



## **Forecasting light vehicle traffic on Australian highways: an overview**

**David Mitchell**  
*BTCE*

**David Cosgrove**  
*BTCE*

**Seu Keow Cheng**  
*BTCE*

---

### **Abstract:**

Getting future infrastructure requirements right requires the right framework for analysis and reliable forecasts of future traffic. The BTCE has developed a light vehicle traffic forecast methodology for use in assessing the adequacy of current and future infrastructure needs for Australia's major highways.

A gravity model of population and real generalised travel cost was used to forecast aggregate inter-regional passenger travel. Passenger traffic mode share on major intercity routes was estimated using a suite of logistic substitution models. Forecast mode shares were then applied to the aggregate passenger travel forecasts to derive light vehicle traffic forecasts. For this work the BTCE developed an extensive data set of passenger transport, covering the period 1970 to the present, using tourism survey data.

Inter-regional light vehicle traffic was assigned to highways using the traffic assignment procedures in *TransCAD*. Assigned inter-regional highway traffic was subtracted from total light vehicle traffic count data to derive local traffic on each highway link. Forecasts were derived by type of vehicle, for each link in the highway system.

Key features of the BTCE's method include the use of separate models of inter-regional passenger, local passenger and commercial vehicle traffic to forecast highway traffic levels, and the development of logistic substitution models for mode share. The logistic substitution models predict the mode share of air will continue to increase on longer routes, while the mode share for car will continue to increase on shorter routes.

The BTCE has tested its methodology using Western Australian traffic count data, and found the forecast methods provide a good approximation to future traffic growth. The BTCE plans to extend its methods to the modeling of freight traffic.

---

### **Contact author:**

David Mitchell  
Senior Research Officer, Bureau of Transport and Communications Economics  
Department of Transport and Regional Development  
PO Box 501, CANBERRA ACT 2601  
Telephone: (02) 6274 7128 Fax: (02) 6274 7170  
Email: [dmitchel@email.dot.gov.au](mailto:dmitchel@email.dot.gov.au)

---

## **Introduction**

The private motor car is by far the most commonly used form of passenger transport today and has been so for at least the last decade. In 1995, 86 per cent of all urban passenger trips, by motorised transport modes, were by passenger car (BIE estimates), the same proportion as in 1986 (FORS 1988). As a proportion of all modes, including walking and cycling, car use accounted for 68 per cent of all urban passenger trips in 1986 (FORS 1988). In non-urban areas car transport accounts for over 65 per cent of all passenger kilometres travelled and is expected to remain the largest mode in the foreseeable future (BTE forthcoming).

Road infrastructure is an essential element of private motor vehicle transport and getting the right level of investment in road transport infrastructure is essential to an efficient road transport sector.

The BIE has developed the Road Infrastructure Assessment Model (RIAM) to assess the adequacy of road infrastructure on the national highway network. RIAM is a strategic model that can be used to project expenditure needs, for increased road capacity, town bypasses and maintenance. The model was used extensively in preparing the BTCE's input (BTCE 1997) to the House of Representatives Standing Committee on Communications, Transport and Microeconomic Reform (HORSCCTMR) - the Inquiry into Federal Road Funding. The Committee's final report considered that the Commonwealth should draw on the work of the BTCE, following refinement of the estimates, in considering its 1998-99 national highway budget (HORSCCTMR 1997, para. 4.163, p. 75).

Road investment needs are largely driven by traffic levels, the mix of heavy vehicles using specific road sections, and the relative condition and width of the road. For the BTCE submission to HORSCCTMR, our team developed a method for forecasting three separate types of traffic that use the national highway system: inter-regional light vehicle traffic, hereafter referred to as 'through traffic', local light vehicle traffic, hereafter referred to as 'local traffic', and commercial vehicle traffic. Forecasts were produced for the whole of the National Highway System, as defined in DoT (1995, p. 3), and some additional roads of national importance. As a by-product of this work, the BTE now has a database of traffic forecasts for over 88 000 different sections of Australia's highway network, although admittedly the majority of these (approximately 78 000 sections) are in WA and Victoria. Road sections vary between 10 metres to over 100 kms in length.

The paper outlines the method for forecasting traffic on Australia's national highway network. Full details of the method will be published in BIE (forthcoming).

## Forecasting highway traffic

A three stage process was developed for forecasting traffic on Australia's national highway network (figure 1). Basecase (1996) traffic levels for each section of the national highway were derived for each of the through traffic, local traffic and commercial vehicle traffic components. In order to more accurately forecast traffic growth on each road section, separate growth models were developed for each traffic type. For example, growth in vehicle traffic on the Nullarbor Plain is largely attributable to through and commercial vehicle traffic, whereas local traffic growth may be more significant on parts of the Hume Highway, especially near urban centres. The growth models we developed were applied to basecase traffic levels to forecast future traffic levels for each section of the national highway network.

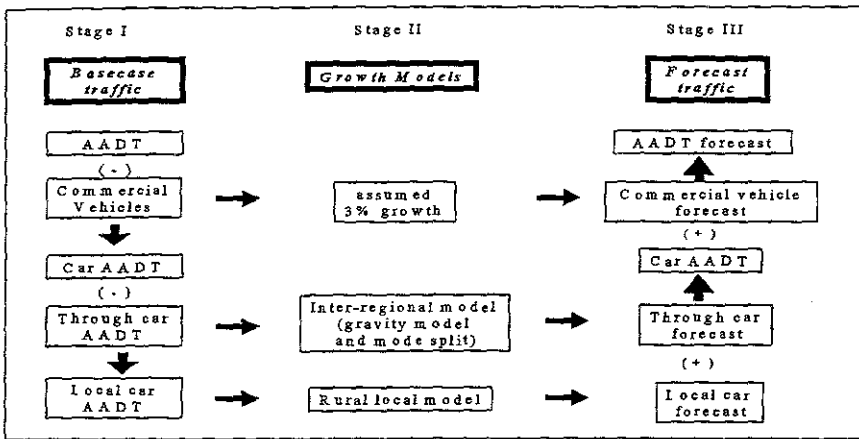


Figure 1 Forecasting annual average daily travel (AADT) on each section of the national highway system

Source: BTCE (1997)

Forecasting through car traffic growth on highways required models for estimating the future demand for inter-regional passenger travel, and mode share models to estimate the proportion of travel that would be undertaken by road. The following sections outline the method used to derive basecase traffic estimates.

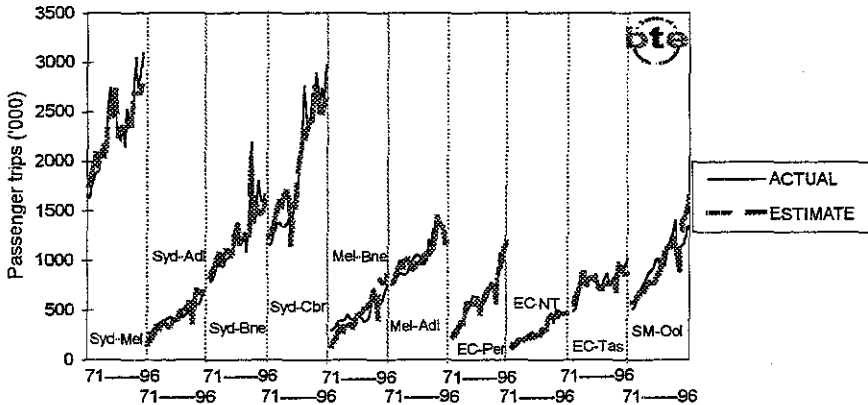
### A gravity model of inter-regional passenger travel

A simple gravity model relationship was proposed to explain demand for inter-regional origin-destination (O-D) passenger travel. Demand for inter-regional passenger travel comprises both household and business travel. Household travel is related to a number of factors, including household income, the relative cost of travel, the propensity to travel, and the proximity of friends and relatives. Business travel is generally a function of economic activity and business costs. The majority of inter-regional passenger car travel is non-business travel (BIR 1997). The gravity model specifies growth in total

travel between two regions  $i$  and  $j$  as a simple function of the endpoint populations and the real generalised cost of travel between the two regions

The gravity model and estimated parameter values are given in equation (1). The estimated gravity model explained almost 85 per cent of the variation in total inter-city O-D passenger travel for 10 major inter-city pairs. A plot of the estimated and actual passenger travel for each of the inter-city pairs is given in figure 2. The estimated model was assumed to hold for inter-regional passenger travel throughout Australia. Using population estimates for each of 91 different regions and the real generalised travel cost between each region pair, we used the gravity model in (1) to generate inter-regional passenger travel estimates for 4095 separate O-D pairs.

$$\text{Passenger trip}_{ij} = \frac{(\text{Population}_i \times \text{Population}_j)^{0.5}}{(\text{Real generalised travel cost} / \text{Real AWE})^{1.25}} \quad (1)$$



**Figure 2** Actual and estimated inter-regional passenger travel, 1970-71 to 1995-96  
 Source: BTE (forthcoming).

Parameter estimates for the gravity model were derived from a cross section - time series regression analysis of O-D passenger trips for 10 inter-city pairs, for the period 1970-71 to 1994-95. The 10 inter-city pairs were: Sydney-Melbourne, Sydney-Canberra, Sydney-Brisbane, Sydney-Adelaide, Melbourne-Brisbane, Melbourne-Adelaide, Eastern Capitals-Perth, Melbourne/Sydney-Coolangatta, Eastern Capitals-Tasmania, and Eastern Capitals-Perth. Data availability and time limited us to using only these 10 inter-city pairs.

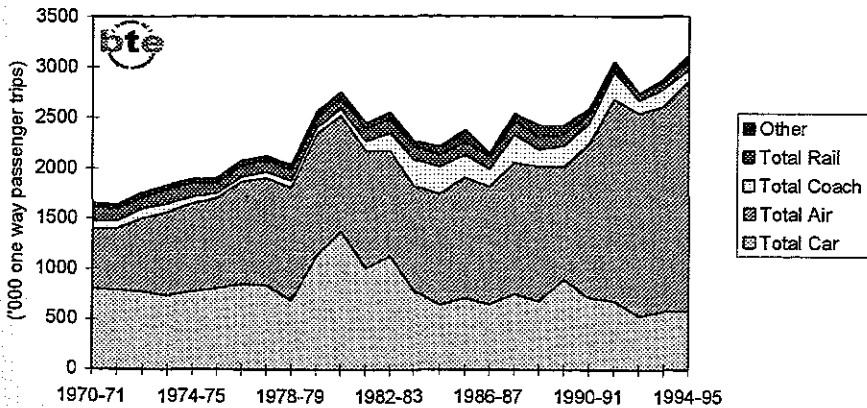
There is a surprising amount of data available on inter-regional passenger travel. However, the data comes from a number of different sources and are often measured using different definitions of a passenger trip. For example, conventional passenger transport data, such as rail passenger statistics (AN 1997) and air passenger statistics (Do TRD 1997) record the number of passengers carried on a particular service, such as the Indian-Pacific, or travelling on a particular stage, such as Sydney-Melbourne. By

contrast, tourism data (BIR 1996) records the number of O-D passenger trips between different geographic regions, by main mode of transport: air, car, train, coach or ferry

The BTE used tourism data from the Domestic Tourism Monitor (DTM) (BIR (1996), and transport data from sources such as DoIRD (1997) and AN (1996)), to estimate O-D passenger travel for each of the 10 inter-city pairs. Transport source data included estimates of bus passenger trips on scheduled services, rail passenger trips and air passenger trips between city pairs (DoTRD 1997). The transport source data was used as a check on the magnitude of the passenger transport estimates given by the tourism data.

Because each of the different data sources relied on different definitions of a passenger trip, all data was converted to the DIM measurement basis to derive comparable measures of O-D inter-city passenger travel. The DIM is a household survey that asks respondents for details of the household's most recent overnight trip. An overnight trip is defined as a recent trip that the survey respondent undertook of at least one night's duration and at least 40 km from their normal place of residence. Details recorded in the DIM include the number of passengers, the main destination and the main form of transport used. Children under 14 years of age are not counted in the DIM's measure of passenger trips.

Figures 3, 4 and 5 illustrate O-D passenger travel estimates, measured on the DIM basis, for Sydney-Melbourne (a long distance route), Melbourne-Adelaide (an intermediate distance route), and Sydney-Canberra (a short distance route).



**Figure 3** Total passenger trips, Sydney-Melbourne 1970-71 to 1994-95 (O-D basis)  
Source: BTE (forthcoming)

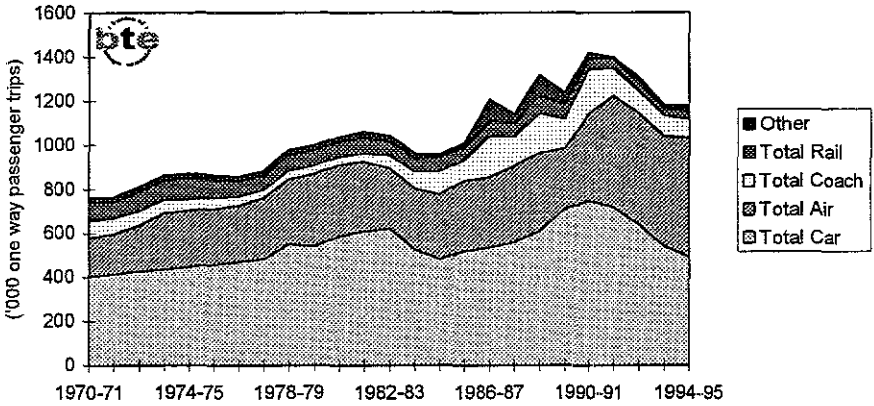


Figure 4 Total passenger trips, Melbourne-Adelaide 1970-71 to 1994-95 (O-D basis)

Source: BTE (forthcoming)

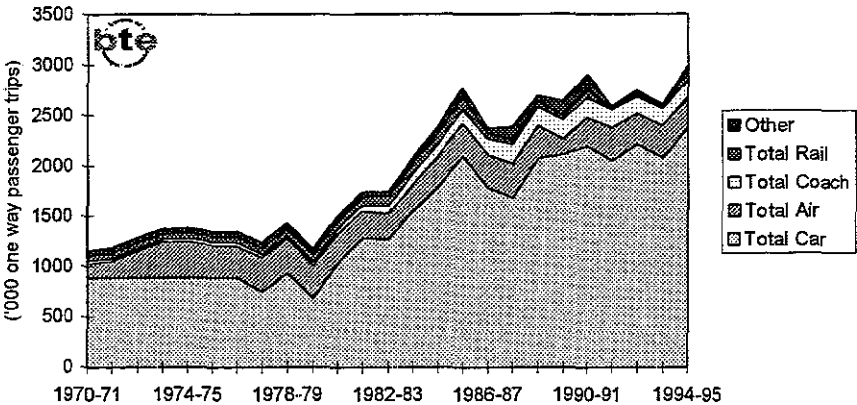


Figure 5 Total passenger trips, Sydney-Canberra 1970-71 to 1994-95 (O-D basis)

Source: BTE (forthcoming)

On the Sydney-Melbourne route, the growth in the share of air travel is noticeable since the early 1970s, and more particularly since domestic airline deregulation in the 1990s. The Melbourne-Adelaide route shows growth in both car and air travel in the late 1970s and early 1980s, and the increase in air's share at road's expense since airline deregulation. On the Sydney-Canberra route, a short distance route, all growth in O-D passenger travel has come from growth in car travel, due largely to improvements in the Hume Highway between Sydney and Canberra that have cut car travel times significantly.

## Mode share models

Mode share models were derived to distribute inter-regional O-D passenger travel across each of the different transport modes. We used the *logistic substitution model* (Gruebler 1990, Marchetti & Nakicenovic 1979, and Kwasnicki & Kwasnicka 1996) to estimate mode shares for inter-regional passenger travel. We used the O-D passenger travel estimates for the 10 inter-city routes to estimate logistic substitution models for each route. The logistic substitution model affords a simple yet robust method for forecasting future mode share. The equations used to estimate the logistic substitution model are given in the appendix.

Figure 6 illustrates the application of the logistic substitution model to the mode share substitution that has occurred in non-urban passenger travel in Australia since World War II. Immediately after the War, rail was the dominant mode of non-urban travel in Australia, with special services often provided between rural towns to cater for the local Saturday afternoon football match. Private car transport had a much smaller share of the market. With post war development, and the increasing affordability of the motor car, car increased its mode share at the expense of rail transport. It is now the predominant form of non-urban passenger transport.

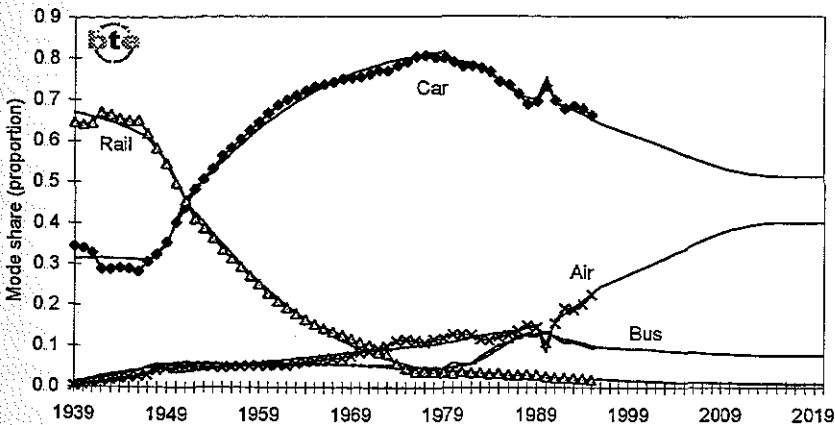


Figure 6 Mode share of Australian non-urban travel

Source: BTE (forthcoming)

The logistic substitution model was fitted to the non-urban passenger travel data shown in figure 6. Air travel has grown in mode share more recently, and the logistic substitution model projects that it will continue to increase its share at the expense of the private motor vehicle. This will not continue indefinitely, however, as most non-urban trips are of a sufficiently short distance to render air travel impractical. For this reason, the logistic substitution model of total non-urban travel was constrained so that air travel would not displace car travel as the largest form of non-urban passenger transport.

Separate logistic substitution models were subsequently fitted to data for each of the 10 inter-city routes. The logistic substitution models of mode share were used to derive mode share forecasts for each route. The mode share forecasts for Sydney-Melbourne and Melbourne-Adelaide O-D passenger travel, figures 7 and 8, suggest, and the mode split models confirm, that air travel's share of inter-city passenger travel will increase on long routes (over 800km), while car will continue to be the dominant mode on shorter routes (less than 400km).

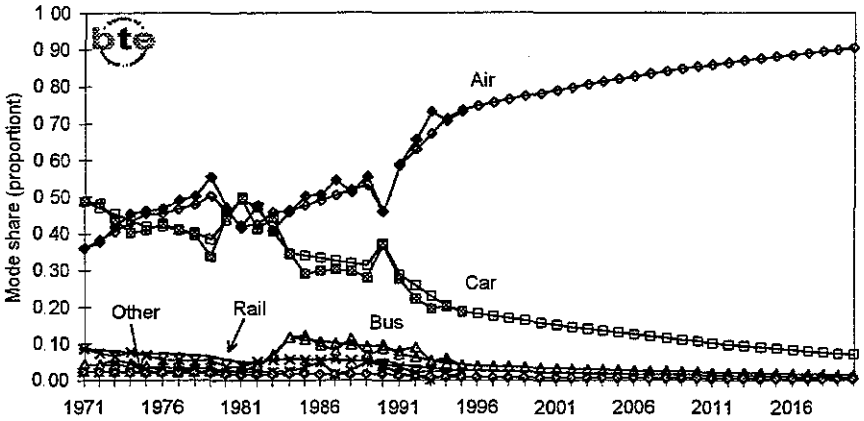


Figure 7 Mode share projections, Sydney-Melbourne, 1971 to 2020

Source: BTE (forthcoming)

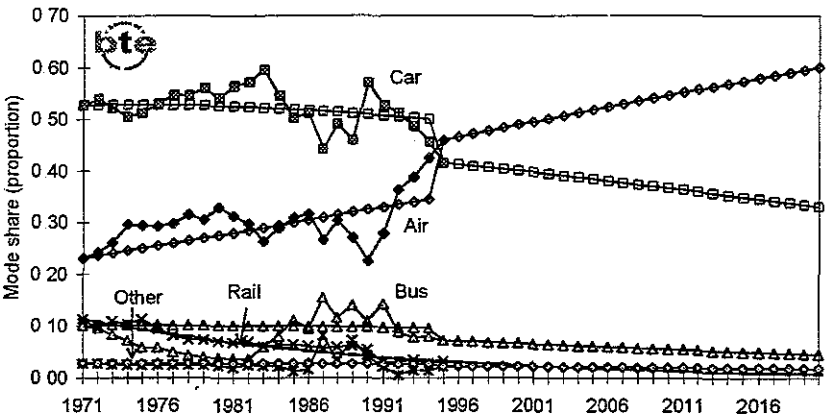


Figure 8 Mode share projections, Melbourne-Adelaide, 1971 to 2020

Source: BTE (forthcoming).



TABLE 1 SIMPLE RULES OF THUMB TO TRANSLATE GROWTH IN TOTAL TRAVEL INTO GROWTH IN CAR TRAVEL

Distance	'Rule of thumb'	Car growth multiplier
Long routes (>800km)	No growth in car travel	0.00
Medium routes (400-800km)	Car gains some of growth	0.70
Short routes (200-400km)	Car winning mode share	1.25
Very short routes (<200km)	Mostly car already	1.00

Source: BTE (forthcoming)

The mode split models for each of the 10 inter-city routes were used to derive simple 'rules of thumb' (table 1) to estimate growth in car passenger traffic from the gravity model forecasts. The rules of thumb were used to adjust growth in car passenger traffic to match growth in car travel's share of inter-regional O-D travel. Again, we implicitly assumed that shifts in mode share on inter-regional passenger travel for the 4095 separate O-D pairs follow the same simple rules of thumb derived for the 10 routes analysed.

#### Traffic assignment - through car traffic

Estimates of through traffic on each section of the highway network were estimated by assigning the 1996 DIM (BTR 1996) estimates of inter-regional car passenger travel demand to the highway network. Traffic was assigned to the highway network using the stochastic user equilibrium traffic assignment method available in *TransCAD 3.0* (Caliper Corporation 1996). The stochastic user equilibrium assignment method permits traffic to use less attractive routes. This avoids assigning all traffic between any two regions to a single route (usually the shortest distance route), and results in more realistic traffic patterns. The highway network used was the Road Transport layer available in the TOPO-10M topographic data set (AUSLIG 1993). Traffic was assigned between 91 different geographical regions. All highway traffic estimates were measured in Average Annual Daily Traffic (AADT) counts.

Estimates of basecase through traffic on each highway section together with estimates of total AADT and commercial vehicle traffic were used to estimate basecase local traffic. Commercial vehicle traffic was obtained from traffic count data supplied by each of the state road authorities. Local traffic, on each road section  $i$  at time  $t$ , was assumed equal to the difference between total AADT less commercial vehicle traffic less through traffic (equation 2).

$$\text{Local Car AADT}_{it} = \text{Total AADT}_{it} - \text{Commercial Vehicle AADT}_{it} - \text{Through AADT}_{it} \quad (2)$$

## Forecasting traffic flows

Forecasts were derived for each of the through, local and commercial vehicle traffic components

Forecasts of through passenger traffic are based on estimates of basecase through traffic levels. We used forecasts of population level, produced by the Australian Bureau of Statistics (ABS 1997) and forecast changes in real generalised travel costs to generate forecasts of inter-regional O-D travel demand for the forecast years 1998, 2005 and 2020. We used the forecasts computed in this way to estimate growth in passenger travel from the basecase for each O-D pair. It was assumed that car passenger travel would grow at a rate equal to growth in total passenger travel adjusted by the car growth multiplier rules of thumb (table 1). Real generalised travel costs were assumed to remain constant to 2020 while real average weekly earnings were assumed to increase by one per cent per annum to 2020. Together this means a reduction in real generalised travel costs of one per cent per annum. Forecast passenger travel demand was assigned to the national highway network, using the same assignment procedure as described above, to derive forecast through traffic on each section of the national highway, for 1998, 2005 and 2020.

Forecast local vehicle traffic was assumed equal to basecase traffic multiplied by growth in the number of local vehicle trips. Growth in local vehicle trips was assumed equal to growth in local population multiplied by growth in the number of vehicles per person within the local area. The Statistical Local Area (SLA) (ABS 1996) geographical area definition was chosen as the relevant local area. Growth in local traffic on each road section was modelled using growth in population and car ownership levels per person within the relevant local area.

Commercial vehicle traffic was assumed to grow at 3 per cent per annum from the basecase. The BTE is currently undertaking research into forecasting freight traffic on Australia's highways.

## **Validating the BTE's forecasting methodology**

To judge the reliability of the forecasting methodology we tested the performance of the methodology using actual data. Estimates of inter-regional passenger travel from the National Travel Survey (NTS) 1977-78 (BTE 1981), adjusted to match the DTIM definition of a passenger trip, and traffic count data for the rural WA road network (Main Roads WA 1996) were used. The WA rural road network has a 20 year time series of permanent count station traffic count data. WA is also of sufficient distance from other major population centres in Australia that it is easy to separate the inter-state traffic from intra-state traffic.

The test procedure compared estimated local traffic growth between 1978 and 1996 with traffic growth predicted using the forecasting methodology, for the same period. The

test involved assigning the NTS 1977-78 data to the highway network and estimating through traffic. We then subtracted the 1978 through traffic on WA road sections from total traffic counts on those sections to derive estimates of 1978 local traffic. We computed the 'estimated' growth in local traffic between 1978 and the basecase (1996) for each WA road section and compared the 'estimated' growth with forecast growth. The test procedure is outlined in figure 9.

Figures 10 and 11 illustrate the relatively close correspondence between historical traffic growth rates and BIE forecast traffic growth rates, for selected sites on WA national highway routes. Median traffic growth on the WA rural roads was between 2 and 3 per cent per annum between 1986 and 1996. Figure 11, shows that the BIE forecasts median traffic growth of between 1 and 2 per cent over the next 25 years. Slower traffic growth on WA rural roads is based on slower growth in rural populations (the population in some rural areas is expected to decline) and slower growth in car ownership levels.

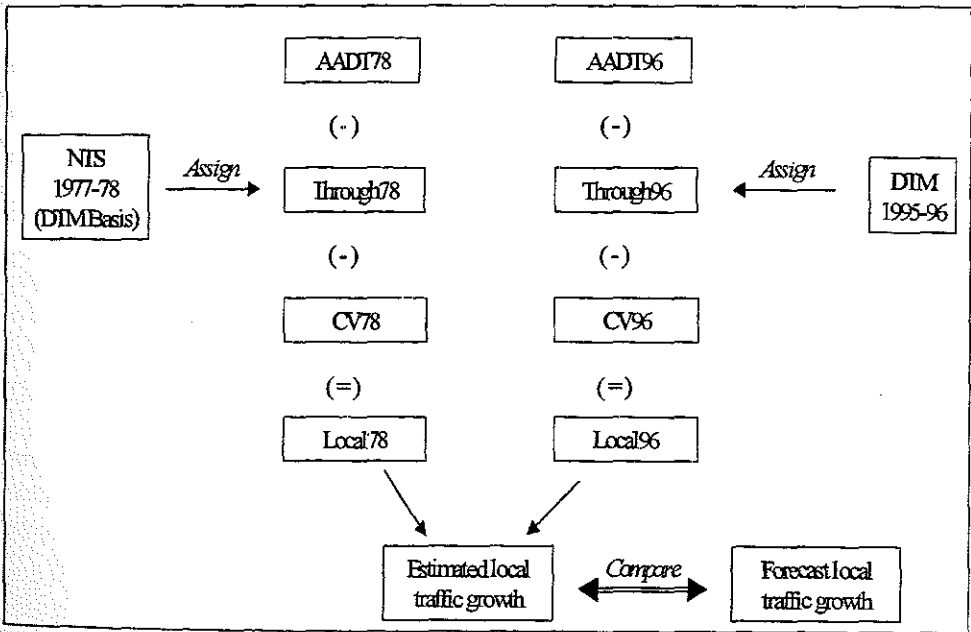
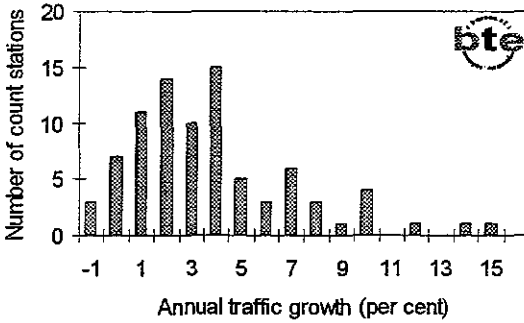
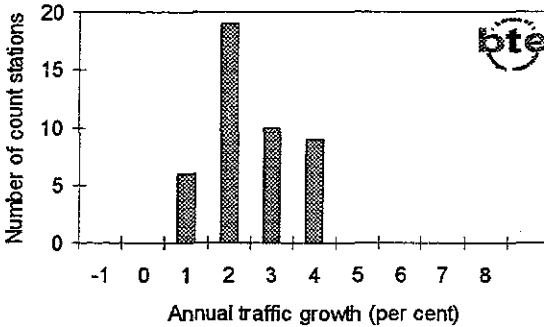


Figure 9 Procedure to validate highway traffic forecast methodology



**Figure 10** Historical traffic growth at WA national highway count stations, 1986-1996  
 Source: Main Roads WA (1996).



**Figure 11** Forecast traffic growth on WA national highway links, 1996-2020  
 Source: BTE (forthcoming).

At traffic count stations where the correspondence in historical and forecast traffic growth is less immediate, almost all of the historical traffic growth appears to have been due to large, one-off increases in the level of traffic, rather than consistent growth. Figure 12 shows historical traffic counts for two such WA rural permanent count stations. Count station 2909 is 2km east of Morawa on Yalgoo Rd (between Mt Magnet and Geraldton) and 8050 is on Marble Bar Rd in the Pilbara. According to Main Roads WA (1997) these sites have averaged logarithmic growth in traffic of over 10 per cent per annum since 1985-86. Figure 12 reveals that this growth is the result of a rapid increase in traffic levels in the late 1980s that did not continue in the early 1990s. These growth spurts are largely in remote rural areas and could be due to new economic activity (eg mining) and/or upgrading of the road.

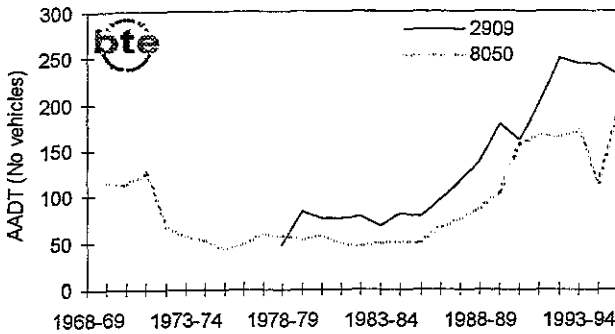


Figure 12 AADT counts at WA rural permanent count stations 2909 and 8050.

Source Department of Main Roads, WA (1996)

## Conclusions

We believe we have developed reliable methods for forecasting light vehicle traffic flows on Australia's major highways. The forecast procedures are, to our knowledge, the first time tourism data has been used in conjunction with transport data in Australia to produce forecasts of highway traffic. Tourism data is a valuable source of long distance passenger transport data. The logistic substitution models, used to forecast mode share trends for inter-regional passenger travel are a major feature of this work. The method can be easily adopted for use in forecasting traffic on any non-urban road section in Australia.

The BTE has tested its forecasting method, using WA traffic count data, and found that it produces reasonably good forecasts. The forecasts, because they are based on forecast population growth, were found to have a smaller amounts of variation in comparison with historical estimates.

The BTE is currently undertaking work to forecast inter-regional freight movements within Australia. We plan to use a similar approach for modelling the freight task, though the differing characteristics of freight commodities will involve separate models for different classes of commodity.

## Acknowledgments

This research was a team effort directed by Dr D Gargett and comprising Ms S Cheng, Mr D Cosgrove and Mr D Mitchell. We are grateful to the Bureau of Tourism Research, the Centre for Tourism and Hotel Management Research, Tourism Tasmania and the Roy Morgan Research Centre for help with the tourism data, and the Roads and Traffic

Authority of NSW, Victorian Department of Infrastructure, SA Department of Transport, Main Roads Western Australia, Queensland Department of Main Roads, Tasmanian Department of Transport, Northern Territory Department of Transport and Works, and the ACT Department of Urban Services for the traffic count data

## Appendix

Equations A 1 to A 4 give the equations used to estimate the logistic substitution model for the passenger travel share of mode  $i$ ,  $f_i$ . Variable  $c_i$  is the competitiveness of mode  $i$ ,  $c_{av}$  is the average competitiveness of all modes,  $\alpha_i$  and  $\beta_i$  are parameter estimates, and time  $t$  refers to a year. We used car travel as the reference mode, subscript  $k$ , in all cases

$$\ln\left(\frac{f_i}{f_k}\right)_t = \alpha_i + \beta_i(t - t_0) \quad \text{or } t \geq t_0 \quad (\text{A } 1)$$

$$c_i = c_k e^{\beta_i} \quad (\text{A } 2)$$

$$f_i(t+1) = \left(\frac{c_i}{c_{av}(t)}\right) f_i(t) \quad (\text{A } 3)$$

$$f_i(t = t_0) = \frac{e^{\alpha_i}}{1 + \sum_j e^{\alpha_j}} \quad (\text{A } 4)$$

## Abbreviations

AADI	Average annual daily traffic
ABS	Australian Bureau of Statistics
AWE	Average weekly earnings
AN	Australian National Railways Commission
AUSLIG	Australian Surveying and Land Information Group
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
BIR	Bureau of Tourism Research
DoI	Department of Transport
DoTRD	Department of Transport and Regional Development
FORS	Federal Office of Road Safety
HORSCCTMR	House of Representatives Standing Committee on Communications, Transport and Microeconomic Reform
RIAM	Road Infrastructure Assessment Model (BTCE)
TransCAD 3.0	TransCAD version 3.0, Transportation GIS Software

## References

- ABS 1997, 'Population Projections for all Statistical Local Areas (SLAs) and Local Government Areas (LGAs) of Australia, 1996 to 2012', Statistical Consultancy Project for the BTCE, ABS, Canberra
- 1996, *Statistical Geography Volume 1, Australian Standard Geographical Classification (ASGC)*, Cat. No. 1216.0, AGPS, Canberra
- AN 1996, *Annual Report 1995-96*, Australian National Railways Commission, Adelaide
- AUSLIG 1993, IOPO-10, Arc/Info, Vector topographic data for GIS - source scale 1:10 000 000, Commonwealth of Australia, Canberra
- BTCE 1997, *Roads 2020*, BTCE Working Paper 35, BTCE, Canberra
- 1995, *Greenhouse Gas Emissions from Australian Transport: Long-Term Projections*, BTCE Report 88, AGPS, Canberra
- BTE (forthcoming), *Forecasting Light Vehicle Traffic*, BTE Working Paper, BTE, Canberra
- 1981, *National Travel Survey 1977-78: Statistical adjustments and final results*, Hirsch, N.A. & Russell, D.A., BTE Occasional Paper 42, AGPS, Canberra
- BTR 1997, *Domestic Tourism Monitor*, BTR, Canberra
- Caliper Corporation 1996, *TransCAD version 3.0*, Caliper Corporation, US
- DoT 1995, *Australian Land Transport Development Program: Progress Report 1993-94*, AGPS, Canberra
- DoTRD 1997, *Air Transport Statistics: Domestic Airlines*, Aviation Statistics Division, DoTRD, Canberra
- FORS 1988, *Day-to-Day Travel in Australia 1985 - 1986*, prepared by Adena, M. and Montesin, H., Instat Australia Pty Ltd for FORS
- Gruebler, A. 1990, *The Rise and Fall of Infrastructure*, Physica-Verlag, Heidelberg, Germany
- HORSCCTMR 1997, *Planning not patching: An inquiry into Federal road funding*, AGPS, Canberra
- Kwasnicki, W. & Kwasnicka, H. 1996, 'Long-Term Diffusion Factors of Technological Development: An Evolutionary Model and Case Study', *Technological Forecasting and Social Change*, vol. 52, no. 1, pp. 31-57, Elsevier Science Ltd, New York
- Main Roads WA 1996, *Traffic patterns rural permanent count sites 1995-96*, Main Roads Western Australia, Government of Western Australia
- Marchetti, C. & Nakicenovic, N. 1979, *The Dynamics of Energy Systems and the Logistic Substitution Model*, RR79-13, International Institute for Applied Systems Analysis, Laxenberg, Austria
- Queensland Main Roads Department 1972, 'A guide to the prediction of rural traffic', Highway Planning Branch, June 1972, Brisbane