of their data on travel behaviour. This survey, like the VATS, is a continuous rolling survey. Once it has been running for a sufficient time, significant data on the levels and types of bicycle use should be available that would be useful for bicycle demand modelling.

Other cities also have developed regional models that are generally at a level of sophistication somewhat below that of Sydney and Melbourne. Perth is currently carrying out a major revamp with a view to developing a thirty year plan. A number of land use forecasts are being developed as the basis of trip generation models. Mode choice is to be modelled across seven modes including bicycles and networks are to be specified that incorporate walking and cycling. It is anticipated for example that there will be special delay functions on links to represent slopes that impact on cycling. Data used for the models includes a household travel survey from 1986, census journey to walk data from 1996 and the Travelsmart data where that is available (basically South Perth).

Adelaide has recently migrated much of its pre-existing model from QRS software to TRIPS with analysis in the TRANSEND software developed by Veitsch Lister Consultants.

North America: A number of American cities have attempted to run regional transport models incorporating bicycles and pedestrians. Noteworthy among these are Portland (Rossi, Lawton et al. 1993), Montgomery County (The Maryland-National Capital Park and Planning Commission 1991; Replogle 1995) and Edmonton (Hunt, Brownlee et al. 1998).

US modellers have put a lot of effort into identifying level of service (LOS) measures for inclusion in their models (Epperson 1994; Sorton and Walsh 1994; Stein 1996). These supply side measures can be useful elements in specifying models but there are no known regional models that incorporate LOS measures for bicycles in a systematic way.

Europe: The British consultancy MVA has developed the TRIPS software that is widely used for transport modelling. It has also produced a bicycle model as part of this package and has applied the model in the city of Leicester. The process is well described in the US Guidelines at http://www.fhwa.dot.gov//////tfhrc/safety/pubs/vol2/sec2.10.htm. The contact person responsible for bicycle modelling at MVA completed a masters degree thesis on a similar theme (Sharples 1993).

In the Leicester model, it is possible to predict the likely bicycle flows on defined links in the system given new links or changes to the characteristic of the links, for example, reductions in road conflicts on a segregated bicycle path. It is also possible to forecast bicycle flows on particular links given an increase in the level of cycling at a future date. It does not however incorporate a mode choice model that is sensitive to changes in network characteristics.

As one would expect, there is some relatively advanced bicycle modelling originating in The Netherlands. DHV Environment and Infrastructure – a consultancy firm working on behalf of the Dutch Ministry of Transport, has developed a network model specially designed for cyclists QUOVARDIS - BICYCLE. This model is fairly similar in concept to the MVA bicycle model discussed above in that it is essentially a traditional four stage model with the mode choice step excluded. It is designed such that TRIPS trip tables can be imported or trip tables and network information from QUOVARDIS-CAR, a motor vehicle modelling software tool can be used.

In addition to being used in The Netherlands, the QUOVARDIS model has been applied in Ipswich in the UK.

8 DISCRETE CHOICE MODELS

Overview: Discrete choice models have become widely used in economics, marketing research and transport. They rely on the theory that peoples' behaviour reflects a choice. Choices are assumed to be made on the basis of the values they place on the attributes of the alternatives. This is a corollary to the assumption in classical economics of rational decision-making (*homo economicus*) based on utility maximising.

A discrete choice transport model predicts a decision made by an individual (choice of mode, choice of route, etc.) as a function of any number of variables. The basic form of most discrete choice models is a multinomial logit model. For a full theoretical exposition of discrete choice models in transport see McFadden (1976); Hensher and Johnson (1981); Ben-Akiva and Lerman (1985).

The models can be estimated using observed behaviour (revealed preference data) or stated preference data or a combination of the two.

Uses: Discrete choice models can provide insights into the major factors affecting a particular decision. Thus in a question of whether a cyclist would choose one route over another, various explanatory variables can be included in a model. For example, route choice could be modelled as a function of system characteristics such as relative distance of alternate routes, intersection delays on alternate routes, existence of a separate bicycle path or on road bike lane and personal characteristics such as age and gender of the rider etc..

Similar models can be used for modelling choice of mode, trip departure time and other features of travel behaviour. Parameters from these models can be used to estimate elasticity of demand with respect to the variable under consideration. Elasticity is an extremely useful concept in understanding demand. Broadly speaking it can be understood as a measure of the percentage change in demand as a result of a 1% change in the variable of interest.

Limitations: It is important to recognise that the assumptions underlying utility theory are not necessarily accurate depictions of the way that human behaviour develops. People do not necessarily choose their behaviour based on the attributes of alternatives. Alternate behavioural assumptions may be developed based on such theories as:

- conditioning;
- habit formation theory;
- cognitive dissonance theory – whereby people reduce mental discomfort by changing their preference structures according to the behaviours they currently exhibit; or,
- satisficing – whereby people do not choose what is optimal but simply get to a level that is acceptable and do not change.

Unfortunately, these alternate theories of human behaviour have not enjoyed the econometric development of random utility models. Logit models in particular are a readily computed, reasonably robust and well understood behavioural modelling framework.

There are certain recognised weaknesses with the logit models – notably the independence from irrelevant attributes assumption. Where similar alternatives (a red bus and a blue bus is the classic transport example) are included in a model choice set, logit models can incorrectly predict the probability of choosing alternatives.

Data issues: These models require significant data especially in the case where estimation is based on revealed preference data. For the models to be estimated, data must be available on the chosen alternative (eg. use of a particular mode or route) as well as the other alternatives. Generally this will require specialised data collection as well as rich data sets such as the Victorian Activity and Travel Survey or Sydney Household travel Survey data.

Stated preference experiments – where respondents are asked what alternative they would choose given hypothetical levels of various attributes of the alternatives – are a good alternative for running discrete choice models. These can provide cheaper data with smaller sample sizes. Sophisticated survey design techniques are required to ensure that realistic responses are provided.

An example of a stated preference mode choice experiment is provided in figure 3 below. In this experiment respondents were asked to evaluate 32 different scenarios using a computer-based survey. They were asked to choose which alternatives they would choose in an average commuting week. In these types of experiments the scenarios are structured so that respondents are forced into a trade-off of the various attributes of the alternatives.

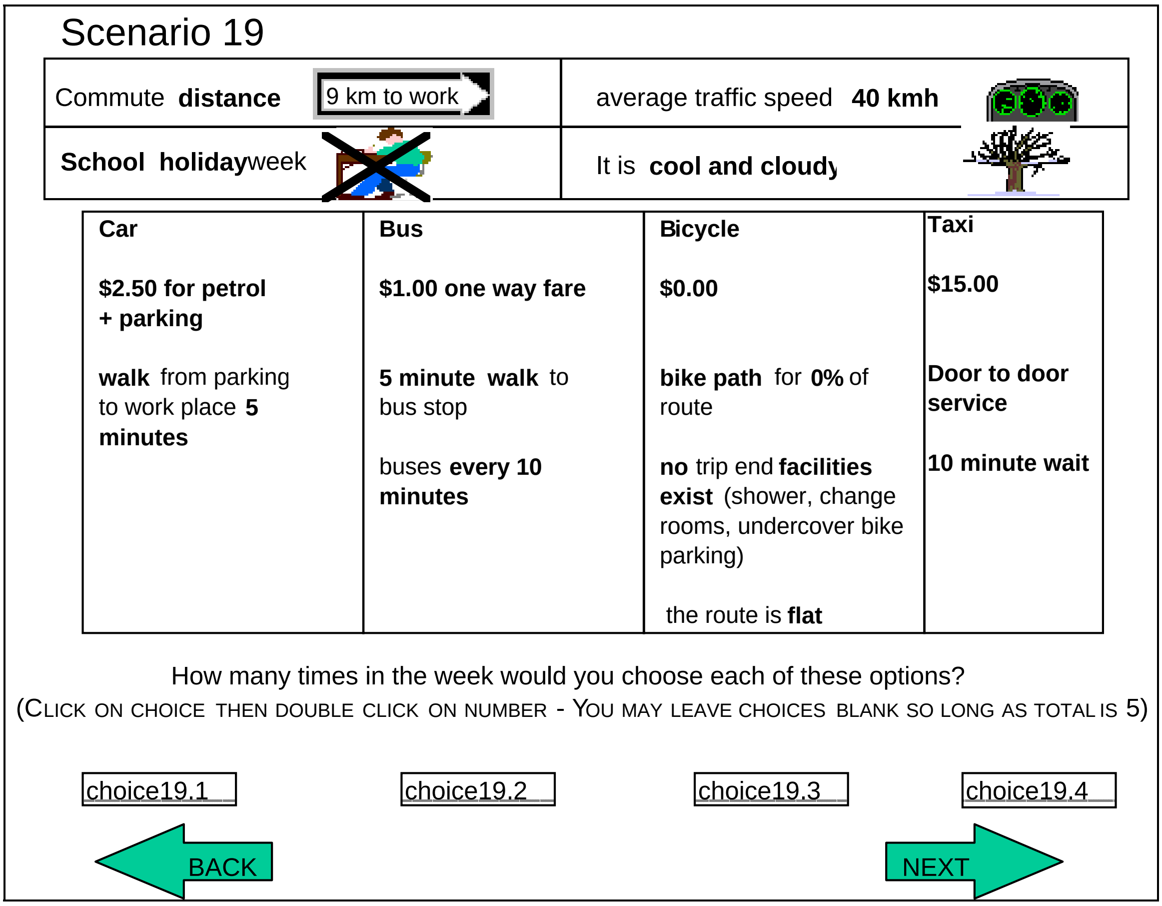

Figure 3 — Stated preference profile, Katz (1996)

Alternatives: Discrete choice methods are clearly useful guides to likely factors influencing choice behaviour. Alternative methods of identifying the relative strength of people's preferences do exist however. For instance, some studies require respondents to rank or rate factors that are most important to their decisions. These ratings or rankings can be modelled in various ways (eg. Multi Criteria Analysis – see Hutchinson (2000) for an example) to weight particular aspects of a given area. These studies may be reasonable, however, they do not directly model people's choices – they rely on assumptions that the things people say are important to them actually motivate their behaviour. This may be accurate in some circumstances but not in others.

Examples:

Some of the earliest examples of applied discrete choice modelling involved bicycles (see for example Ben-Akiva and Richards (1976); Bradley and Bovy (1984)). In the first case, extremely detailed data was available from Dutch household interview surveys and a series of discrete choice models were estimated. In the second case, stated preference was used to derive a route choice model. Route factors include facility type, surface quality, traffic level, and travel time (each described qualitatively at three levels).

In Australia, discrete choice methods have been widely applied and are used to provide some of the parameters for regional transport models. They have also been applied by transport consultants to derive patronage forecasts of various proposed and contemplated transport projects such as the VFT, the new Brisbane airport rail link etc..

The known Australian applications of discrete choice methods to bicycle use are limited to Katz (1996) at this point. In that study choice was modelled using a separate stated preference experiment specifically designed for commute trips. The survey was administered to a small sample to demonstrate the suitability of the methodology. The experiment reduced the impact of short term inter-personal and structural constraints by positioning the choice context four years into the future.

The stated preference models extended the participation models by causing the respondents to trade-off the various attributes included in the experiment. Multinomial-logit models and nested-logit models were estimated and very good results were obtained in terms of goodness of fit. The models allow testing of the impact of many variables on the relative attractiveness of car, bus and bicycle under a range of different conditions.

Important variables determining choice of bicycle for commuting were trip distance, the proportion of the trip on a bicycle path and existence of facilities such as showers, change rooms and bicycle parking. Perceptions of cycling as good for the environment and about safety and dignity were important variables in the models. Variables likely to precipitate a change from car use were increases in the cost of petrol and parking, and reductions in average traffic speed. Elasticities for key policy variables are presented. These suggest, among other things, that the provision of additional bicycle path will have a significant effect on the likelihood of using a bicycle for a specified trip (elasticity approximately 0.6) . Reducing trip distances also has a significant effect with an elasticity of 0.8 for distances ranging from 3 km to 12 km.

9 OTHER ADVANCED APPROACHES TO BEHAVIOURAL MODELLING

This section is intended to reference some of the advanced alternative modelling approaches that have been suggested as being applicable to bicycle demand modelling.

9.1 Structural equation modelling

Structural equation modelling is a statistical technique that relaxes some of the assumptions inherent in the regression models with which most researchers are familiar (see Bollen (1989)). It is generally associated with LISREL statistical package. It allows dependent relationships between several variables to be tested within the same modelling framework.

With a substantive understanding of relationships, causal paths can be evaluated between different variables and measurement models estimated for latent variables. It would be possible to develop structural equation models of propensity to use bikes. Such a model would be able to attach coefficients to path relationships and thereby give a more precise indication of the interrelationships between variables affecting bicycle use.

9.2 Activity modelling and transport behaviour modification programs

Activity modelling has long been promoted as an insightful way to examine peoples' transport behaviour (Jones 1979; Jones 1979; Clarke, Dix et al. 1981; Fox 1995). This is particularly the case as the commute trip assumes a lesser importance in the overall transport demand and the different activities that provoke travel become increasingly important to understand.

In some ways the situational group approach of Brög, (1982) shares quite a lot with the approach of activity modellers. Its major advantages are in getting away from the somewhat questionable behavioural frameworks offered by discrete choice models and the richness of the analysis where coding of activities is well thought out.

Unfortunately, we are still quite a way from having workable models that integrate activity models with regional travel models or network models.

10 GIS BASED APPROACHES

Overview:

Geographical Information Systems (GIS) allow for the integration of spatial and tabular data. GIS can manage and present complex spatial data. Studies that utilise GIS have the capability of analysing 'real world' data, providing results based on actual cyclist choices and GIS packages can handle the fine scale spatial data desirable for bicycle research.

Uses: Most GIS systems in use in Australia (largely by local government) essentially work as advanced inventory management systems. In this role they can be very valuable in managing the elements that make up a bicycle network. They do have other features however that make them suitable for demand modelling and facility planning.

There are a number of data elements attached to various features of GIS systems. Population data is referenced to polygon elements (often representing census collector districts), network data is referenced to line elements, and features may be referenced to points. Broadly speaking, lines and features can be used to describe a network and the polygons can be used to incorporate aggregate demand measures.

One of the most important features of a GIS system is its ability to superimpose results onto maps. This is especially important for presenting models to a mixed audience. It also assists in error checking – it is more likely that obvious errors will be spotted when put in their physical context.

Limitations: Experience with relational databases and particular GIS software is required for effective use of GIS.

Data issues: While there is a substantial amount of network data already built into most GIS systems, it is necessary to obtain additional data to specify a bicycle network.

Similarly, population data may be already available within the GIS system being used but relevant information on cycling may need to be obtained through special purpose surveys.

Examples:

A useful Australian example of a cyclist route choice model using GIS was developed at the University of Queensland (Hutchinson 2000). Taking advantage of the new opportunities presented by the application of Geographical Information Systems (GIS) to local bicycle planning , multiple criteria were used to form a predictive model that reveals the route a cyclist will likely use to reach a specific destination.

The study was based on cyclists travelling to the University of Queensland's St Lucia Campus in Brisbane. An initial survey of bicycle riders on campus was analysed using Multiple Criteria Analysis. This indicated that riding space, directness of route, quality of route surface and slope were the most influential factors determining route choice for this particular population of cyclists. Data on each of these four factors was then integrated into one single 'cost layer' that formed the predictive model. To test the effectiveness of the model, real world data was obtained via a second rider survey. For each returned survey the cyclist's origin and destination pair was used to create three possible routes, which were comparatively analysed against the actual route taken by the cyclist. From the analysis, two sets of results were obtained; results that outlined the effectiveness and robustness of the model and results that add to empirical knowledge on cycling.

On average the model predicted 70.5% of the links ridden by the cyclists surveyed. It was found that the spatial locations of cyclists' origins are closely related to the accuracy of the model, implying that the model is sensitive to route options available to the cyclist and the differences between these routes. The model performed worse for shorter trips (less than 2 km) where less deviation from the shortest path was observed.

Another example of a GIS application in Australia is Wigan, Richardson and Brunton (1998) which used a GIS to investigate trip generation characteristics of the Lower Yarra bike facility - a well-connected and promoted facility. Data included in the GIS analysis were adjacent population demographics, and connectivity to these residential areas. The results of this analysis then became the basis for predicting potential levels of use at another multiple use trail (the Maribrynong Trail, which does not benefit from equivalent access and public promotion), assuming similar conditions existed.

User surveys from the Yarra trail were used to develop a trip length distribution model and trip generation rates for postal code zones within the study area. These rates were compared to population densities in postal code areas at various distances from the Maribrynong Trail and calculated distances from the trail to the postal area centroids (geographic center of the polygon area). Using this sketch plan method, Wigan *et al* estimated a potential 500 percent increase in use, if improvements in facility access and promotion were undertaken.

11 CONCLUSIONS

There is a variety of demand modelling techniques at the disposal of transport planners and bicycle planners in particular. Many of these are dependent on obtaining appropriate data and having the technological expertise available to implement the methods.

Some of the easier methods such as comparison studies can be used to support proposals at the local level. For more widespread bicycle facilities and programs involving significant expenditure, a more rigorous forecasting framework is likely to be required.

Such a framework is likely to need to be developed alongside regional travel models. These models are not currently equipped to evaluate the case for improvements in the bicycle network because of their reliance on calibration based on existing travel patterns – bicycle use is generally too insignificant in Australian cities to provide the basis for calibration within regional travel models.

In order to develop tractable models of the role of bicycles within existing and forecast transport systems it would be possible to develop a number of the techniques described in this guide. In particular, the use of sketch planning techniques with simplified networks and using behavioural parameters from discrete choice models could be a profitable area for regional planners. These could be used to alongside some of the visioning exercises that are becoming increasingly popular (eg. Queensland Transport and Main Roads (1999)).

The availability of GIS modelling techniques also offers considerable scope for developing a better understanding of where bicycle demand can be expected and relating that demand to the urban landscape in a readily comprehensible fashion.

GIS systems can be used to enhance local area bicycle plans and local area integrated transport planning.

12 CONTACTS

Name	Organisation	Telephone
Alastair Cumming	VicRoads	03 9854 2592
Frank Milthorpe	Transport Data Centre NSW Department of Transport	02 9268 2937
Rosemarie Spiedel	Cycling Promotion Fund	03 9755 3557
Kim Dorrestyn	Dorrestyn and Co Pty Ltd	08 8395 2999
Lindsay Oxlad	Transport SA	08 8343 2985
Marc Wigan	Oxford Systematics	03 9459 9671
Edward Chung	Victorian Department of Infrastructure	03 9655 6528
Edmund Chandra	Main Roads Queensland	07 3834 5517
Steve Piotrowski	Transport WA	08 9231 2761

Internet email groups Bike-oz@cyclery.com Bfa-oz@cyclery.com

13 BIBLIOGRAPHY

Atkins, S. T. (1987). "The crisis for transportation planning modelling." Transport Reviews 7(4): 307-325.

Australian Bureau of Statistics (1996). Transport patterns and preferences in New South Wales. Sydney.

Austroads (1999). Australia Cycling 1999-2004 The National Strategy. Sydney, Austroads.

Ben-Akiva, M. and S. R. Lerman (1985). Discrete Choice Analysis: Theory and Application to Travel Demand. Cambridge Massachusetts, The MIT Press.

Ben-Akiva, M. and M. Richards (1976). Disaggregate multimodal model for work trips in The Netherlands. Transport Research Record 569.

Bollen, K. A. (1989). Structural equations with latent variables. New York, John Wiley and Sons.

Bradley, M. A. and P. L. Bovy (1984). A stated preference analysis of bicyclist route choice. Transportation Planning Methods, PTRC 12th Summer Annual Meeting, July 1984.

Brög, W. (1982). The acceptance of polices to encourage cycling. Transportation Research Board, Washington, Socialdata, Muenchen, Germany.

Brög, W., E. Erl, et al. (1983). Maximal share of cyclists using a nationwide status quo forecast as the background, Socialdata, Muenchen, Germany.

Clarke, M., M. Dix, et al. (1981). Recent Advances in Activity -Travel Analysis. 60th Annual Meeting of The Transportation Research Board, Washington.

Datacol (1992). ACT Bicycle Policy - Market Survey, Department of Urban Services.

Department of Transport Western Australia (2000). Travelsmart; A cost effective contribution to transport infrastructure. 2001.

DHV Environment and Infrastructure ((no date)). QUOVADIS-BICYCLE User's Manual. AmersFoort, Netherlands, Dutch Ministry of Transport.

Epperson, B. (1994). "Evaluating Suitability of Roadways for Bicycle use: Towards a Cycling Level-of-Service Standard." Transportation Research Record 1438.

Fox, M. (1995). "Transport planning and the human activity approach." Journal of Transport Geography 3(2): 105-116.

Goldsmith, S. (1997). Draft: Estimating the Effect of Bicycle Facilities on VMT and Emissions, Seattle Engineering Department,.

Hensher, D. A. and L. W. Johnson (1981). Applied Discrete-Choice Modelling. London, Croom Helm Ltd.

Hunt, J. D., A. T. Brownlee, et al. (1998). Design and Calibration of the Edmonton Transport Analysis Model. 1998 Transportation Research Board Annual Meeting, Washington DC.

Hutchinson, N. (2000). Predicting bicyclists preferred routes. Geographical science and planning. Brisbane, University of Queensland: 155.

Jones, P. (1979). Activity Approaches to Understanding Travel Behaviour : Workshop Assessment. Fourth International Conference on Behavioural Travel Modelling, Eibsee, Germany.

Jones, P. (1979). A Methodology for Assessing Transportation Policy Impacts. 58th TRB annual meeting, Washington.

Katz, R. (2000). The Role of Bicycles in Greenhouse Gas Reduction. Canberra, Roads and Traffic Authority of NSW: 24.

Katz, R. J. (1996). Demand for bicycle use: A behavioural framework and empirical analysis for urban NSW. Graduate School of Business. Sydney, The University of Sydney.

Lewis, C. and J. E. Kirk (1997). Central Massachusetts Rail Trail Feasibility Study. Boston, MA, Central Transportation Planning Staff,.

Market and Communications Research (1998). SafeST Research Queensland:March 1998 Report. Alderly, Queensland Transport and BCM Partnership.

Market and Communications Research (1999). SafeST Research Queensland: Wave 2 -- July 1999 Report. Alderly, Queensland Transport and BCM Partnership.

McFadden, D. L. (1976). The Theory and Practice of Disaggregate Demand Forecasting for Various Modes of Urban Transportation. Seminar on Emerging Transportation Planning Methods, Daytona Beach Florida, US Department of Transportation.

McNamara, R. (2000). GGAP figures for estimating car KM displaced. Brisbane, Queensland Transport: 2.

Milthorpe, F. W. (1993). Preliminary analysis of 1991 census journey to work data. Sydney, Institute of Transport Studies.

Morgan-Thomas, E. (1992). Why Don't You Commute by Bicycle? Ausbike 92 -Cyclist Behaviour and Planning, Melbourne.

MVA (1995). Leicester Bicycle Model Study, Final Report, prepared for Leicestershire County Council.

Nash, C. (1982). Economics of public transport. Harlow, Longman Group.

Ortuzar, J. d. D. and L. G. Willumsen (1990). Modelling Transport. Chichester, West Sussex, John Wiley and Sons.

Queensland Transport and Main Roads (1999). 4seeable Futures. Brisbane, Queensland Government.

Replogle, M. (1995). Integrating pedestrian and bicycle factors into Regional Transportation Planning models. Washington, Environmental Defence Fund.

Roads and Traffic Authority (1991). Road Transport Future Directions - Report on Options, RTA.

Rossi, T., T. K. Lawton, et al. (1993). Revision of Travel Demand Models to Enable Analysis of Atypical Land Use Patterns, Cambridge Systematics, Inc. and Metropolitan Service District.

Saul, P. (2001). “Take a good look over the horizon.” Business Review Weekly (April 27 2001): 112-114.

Sharples, R. (1993). “Modelling Cyclists in SATURN.” Traffic Engineering and Control: 472-475.

Sorton, A. and T. Walsh (1994). “Bicycle stress level as a tool to evaluate urban and suburban bicycle compatibility.” Transportation Research Record 1438.

Spectrum Research (1987). Survey of Cyclists Characteristics and Cycling Patterns, State Bicycle Committee Victoria.

Steer Davies and Gleave (2000). Cycling Data and Indicator Guidelines. Melbourne, Commonwealth Department of Health and Aged Care & developed in conjunction with the Australian Bicycle Council.

Stein, W. R. (1996). Pedestrian and bicycle modeling in North America's urban areas: A survey of emerging methodologies and MPO practices. Civil **E**ngine**e**ring, Georgia Institute of Technology: 64.

The Maryland-National Capital Park and Planning Commission (1991). A Transportation Planning Model For Montgomery County.

Tisato, P. and T. Robinson (1999). A cost benefit analysis of travel blending. 23rd Australasian Transport Research Forum, Perth, Western Australian Department of Transport.

US Department of Transportation (1999). Guidebook on methods to estimate non-motorised travel: Overview of Methods. Washington DC, FHWA.

Waldman, J. A. (1977). Cycling in towns: a quantitative investigation, Department of Transport.

Wigan, M., A. Richardson, et al. (1998). Simplified Estimation of Demand for Non-motorized Trails Using GIS. Transportation Research Board Annual Meeting, Washington DC.

INFORMATION RETRIEVAL

Austroads (2002), **Forecasting Demand for Bicycle Facilities**, Sydney, A4, 42pp, AP-R194/01

KEYWORDS

Bicycle, Demand, Facilities, Forecast, Strategy

ABSTRACT

This guide examines methods by which demand for cycling under different conditions can be estimated, and provides a framework for analysing data to develop demand forecasts for bicycle use. The guide is based on an international review of literature with an Australian focus on the purposes, advantages, limitations and methods of demand forecasting. The call for research in this area stemmed from the need for further policy development, evaluation and implementation of the Australian Bicycle Council's 'National Strategy 1999 – 2004'.

All major forecasting methods are reviewed in the guide and grouped into eight categories including; comparison studies, aggregate behaviour studies, maximal share studies, sketch-plan method, regional travel models, discrete choice models, advanced behavioural modelling techniques and GIS based methods.

In forecasting demand for bicycle facilities, the guide can assist practitioners in selecting the most appropriate forecasting method(s) based on the level and intensity of data requirements/collection, the size and scope of the proposed facility, and the level of technical skill required.

AUSTROADS PUBLICATIONS

Austroads publishes a large number of guides and reports. Some of its publications are:

AP-1/89	Rural Road Design
AP-8/87	Visual Assessment of Pavement Condition

Guide to Traffic Engineering Practice

AP-11.1/88	Traffic Flow	AP-11.9/88	Arterial Road Traffic Management
AP-11.2/88	Roadway Capacity	AP-11.10/88	Local Area Traffic Management
AP-11.3/88	Traffic Studies	AP-11.11/88	Parking
AP-11.4/88	Road Crashes	AP-11.12/88	Roadway Lighting
AP-11.5/88	Intersections at Grade	AP-11.13/95	Pedestrians
AP-11.6/93	Roundabouts	AP-11.14/99	Bicycles
AP-11.7/88	Traffic Signals	AP-11.15/99	Motorcycle Safety
AP-11.8/88	Traffic Control Devices		

AP-12/91	Road Maintenance Practice
AP-13/91	Bridge Management Practice
AP-14/91	Guide to Bridge Construction Practice
AP-15/96	Australian Bridge Design Code
AP-17/92	Pavement Design
AP-18/00	RoadFacts 2000
AP-22/95	Strategy for Pavement Research and Development
AP-23/94	Waterway Design, A Guide to the Hydraulic Design of Bridges, Culverts & Floodways
AP-26/94	Strategy for Structures Research and Development
AP-29/98	Austroads Strategic Plan 1998–2001
AP-30/94	Road Safety Audit
AP-34/95	Design Vehicles and Turning Path Templates
AP-36/95	Adaptions and Innovations in Road & Pavement Engineering
AP-38/95	Guide to Field Surveillance of Quality Assurance Contracts
AP-40/95	Strategy for Ecological Sustainable Development
AP-41/96	Bitumen Sealing Safety Guide
AP-42/96	Benefit Cost Analysis Manual
AP-43/00	National Performance Indicators
AP-44/97	Asphalt Recycling Guide
AP-45/96	Strategy for Productivity Improvements for the Road Transport Industry
AP-46/97	Strategy for Concrete Research and Development
AP-47/97	Strategy for Road User Cost
AP-48/97	Australia at the Crossroads, Roads in the Community — A Summary
AP-49/97	Roads in the Community — Part 1: Are they doing their job?
AP-50/97	Roads in the Community — Part 2: Towards better practice
AP-51/98	Electronic Toll Collection Standards Study
AP-52/97	Strategy for Traffic Management Research and Development
AP-53/97	Strategy for Improving Asset Management Practice
AP-54/97	Austroads 1997 Bridge Conference Proceedings — Bridging the Millennia
AP-55/98	Principles for Strategic Planning
AP-56/98	Assessing Fitness to Drive
AP-57 & 58/98	Cities for Tomorrow — Better Practice Guide & Resource Document
AP-59/98	Cities for Tomorrow — CD
AP-60/98	Guide to Stabilisation in Roadworks
AP-61/99	Australia Cycling 1999-2004 — The National Strategy
AP-62/99	*e*-transport — The National Strategy for Intelligent Transport Systems
AP-63/00	Guide to the Selection of Road Surfacings
AP-64/00	Austroads 4th Bridge Conference Proceedings — Bridges for the New Millenium
AP-G65.1/01	Road Condition Monitoring Guidelines: Part 1 – Pavement Roughness
AP-G66/02	Asphalt Guide
AP-G67/02	Travel Demand Management Guidelines
AP-G68/01	Guide to Heritage Bridge Management
AP-G69/02	Urban Road Design Guide

These and other Austroads publications may be obtained from:

ARRB Transport Research Ltd
500 Burwood Highway
VERMONT SOUTH VIC 3131
Australia

Telephone: +61 3 9881 1547
Fax: +61 3 9887 8144
Email: donm@arrb.com.au
Website: www.arrb.com.au

or from road authorities, or their agent in all States and Territories; Standards New Zealand; Standards Australia & Bicycle New South Wales.