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Estimating urban traffic and congestion cost trends for Australian cities

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Foreword

This report presents the results of a Bureau of Transport and Regional Economics (BTRE) study to identify long-term trends in urban traffic growth, to estimate the consequent impacts of that traffic growth on urban congestion levels, and to attempt a suitable quantification of the social costs arising from those congestion levels. The study deals with the eight Australian capital cities, and presents *base case* (or business as usual) projections to 2020 of *avoidable* social costs of congestion for Australian metropolitan traffic. This work updates and revises previous congestion cost projections published by the Bureau (such as Information Sheet 14, BTE 1999), and has been completed to inform the Urban Congestion Review, which was commissioned by the Council of Australian Governments (COAG).

The traffic forecasts contained in this report are derived from BTRE base case projections of Australian transport activity (for the most recent published data see *Greenhouse Gas Emissions from Australian Transport: Base Case Projections to 2020*, BTRE 2006a). The costing methodology used for this study relies on the results of previous Bureau work using network models to estimate congestion impacts for Australian cities (such as Report 92, *Traffic Congestion and Road User Charges in Australian Capital Cities*, BTCE 1996b). It is important to note that the current BTRE approach to estimating congestion costs is an aggregate modelling one, i.e., it does not directly use detailed network modelling. Network models generally attempt to simulate the traffic flows on a city's road system in considerable detail; whereas the aggregate method aims to provide broad estimates of the scale of a city's congestion situation using aggregate indicators of a city's overall average traffic conditions.

The main advantage of this aggregate approach relates to the ability to generate congestion cost estimates and projections with much lighter computational and information resources than required by data-intensive network or microsimulation models. The main disadvantage relates to the approximate nature of such aggregate costings—with congestion being such a non-linear, inhomogeneous and stochastic process, highly accurate, location-specific assessments of its impacts can typically only be accomplished using detailed network models.

Aggregate national congestion cost estimates do not serve in any way to replace the results of detailed traffic simulation models conducted at a jurisdictional level (for both existing or future studies)—but are intended as a complement to their more in-depth findings. The results presented in this report are therefore provided as 'order of magnitude' evaluations—to help with considerations dealing with the likely aggregate costs of urban transport externalities for Australia, and their likely future trends. However, even with these caveats, the forecasts suggest an appreciable increase in the social costs of congestion over the next 15 years under a business-as-usual scenario.

The BTRE acknowledges the important contributions made by State and Territory colleagues through the Urban Congestion Management Working Group of the Standing Committee on Transport (SCOT). The study was undertaken by Dr David Cosgrove and Dr David Gargett.

Phil Potterton
Executive Director
Bureau of Transport and Regional Economics
April 2007

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At a glance

- This report has been completed to inform the Urban Congestion Review, commissioned in February 2006 by the Council of Australian Governments.
- Total travel in Australian urban areas has grown ten-fold over the last 60 years. Private road vehicles now account for about 90 per cent of the total urban passenger task (up from around 40 per cent in the late 1940s). The current trend of near linear increases in aggregate urban traffic is forecast to continue over the projection period, with total kilometres travelled growing by 37 per cent between 2005 and 2020. Commercial vehicle traffic is forecast to grow substantially more strongly (averaging around 3.5 per cent per annum) than private car traffic (at about 1.7 per cent per annum).
- BTRE estimates of the 'avoidable' cost of congestion (i.e. where the benefits to road users of some travel in congested conditions are less than the costs imposed on other road users and the wider community) for the Australian capitals (using an aggregate modelling approach) total approximately $9.4 billion for 2005. This total is comprised of $3.5 billion in private time costs, $3.6 billion in business time costs, $1.2 billion in extra vehicle operating costs, and $1.1 billion in extra air pollution costs. The estimates do not take account of the implementation costs of any congestion alleviation measures, and are not strictly comparable to standard measures of aggregate national income (such as GDP).
- BTRE base case projections have these social costs of congestion rising strongly, to an estimated $20.4 billion by 2020. The city specific levels rise from $3.5 billion (2005) to $7.8 billion (2020) for Sydney, $3.0 billion to $6.1 billion for Melbourne, $1.2 billion to $3.0 billion for Brisbane, $0.9 billion to $2.1 billion for Perth, $0.6 billion to $1.1 billion for Adelaide, $0.11 billion to $0.2 billion for Canberra, about $50 million to $70 million for Hobart, and $18 million to $35 million for Darwin.
- The complex nature of congestion effects leads to reasonable levels of uncertainty in such cost estimations. However, irrespective of questions over exact dollar valuations of congestion costs, sensitivity testing implies that, in the absence of improved congestion management, it will be challenging to avoid escalating urban congestion impacts, given the rising traffic volumes expected within the Australian capital cities.

Summary

Background

In February 2006, the Council of Australian Governments (COAG) commissioned a review of urban congestion trends, impacts and solutions (COAG 2006).

The Bureau of Transport and Regional Economics (BTRE) was subsequently commissioned to undertake a study to:

1. Examine main current and emerging causes, trends and impacts of urban traffic growth and congestion.
2. Identify any deficiencies in information and make recommendations regarding the collection and sharing of nationally consistent data.

The BTRE study (which commenced prior to the COAG Review, as part of the BTRE research program) analyses a number of the underlying factors contributing to the growth in traffic volumes and congestion intensity (across the metropolitan road networks), and the impact on traffic delays, travel reliability, and congestion's spread in both area and duration. The study then provides estimates of the economic costs of these growing time losses, and other social and economic consequences of growth in urban traffic congestion.

The study estimates the level of average trip delay (and other social impacts) of current congestion levels and forecasts how these will likely vary over time. A consistent aggregate methodology for estimating the average *avoidable social costs of congestion* is presented, along with projected future cost levels (which have implications for identifying the most economically-efficient level of congestion management).

It is important to stress that the current BTRE approach to estimating congestion costs is an *aggregate* modelling one, i.e., it does not use detailed network models. Network models generally simulate the traffic flows on all of a city's major roads, often in great detail; whereas our aggregate method aims to roughly estimate the scale of a city's congestion situation using aggregate indicators of a city's overall average traffic conditions. The main advantages of this aggregate approach relate to the ability to generate congestion cost estimates and projections with relatively slight computational and data resources. (Network or microsimulation models tend to require extensive data input and a considerable level of computational and maintenance support.) The main disadvantages relate to congestion being such a non-linear, inhomogeneous and stochastic process that highly accurate assessments of its impacts can really only be accomplished using detailed network models. As yet, however, there are no complete estimates of the cost of congestion (for Australian cities) using a network modelling approach.

The congestion cost estimates presented in this study are therefore provided as 'order of magnitude' evaluations—to help with considerations dealing with the likely aggregate costs of urban transport externalities for Australia, and their likely future trends. Detailed assessments of each of the cities' congestion impacts, especially analyses at the level of particular major city roads or thoroughfares, should continue to be pursued at the jurisdictional level using the appropriate network modelling frameworks. In fact, the BTRE is hopeful that not only will the various jurisdictions continue to develop traffic and congestion modelling techniques on their road networks, but that the results of such modelling will continue to improve understanding of congestion occurrence in Australian cities (and lead to more consistent comparisons being made between studies done in the various cities).

Though the congestion costing methodology used for this study does not directly rely on running detailed network models, the approach has been based on the results of network modelling of Australian cities' road systems—both from the literature and from previous Bureau work using network models to estimate congestion impacts (for example, Report 92, *Traffic Congestion and Road User Charges in Australian Capital Cities*, BTCE 1996b). The modelling of congestion for this study also draws on other previous Bureau work, including the results of BTCE (1996a) Report 94 (see Chapter 18 and Appendix XIII), Information Sheet 16, BTE (2000) and *Urban Pollutant Emissions from Motor Vehicles: Australian Trends to 2020* (BTRE 2003a).

The traffic forecasts contained in this report are derived from *base case* (or 'business as usual') projections of Australian transport sector activity. Projections are provided to 2020. This work updates previous BTRE projections of aggregate urban transport tasks using a suite of different demand models—utilising various modelling approaches (e.g. structural, econometric and dynamic fleet models) to project the different modal task components, and by aggregating estimates of demand levels for various transport sub-sectors to obtain sector totals (often termed a 'bottom-up' modelling approach). Previous Bureau reports published on our aggregate demand modelling include BTRE (2002a) Report 107, BTCE (1995) Report 88, BTCE (1996a) Report 94, BTCE (1997) Working Paper 35 and BTRE (2006c) Report 112. Extensions and revisions to Report 107 have also been prepared in more recent years (BTRE 2003a, 2003b, 2006b).

Report outline

This BTRE Working Paper is composed of two sections:

- Part I—dealing with trends in transport tasks (urban passenger and freight movement) and traffic growth for the capital cities; and
- Part 2—dealing with the estimation of the costs of congestion for the capital city road networks.

The report gives updated forecasts of urban transport demand and updated forecasts of the consequent traffic growth in Australian cities. The forecasting process entails examining the factors influencing the demand for urban road use, and assessment of trends in population growth and distribution, income growth, and demand for urban freight, service provision and passenger movement. The transport task estimates address trends in public transport patronage and the implications for forecasts of total vehicle kilometres travelled (VKT).

Part 2 of the report provides updated estimates of congestion trends and the likely magnitude of the social costs of congestion associated with the traffic growth patterns described in Part 1. The methodology assesses the impacts that changing travel volumes are likely to have on changing average traffic profiles and the distribution of vehicle traffic and congestion. The models contain a number of adjustable input parameters and default city-by-city calibrations that can be updated or revised if more detailed or network-specific data later become available.

Due to the complexity of the congestion problem, and the difficulty in collating enough information to model every intricate facet of road system performance, the modelling has had to include a variety of simplifying assumptions and approximations. Some of the major areas of modelling uncertainty surround the issues of:

- Possible peak-spreading of traffic volumes in the future (especially considering some major urban freeways are already operating at close to full capacity during the peak hours). The BTRE model allows for a degree of future peak-spreading (the effects on the estimates, if actual future spreading is greater or smaller than currently modelled, is addressed in a latter section of Part 2 on model sensitivities).
- What exact value do different parts of the community place on their time (for example, whether people value *waiting time* more highly than *trip time* reliability; whether delays during various trip purposes are felt more strongly than during others; or whether delay during longer trips is worse than during shorter trips). Basically, two of the most important uncertainties concern the question of the most suitable *dollar* value for an hour of time lost to congestion delay (either for business road use or for private travel), and the question of what proportions of urban trips are not highly time-sensitive. (The dependence of the estimates on the default parameter settings for average values of time is also addressed in Part 2).
- Comparison speed values. When calculating how much delay congestion causes, recorded average traffic speeds have to be compared with a less-congested benchmark speed (such as the *free-flow* speed—how fast a car is able to travel at, on that particular road link, if no other vehicles are present). For actual road systems, the definition and estimation of such speeds is typically complicated and fairly approximate (often involving limited floating-car surveys).

- Supply-side factors for urban road networks (such as, likely trends in future network capacity expansion—including both further road construction and other transport infrastructure development; and medium to longer term plans for urban development and provision of transport services). The BTRE base case scenario for congestion cost projections assumes that an increase of about one per cent per annum (in total available lane-kilometres) would be representative of long-term road provision trends for our capital cities, and continues this trend to 2020. This assumption could prove to be conservative, since traffic management systems within our cities will also tend to be developed further over time, and could also serve to increase overall future network capacity. However, addressing the likely impacts of such progression in travel management practices is probably best handled within possible further work on *congestion reduction scenarios*—rather than the *business-as-usual* projections of this study.

- Demographic effects—which can influence not only total demand levels but also elements of trip distribution (for example, peak-spreading of trips may increase in the future at even faster rates, as the average age of the population and retirement rates increase, and a growing proportion of travellers are not constrained to travel during the standard work-day peak hour). Though the BTRE demand projections make allowances for a fairly wide range of demographic effects (e.g. trends in average age of the population, average employment levels and typical household sizes), these analyses—like the current BTRE traffic flow modelling—are also at an *aggregate* level. Modelling approaches dealing with specific future changes to urban form and with a fine-grained level of demographic detail (i.e. dealing with each city's population and employment distribution) are beyond the scope of this study.

- The possible flow-on effects of urban congestion. The costs presented in this report primarily relate to estimated valuations of excess travel time for road users (with some allowance for the inefficiency of vehicle engine operation under stop-start conditions, leading to higher rates of fuel consumption and pollutant emissions). However, there is a series of other possible consequences of urban congestion—ranging from some businesses having to re-locate or close (due to restrictions on their operations from congestion delays), to widespread psychological stress and irritation from coping with heavy traffic levels, to reducing the efficiency of public transit and the attractiveness of transit or non-motorised transport options. Estimation of costs for these wider effects is difficult (with the literature covering suitable quantification methods being, so far, very limited), and also tends to be beyond the scope of this study (though this issue is briefly considered in the sensitivities section of Part 2).

Related to this final dot point, is the issue of how many other costs, besides the average delay experienced on travel in heavy traffic, are already implicitly borne by a city's population due to the level and distribution of current urban congestion. For example, land and housing values are typically much higher in areas (such as those in the centre of the city) that allow shorter commuting times and better transport access to major amenities. There are also issues of wasted infrastructure resources where unmanaged congestion on some urban freeways causes flow breakdowns that reduce vehicle throughputs, to only a small proportion of the road's design capability, for much of the peak periods. As well, there are typically costs associated with urban decentralisation—which is often prompted by rising congestion levels—where the prices for a wide variety of urban goods and services will partially reflect the difficulty in delivering such goods and services over a widespread, densely trafficked network.

Even though congestion is to a certain extent self-limiting (that is, if enough people try to enter an already busy traffic stream, then the congestion will eventually get so severe that some are deterred from travelling), there are still costs associated with such feedback constraints. Not only will average queuing times and flow disruptions continue to increase for those choosing to still travel, but those having their travel deferred (to a less convenient time) or discouraged by congestion suffer a loss of utility. Such losses in consumer utility mean that even natural behavioural effects that tend to improve the incidence of peak congestion levels (such as trip timing decisions resulting in *peak-spreading*) will also have some associated costs to travellers. Thus the broad pricing question could be framed in terms of whether better alternatives exist than to rely on the costs implicit in such individual and community 'self regulation'. Estimates of the aggregate social costs of congestion, such as those provided by this report, help to focus on the search for the most cost-effective solutions.

Part 2 of the report closes with a brief summary of the BTRE's assessment of the main data shortcomings and information gaps (within the current dataset collection processes) that have a bearing on congestion intensity and traffic demand management. Basically, various jurisdictions' on-going Traffic Systems Performance Monitoring tends to collect a reasonable amount of useful congestion-related data (such as details on average traffic flows), but there still appears to be a relative scarcity of quality data on:

- the details of urban freight distribution (and therefore on the impacts of congestion on freight costs);
- variability in average trip times (where road users appear to place a high premium on travel time reliability); and
- the composition of the traffic mix and how it varies over the hours of the day (not only in terms of vehicle type, but also with regards to the purposes or destinations of the various journeys).

As greater quantities of data continue to be collected in real-time, there would undoubtedly be social benefits in the greater provision of real-time traffic information systems, e.g, internet sites showing current traffic performance statistics to aid travellers' trip planning, allowing trips to be rescheduled or re-routed (if notified of a particular incident or irregular delay on their usual route).

Methodology

The BTRE aggregate approach is summarised below. (Also, for a schematic diagram roughly summarising the main steps involved in the estimation and projection process, see Appendix figures A.2 and A.3.)

Note that the current methodology addresses estimated traffic volumes and congestion costs for metropolitan areas—i.e. the Statistical Divisions of the eight State/Territory capital cities. The estimates would be higher to some extent if all the regional urban areas, such as Newcastle, Geelong or parts of South-East Queensland, were also included.

Passenger traffic forecast

Trends in passenger travel in each capital reveal that:

(1) Total passenger kilometres per person have been increasing as income per person increase.

(2) However, for most cities that increase in *travel per person* has just about saturated.

(3) Therefore, the rate of increase in total city travel will tend, in the near future, to fall and equal the rate of population growth of the city concerned.

(4) Furthermore, in almost all cities, the share of car and urban public transport has been virtually constant for around 30 years (typically about 90 per cent of motorised passenger-kilometres done in light motor vehicles and about 10 per cent for rail, bus and ferry).

Therefore, at a base level, forecasting of car travel can be done (within a business-as-usual scenario) by (1) relating car travel per person to income per person and (2) multiplying resulting car-kilometres per capita (derived from projected income levels) by projected population levels.

Freight traffic forecast

Trends in freight haulage in each capital have been related to (national) GDP per person. Estimated freight task per capita are then also multiplied by the city population. Assumptions are then made about the likely split between vehicle types (light commercial vehicles, rigid trucks and articulated trucks) and about future average loadings per vehicle (by vehicle type).

The result is a forecast of aggregate vehicle kilometres by vehicle type for each city.

Resulting traffic forecasts—freight and passenger vehicles

The forecast growth in car traffic in the cities tends to decelerate over time, in the base case, due to the modelled saturating trend of car travel per person against income.

Balancing this slowing car growth is rapid growth in the light commercial vehicle (LCV) fraction of the traffic (which is already a substantial part of the traffic stream). Heavy trucks also grow quickly but from the base of a small fraction of the current traffic stream. Annual growth in total VKT by LCVs has averaged between 3 and 4 per cent for well over 20 years, and the base case essentially continues this trend to 2020, with continued (projected) economic growth leading to continued VKT growth. This relatively high level of commercial traffic growth is predicated on the assumption that there will be no decoupling of activity in the freight and service sectors from overall income trends (i.e. GDP per person) during the projection period. When (or if) such decoupling does occur, as has already happened for the passenger sector, VKT growth for LCVs and trucks will also be expected to decelerate, but the evidence suggests that such a saturating trend in per capita freight movement is unlikely in the short to medium term (e.g. see Appendix figure A.1).

The result is near linear increases in traffic over the time period investigated for recent congestion trends (i.e. between 1990 and the present), continuing over the projection period (i.e. the present to 2020). In other words, approximately as much traffic in absolute terms will be added to the average city network in the next 15 years as was added in the past 15 years.

For aggregate metropolitan traffic growth, the BTRE base case projections have total annual kilometres travelled (in passenger car equivalent units, PCU-km) increasing by close to 37 per cent between 2005 and 2020—from around 138 billion PCU-km in 2005 (across all eight capital cities) to 188 billion in 2020. By city, the projected PCU-km increases (using base case input assumptions to the BTRE models) are about 38 per cent for Sydney, 33 per cent for Melbourne, 46 per cent for Brisbane, 27 per cent for Adelaide, 44 per cent for Perth, 13 per cent for Hobart, 40 per cent for Darwin and 29 per cent for Canberra. Variations in forecast city growth rates for VKT (e.g. the high growth in Brisbane, Perth and Darwin, and the low growth in Hobart) are due largely to variations in projected population growth.

The costs of congestion

Congestion imposes significant social costs with interruptions to traffic flow lengthening average journey times, making trip travel times more variable and making vehicle engine operation less efficient. The (generalised) cost estimates presented in this report include allowances for:

- extra travel time (e.g. above that for a vehicle travelling under less congested conditions),
- extra travel time variability (where congestion can result in trip times becoming more uncertain—leading to travellers having to allow for an even greater amount of travel time than the average journey time, in order to avoid being late at their destination),
- increased vehicle operating costs (primarily higher rates of fuel consumption), and
- poorer air quality (with vehicles under congested conditions emitting higher rates of noxious pollutants than under more freely flowing conditions, leading to even higher health costs).

Three different 'cost of time delay' calculations are often made, specifically:

(1) Total Cost of Congestion Estimate—total delay values use actual travel speeds versus estimated free flow speeds (e.g. versus what speed one could typically average travelling across the city in the middle of the night).

(2) External Cost of Congestion Estimate—still based on actual travel speeds versus free flow speeds, but estimates that portion of *total* costs that road users impose on others (through not having to personally meet the total costs caused by their travel decisions).

(3) Deadweight Loss Cost of Congestion—the increase in net social benefit if appropriate traffic management or pricing schemes were introduced and optimal traffic levels were obtained. Basically, the problem with a currently congested traffic flow is that it includes a quantity of travel for which the total costs to society exceed the benefits of that element of travel. The net loss on this amount of travel (after converting hours lost to delays into dollar terms) is given by the deadweight loss (DWL). Avoiding this loss would produce a net social benefit—leading to the common descriptions of such DWL values as a measure of the *'cost of doing nothing about congestion', or the 'avoidable cost of traffic congestion'*.

Though somewhat more involved to estimate, the third cost definition is generally preferable from a theoretical standpoint—especially for policy assessment. The 'avoidable cost of congestion' is a direct measure of what can, in principle, actually be achieved by tackling the congestion problem. It is typically of much greater policy relevance than *total delay* costs, because there is a possibility of obtaining the net benefits described in the third definition (i.e. given by DWL valuations), while it will not typically be feasible to reduce total delay costs to zero for real-world traffic streams.

Therefore, the primary values derived by this study to refer to the *'social costs of congestion'* are the estimated deadweight losses (DWLs) associated with a particular congestion level—which, reiterating, give a measure of the *costs of doing nothing about congestion or the avoidable costs of traffic congestion*. That is, DWL valuations give an estimate of how much total costs (for time lost and other wasted resources) could be reduced if traffic volumes were reduced to the *economically* optimal level. This optimal level is defined as the traffic volume (and distribution) that would result if, for a given travel demand, the generalised cost that motorists based their trip decisions on was equal to the *marginal* travel cost rather than on their private, individual travel costs (i.e. on the current *average* generalised travel cost). That is, if through an appropriate transport demand management or pricing instrument, each motorist choosing to enter already congested traffic had to take account of not only their personal travel time costs, but also the cost of all the extra delay that their entry into the traffic stream is likely to impose on others.

Essentially, there is no way to avoid all the *total delay* costs since actual traffic volumes cannot travel at free flow speeds at all times. Whereas the portion of total costs that could theoretically be saved, if some traffic management strategy was capable of changing traffic conditions to the economically optimal level, can be estimated by the deadweight loss associated with that change in traffic level. A DWL value will still tend to be an upper bound for the actual social benefits achieved by any particular congestion reduction strategy since it would take a perfectly variable management scheme, that targeted congestion by exact location and time of day (depending on the changing traffic levels on each of the network's road links), to obtain the economic optimum. However, it will be a substantially closer guide to actual obtainable benefits than a total delay cost estimate.

Of course, actually putting a particular traffic management strategy into practice will also tend to involve implementation, possible extra infrastructure, and on-going administration costs—all of which will have a bearing on how much of the full *theoretical* benefit level would in fact be gained. That is, the (avoidable social) cost values given in this report do not directly refer to actual obtainable savings for congestion reduction measures since the introduction and running costs will vary from measure to measure (and in some cases will be considerable), and are not taken account of within the congestion cost valuations of this report.

A related point is that even though the congestion costs derived by this study are considerable (as is typically the case for any such derivations that use standard assumed values of time), the dollar values obtained are not directly comparable to aggregate income measures (such as GDP). Some elements involved in the costings would have GDP implications (e.g. the timeliness and reliability of freight and service deliveries will impact on business productivity levels). However, a major proportion of the derived cost values refer to elements that play no part in the evaluation of GDP, such as private travel costs. Say, for example, that some congestion measure did happen to successfully reduce a city's traffic to the economic optimum, thereby 'saving' the *avoidable congestion costs*, and resulting in many travellers being able to take their trips less encumbered by congestion delays. Though these time savings would undoubtedly have benefits for many road users (where the DWL calculations attempt to suitably evaluate the net changes in road user utility in dollar terms), such benefit amounts—especially with regard to private individuals—will not have a clear-cut bearing on the size of any GDP changes that happen to flow from the congestion reduction.

When calculating the avoidable delay costs, the BTRE congestion model separately estimates travel characteristics by private cars, business cars, LCVs, buses and trucks, and uses different hourly delay cost rates for each category. The models use speed-flow curves, for various road types and city areas, to derive aggregate traffic delay estimates by time of day.

Various adjustable parameters are used in the modelling, including a cost for variability of travel time, percentages of short trips (where delay will not be noticeable), and an allowance for a proportion of total trips to be less time-sensitive than average. The model also allows for increasing delay costs in peak traffic periods (which is capable of generating some peak spreading).

Once time delay has been calculated, and converted into dollar terms (using appropriate *values of time*), other social costs associated with congestion (i.e. extra vehicle operating costs and air pollution costs) are also calculated. These other costs are added to the estimates of deadweight losses (associated with the calculated level of aggregate delay) to generate our national estimates for the *Avoidable Social Costs of Congestion*.

Congestion cost estimates

BTRE *aggregate* congestion estimates for this study give a total of about $9.4 billion for the 2005 social costs of congestion[1] (on the basis of *potentially avoidable costs,* calculated from the deadweight losses associated with current congestion levels across the Australian capitals). This total is comprised of approximately $3.5 billion in private time costs (losses from trip delay and travel time variability), $3.6 billion in business time costs (trip delay plus variability), $1.2 billion in extra vehicle operating costs, and $1.1 billion in extra air pollution damage costs. The national total is spread over the capital cities, with Sydney the highest (at about $3.5 billion), followed by Melbourne (with about $3.0 billion), Brisbane ($1.2 billion), Perth ($0.9 billion), Adelaide ($0.6 billion), Canberra ($0.11 billion), Hobart ($50 million) and Darwin ($18 million).

BTRE aggregate projections (using the base case scenario for future traffic volumes) have the avoidable social costs of congestion more than doubling over the 15 years between 2005 and 2020, to an estimated $20.4 billion. Of this $20.4 billion total, private travel is forecast to incur time costs of approximately $7.4 billion (DWL of trip delay plus trip time variability), and business vehicle use $9 billion (DWL of trip delay plus variability). Extra vehicle operating costs contribute a further $2.4 billion and extra air pollution damages a further $1.5 billion. The city specific levels rise to approximately $7.8 billion for Sydney, $6.1 billion

1 *In estimated costs to Australian economic welfare, and not in terms of measured economic activity or gross domestic product (and therefore not directly referable to as a proportion of GDP).*

for Melbourne, $3.0 billion for Brisbane, $1.1 billion for Adelaide, $2.1 billion for Perth, $0.07 billion for Hobart, $35 million for Darwin, and $0.2 billion for Canberra.

As mentioned previously, it should be stressed that even though these cost levels are *theoretically* avoidable, they do not *directly* relate to any net savings that may be possible under any particular congestion abatement policies, and do not provide an explicit (or *directly quantifiable*) estimate for the magnitude of any changes to GDP resulting from such policies. A DWL valuation gives an (order-of-magnitude) estimate of the worth society places on the disadvantages of current congestion related delays and transport inefficiencies, relative to travel under less-dense traffic conditions (i.e. at economically optimal traffic levels). The (DWL-derived) aggregate cost values given in this report:

- do not allow for any of the wide range of costs that would be associated with actually implementing specific traffic management measures—where the introduction of any measure aimed at congestion reduction will typically incur both set-up and ongoing operating costs (which will have to be considered separately from any of the benefits arising from changes in consumer utility that are estimated by DWL reductions); and
- do not evaluate how the flow-on effects of congestion reductions will impact on general economic activity. While personal travel costs influence the availability and cost of labour, the largest component of these estimated costs (i.e. travel time) is not directly measured in GDP. Though congestion reductions will typically have productivity benefits (e.g. through reductions in labour and housing costs), the difficult question of precisely quantifying all the flow-on impacts on measured GDP is beyond the scope of this study.

Note that, even after allowing for the issue of implementation costs, many studies that give congestion cost estimates are less than fully suitable for assessing the actual impacts of congestion on society—by which we mean suitably valuing the *avoidable* social costs of congestion (i.e. those costs that potentially could be saved under appropriate policy interventions). This is because such studies are usually based on the *total* time costs for congestion delay which, as discussed previously, refer to the differences in costs between average travel at congested traffic levels and travel under *totally uncongested* or *free-flow* conditions. Total costs of congestion delay (i.e. 'the costs of congestion relative to free-flow') estimates are derived by the BTRE methodology but only as intermediate values, used to then derive the DWL values ('the cost of doing nothing about congestion').

Since total delay values are based on the value of the excess travel time compared with travel under completely free-flow conditions—an unrealisable situation for actual road networks—they are rather poor measures of the social gains that could be obtained through actual congestion reduction, and are typically only given in this paper for comparison purposes.

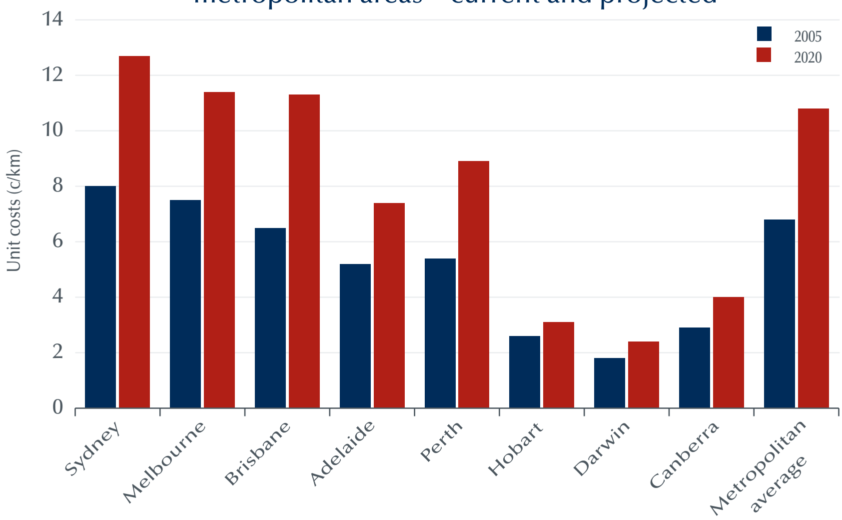
For example, to compare with those studies quoting only total delay costs, the current BTRE analysis has an Australian total of $11.1 billion for total annual delay costs over the eight capitals for 2005 (that is, excluding the cost elements for trip variability, vehicle operating cost and air pollution)—compared with around $5.6 billion for the preferable deadweight loss valuation of delay.

The base case demand projections have the value of *total* metropolitan delay (i.e. cost of excess travel time compared with completely free-flow conditions, and excluding the cost elements for trip variability, vehicle operating cost and air pollution) rising to about $23 billion by 2020—compared with the portion of this total cost of about $12.6 billion for the (DWL-derived) *avoidable costs of traffic congestion delay* for 2020.

Note that the estimated levels of total delay costs given here are lower than values previously issued in BTCE Information Sheet 14 for total delay costs, yet allowing for methodological differences, the national results are of a similar order of magnitude. In fact, if allowance is made for the parameters in the current methodology that tend to lower the cost estimates, relative to the much more simplistic derivations in Information Sheet 14—such as, for a percentage of trips to be below the threshold of noticeable delay, for a percentage of trips to be less time sensitive than average, for vehicle occupancy to vary over the day, for lower delay levels experienced on local roads, and for travel to peak-spread where possible—then the national *total delay* cost levels are quite comparable. However, the city-by-city composition of the updated congestion estimates presented here (see figure S.1) are considerably different from the previous Bureau values given in Information Sheet 14.

The average *unit costs of congestion* (that is, total avoidable congestion costs for metropolitan Australia divided by total VKT in PCU-km terms) are forecast to rise by around 59 per cent over this period—as average delays become longer, congestion more widespread and the proportion of freight and service vehicles increases. This is equivalent to a roughly 87 per cent increase in (metropolitan average) per capita congestion costs between 2005 and 2020. Figure S.1 displays how the unit congestion costs (cents per PCU-km) vary between the capital cities. The rightmost columns of Figure S.1 refer to weighted average values across all Australian metropolitan areas i.e., averaging the aggregate cost for the whole eight capitals across the aggregate VKT level.

Figure S.1 Average unit costs of congestion for Australian metropolitan areas—current and projected



Note: Costs here refer to avoidable social costs, and are based on the deadweight losses associated with the congestion levels. That is, these unit social costs refer to the estimated aggregate costs of delay, trip variability, vehicle operating expenses and motor vehicle emissions—associated with traffic congestion above the economic optimum level for the relevant networks—divided by the total VKT (in PCU-km) on the network.

Source: BTRE estimates.

As mentioned previously, both the complex nature of attempting to mathematically replicate the occurrence of urban congestion and the approximations inherent in the Bureau's chosen aggregate methodology, lead to significant levels of uncertainty in the cost estimation process. As a guide to the level of approximation, and how wide the ranges are likely to be for the actual social costs of congestion, the report also contains the results of various sensitivity tests. Basically, these tests alter the input assumptions and the default parameter settings for the models to see how sensitive the final cost estimates are (to possible variation or uncertainty in such input values).

The following chart (figure S.2, adapted from figure 2.49 in the sensitivity section of the report) illustrates a typical range of variation in the cost estimates, depending on the exact input assumptions. The base case scenario values are plotted, along with both a high scenario (which is based on the highest likely population and economic growth over the projection period, coupled with minimal levels of future traffic peak spreading and significantly higher trip variability costs) and a low scenario (based on inputs of the lowest likely population and economic growth over the projection period, maximal levels of traffic peak spreading and with the proportion of trips assumed to not be time-sensitive set significantly higher).

A variety of other sensitivity tests for input parameter ranges and for model scenarios are also presented in the latter section of Part 2 of the report. One scenario estimated the rough effect on the modelled results of inputting acute (high and low) settings for urban public transit patronage and non-motorised transport participation—basically doubling non-car passenger-kilometre (pkm) task in the high scenario and setting it to zero in the low scenario, across the whole modelled time period (see figure 2.48). The model-response sensitivity scenario for a theoretical doubling of non-motorised and UPT travel (with approximately 12 per cent of aggregate urban pkm assumed to switch out of cars) shifted the model's aggregate cost curve down on average by approximately 25 per cent. This impact, while substantial, is roughly equivalent to having each annual congestion cost value in the base case reached around 5 years later than in the timeline for base case projection.

There are a variety of modelling approaches typically used for estimating congestion costs—some studies (including this current analysis) use aggregate methods, which are computationally straightforward but very approximate; others are based on detailed network models, which allow more precise traffic specifications but are much more data-intensive and difficult to adequately calibrate. The relative simplicity of aggregate methods means that, generally, they are readily calibrated. The current BTRE models have been calibrated against aggregate network performance data collected by the various State road authorities (including the annual statistics reported to the Austroads *National Performance Indicators*). Though this allows current congestion cost levels to be suitably benchmarked against actual on-road conditions, aggregate methods are very blunt instruments for projecting congestion occurrence. Traffic congestion projections are much more accurately performed using suitably calibrated network models and the BTRE is hopeful that the various jurisdictions will continue to work towards more detailed, and more nationally consistent, network modelling tools.

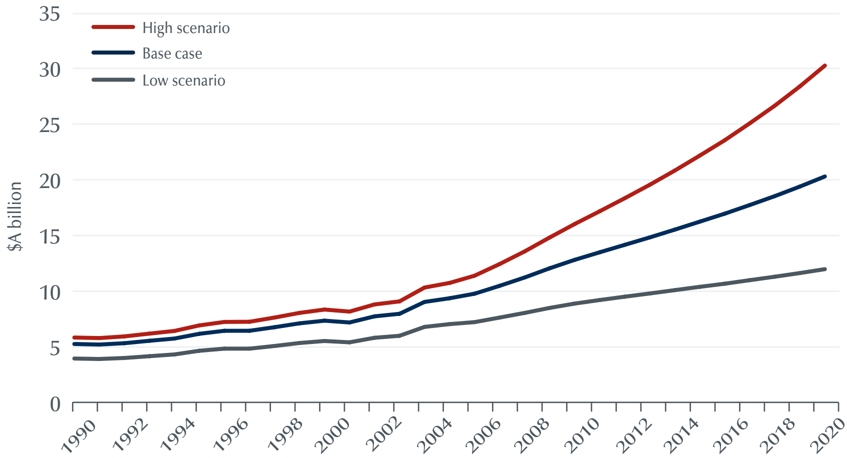
Though various Australian studies have tended to derive significantly varying congestion cost estimates, much of the variation can usually be explained by definitional differences (e.g. exactly which congestion effects are included in the costings) or by different input parameters or assumptions (e.g. underlying population or VKT growth rates, the dollar *value of time* for travel costs, or what *free* speed values are estimated for the network links). Probably the most significant factor in correctly determining the level of congestion costs is the assumed value of time used, where there is high uncertainty in how adequately standard values of time capture the worth that travellers actually attach to delays, and little data available on how the time values vary over different trip types and trip timings. If most urban trips in Australia are actually significantly less time sensitive than implied by the standard value of time, then the congestion cost estimates would have to be much lower than given in the current base case values.

In summary, and allowing for the uncertainty ranges discussed above, the costs imposed on Australian society by urban traffic congestion are likely to fall in the range of $5 to $15 billion for current levels—in terms of theoretically *avoidable* costs (i.e. if appropriate traffic management or pricing schemes were introduced so as to reduce traffic conditions to economically optimal levels)—with a median value of around $10 billion. This is likely to rise, under base case demand growth assumptions, to a level of between 10 and 30 billion dollars by 2020, with a median projected value for *avoidable* social costs of congestion of around 20 billion dollars.

Though this range of likely values for national congestion impacts is quite large, even the lower bound values still indicate that urban traffic congestion imposes considerable costs on Australian society. Note also that the sensitivity scenarios have been framed primarily to demonstrate the dependence of the estimates on the input assumptions, rather than necessarily as *plausible* scenarios for the future in their own right. For example, given the wide range covered by the input variable settings for the two scenarios in figure S.2, it is highly likely that any *realistic* base case scenario to 2020 (run on the current BTRE model framework) would fall well between the upper and lower bounds displayed. Furthermore, most of the sensitivity analyses relate more to uncertainty over the exact valuation *level* for congestion costs (i.e. mainly concern definitional issues, such as what is the precise value of time felt by urban commuters or what is the most appropriate comparison speed to calculate average delays from) than to the *projected trend* in increasing cost levels. Practically all of the scenarios tested still exhibited between a twofold and threefold increase in projected congestion costs for the period of 2005 to 2020. Network modelling of individual Australian cities has typically derived projected cost trends with similar or stronger growth rates (e.g. see table 3.1, page 62, of VCEC 2006).

So, irrespective of the questions over exact dollar valuations raised by the sensitivity tests, the principal finding of this study remains: that, in the absence of improved congestion management, rising traffic volumes in the Australian capitals are likely to lead to escalating congestion impacts, such that the net social costs of congestion over the next 15 years (under a business-as-usual scenario) are likely to at least double.

Figure S.2 Trends in avoidable social costs of congestion—scenario results



Source: BTRE estimates.

Part 1—Traffic growth

Trends in traffic and congestion in Australia's capital cities

The types of growth that can cause problems for transport systems include:

- sudden growth such as export demand surges;
- unfunded growth where infrastructure struggles to cope; and
- growth in confined spaces.

The topics discussed in this section of the report are mainly concerned with the latter type of growth—where we examine the continuing traffic growth that underlies the increasing problems posed by urban congestion within the capital cities of Australia.

This part of the report looks at traffic growth *trends*, starting by examining the two major components of traffic growth—the passenger and freight tasks in our cities.

Growth in urban passenger demand

In the 60 years since the end of the Second World War, Australian cities have been transformed from fairly tightly knit core-and-spoke configurations, to sprawling suburban low-density configurations.

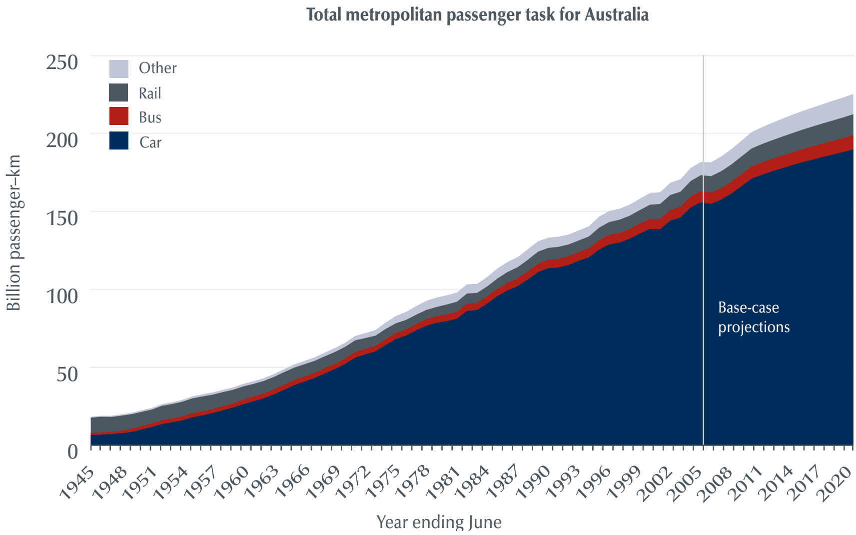
This transformation of urban land use has been accompanied and made possible by a rapid improvement and spread of the road system and an even more rapid expansion in car ownership (motor vehicles per person).

Figure 1.1 shows the 60 year growth in total passenger-kilometres (pkm) in our capital cities. The total task estimates for 1945 to 1976 are derived from a combination of aggregate national data and, where available, State/Territory-specific travel trend information. The data from 1977 to 2004 represent the summation of estimates made by the BTRE for each of the eight capital cities using detailed jurisdiction-specific passenger data. The forecasts are derived on a primarily national aggregate basis—but using a methodology that allows for each State/Territory's differing vehicle fleet and average personal travel characteristics.

As shown in figure 1.1, total travel in the urban areas of Australia has grown remarkably—ten-fold over 60 years. Almost all of that growth came from cars and 'other' road vehicles (mostly light commercial vehicles used for private purposes and motorcycles). As shown in Figure 1.2, private road vehicles ('car plus other' in the graph) represent about 90 per cent of the motorised passenger transport task in our capital cities. Urban public transport (UPT), though generally an important component of peak travel in many central business districts (CBDs), represents only a fairly minor share of today's total urban passenger task. Moreover, UPT's modal share has been remarkably constant since the early 1980s, when the long downward trend, following World War 2, in the transit share finally halted.

This picture is repeated when we consider the summed dataset for the eight capitals (see figures 1.3a and 1.3b). Today, UPT is growing, but for most jurisdictions only at rates comparable to the growth in travel by private road vehicles. This relative constancy of its share, combined with the dominance of car travel, allows us to analyse the growth in private road vehicle traffic in comparative isolation from the other forms of urban passenger transport.

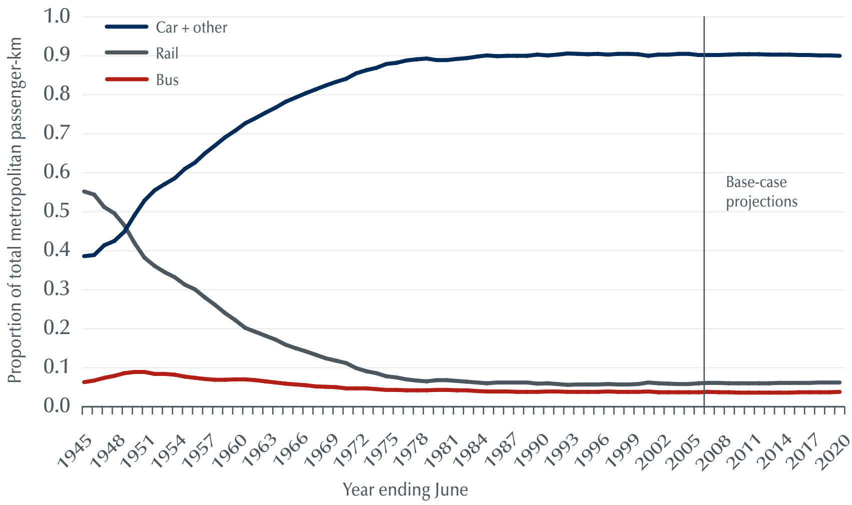
Figure 1.1 Historical and projected urban passenger movement, Australian metropolitan total



Note: 'Other' primarily consists of non-business use of light commercial vehicles (LCVs)—with contributions from motorcycles, non-business use of trucks, and urban ferries.

Sources: BTRE (2003a, 2006a), BTRE estimates.

Figure 1.2 Historical and projected modal share, Australian metropolitan passenger travel



Note: 'Other' primarily consists of non-business use of light commercial vehicles (LCVs).

Sources: BTRE (2003a, 2006a), BTRE estimates.

Note that the values for bus passenger task and for bus VKT in this report (not only in the above two figures but also in all Table, Figure and text values to follow) refer to total commercial bus usage in metropolitan areas (i.e. all travel by commercial passenger vehicles with 10 or more seats). This includes not only the task carried by transit fleets, both privately-owned and government run, but also a lesser component of the total task due to charter/hire vehicles (which are often considerably smaller than a standard transit route bus). Therefore, the values given here for 'UPT' task (which sum heavy rail, light rail, bus and ferry passengers) are generally a little higher than if only the task carried by dedicated transit vehicles was included in the 'bus' estimates.

The main 'drivers' (or generators) behind the growth in total passenger travel in our cities (as well as behind the growth in travel by private road vehicles) are increases in population and increases in per capita travel (particularly as a result of rising per capita incomes). As is shown in figure 1.3c, there is a saturating relationship between increases in annual passenger-kilometres per person and per capita income. This relationship implies that saturation in per person travel could be mostly complete by 2020. Thereafter, population increase will tend to be the primary driver of increases in travel in our cities. Yet, at least until then, income increases will likely continue to add to per capita travel, and total passenger travel will grow at a faster rate than population.

The patterns in figures 1.3a to 1.3c are repeated in all the capital cities.

Sydney (see figures 1.4a to 1.4c) has experienced almost a doubling of the passenger transport task between 1977 and 2004. It has more urban public transport than the other capitals, due to large numbers of passengers taken relatively long distances by the rail system. However, even though the UPT mode share at 13 per cent is high, it has been virtually constant for many years (as in most other capitals). Per person travel is showing fairly clear signs of nearing saturation, at below 14 000 km per person. The main passenger modes are light motor vehicles (i.e. cars and personal use of LCVs), rail and bus.

Melbourne (figures 1.5a to 1.5c) has doubled the passenger transport task over the period. It has a lower UPT share (constant at about 8 per cent). Average travel per capita is above 14 000 km and still showing some signs of further increase. The main modes are car, LCV, rail, light rail (trams), and bus.

Passenger travel in Brisbane (figures 1.6a to 1.6c) in 2004 is 2.5 times higher than in 1977. Again the UPT mode share is virtually constant, at about 8 per cent. Per person travel is showing signs of approaching stability at about 13 000 km per person per year. The main modes are car, LCV, rail and bus.

Adelaide (figures 1.7a to 1.7c) has shown slower growth in demand for passenger travel, with the total increasing 65 per cent from 1977 to 2004. UPT share has been drifting down over the period, but for recent years has been virtually constant at about 5 per cent. Per capita travel in Adelaide could possibly still be growing, and is currently around 13 000 km per person. The main modes are again car, LCV, rail and bus.

Passenger travel in Perth (figures 1.8a to 1.8c) slightly more than doubled from 1977 to 2004. The UPT share has come up from 5 ½ to 7 ½ per cent with the opening of the northern rail line and will probably approach 9 per cent with the opening of the southern line. But barring new rail lines, the UPT share is then likely to remain fairly constant (at a level below 10 per cent). Per person travel, currently around 13 000 km, is continuing to increase, and does not appear to have saturated yet with respect to per capita income levels. Once again, in order of task share, the main modes are car, LCV, rail and bus.

Hobart (figures 1.9a to 1.9c) is unique among the capitals for three reasons. First, it has shared with Adelaide slower growth in passenger travel (2004 at 1.75 times the 1977 level). Secondly, its total bus task has remained fairly constant over time (allowing for bus travel in charter/smaller buses, since it appears that Hobart's UPT bus patronage has declined over time) so bus mode share has been declining in Hobart. Thirdly, travel per person started at the lowest level of all the capitals (8000 km per annum), and looks set to saturate at a relatively low level (in the order of 12 000 km). The main modes are car, LCV and bus.

Darwin (figures 1.10a to 1.10c) is also different from the other capitals, but for almost the opposite reasons to Hobart. It has registered the highest growth in passenger travel of any of the capitals (2004 at 2.7 times 1977 levels)—though from a comparatively low base. It has also seen mode share for bus travel increase over the period (although lately this has levelled off at a relatively high 10 per cent of total pkm).

Darwin's per capita travel looks to be approaching saturation (between 11 000 and 12 000 km). The main modes are car, LCV and bus.

Canberra's passenger travel (figures 1.11a to 1.11c) has more than doubled over the period. Mode share for buses is virtually constant at 6 per cent, and passenger travel per person appears to be practically saturated, at about 15 500 km per annum.

Part 2 of this paper provides detailed tables for annual travel trends (VKT) for the passenger vehicle fleets of each of the capital cities.

The procedure for translating this understanding of the patterns of passenger travel demand growth into forecasts of private vehicle traffic is documented after we examine the drivers behind the growth in the freight task in the cities. (For a schematic diagram briefly summarising the main steps in the BTRE transport demand forecasting approach, see Appendix figure A.2.)

Figure 1.3a Historical trend in metropolitan passenger travel

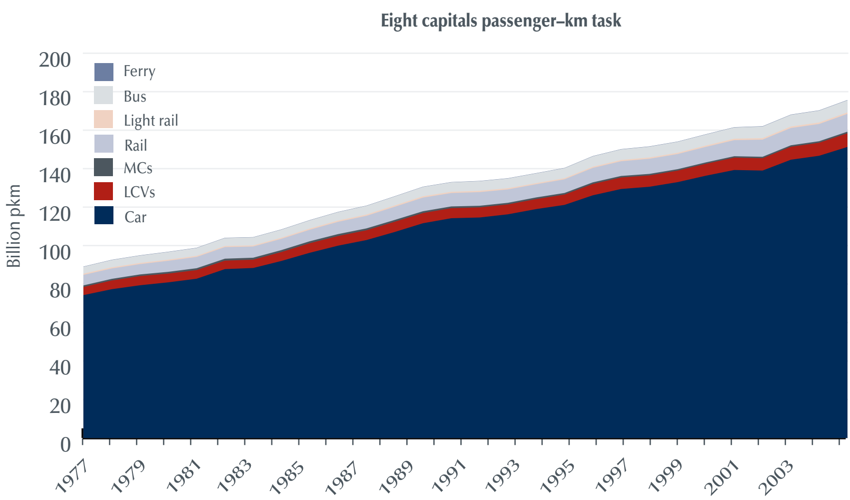


Figure 1.3b Historical trend in passenger mode share

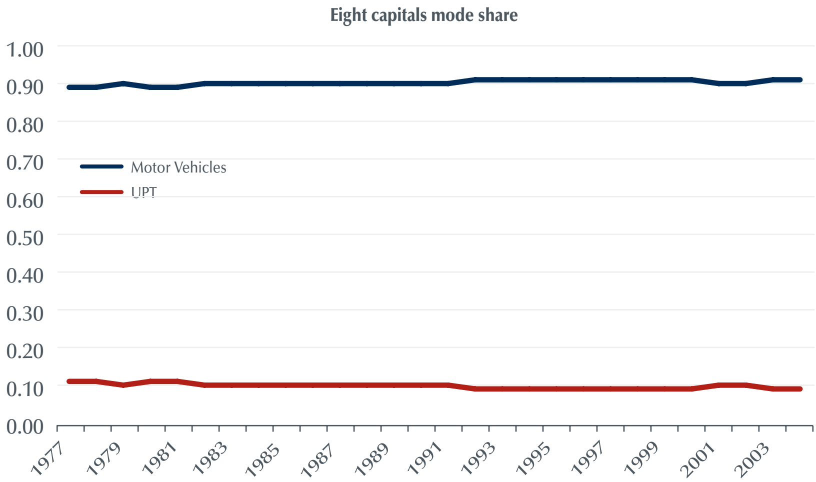


Figure 1.3c Relationship of per capita travel to per capita income

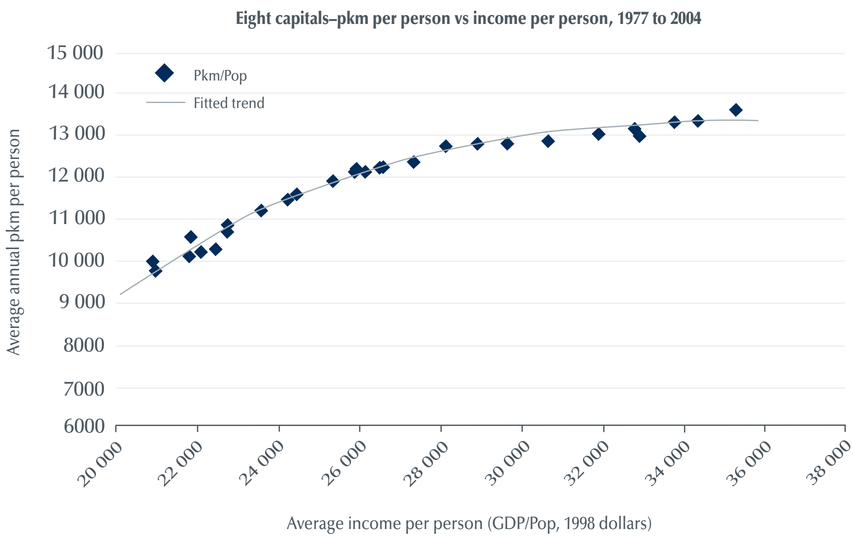


Figure 1.4a Historical trend in Sydney passenger travel

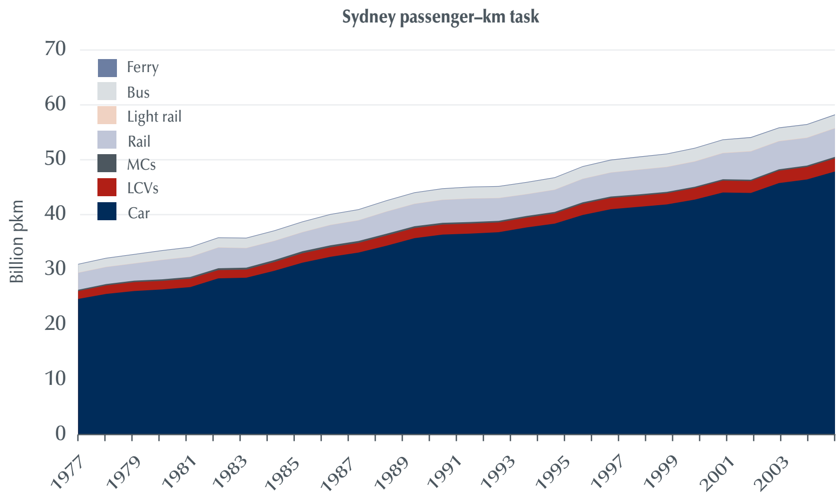


Figure 1.4b Historical trend in Sydney passenger mode share

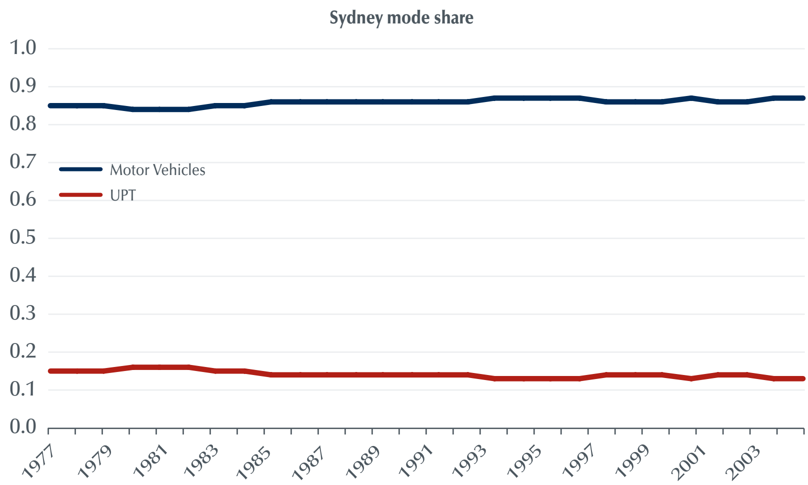


Figure 1.4c Relationship of per capita travel to per capita income, Sydney

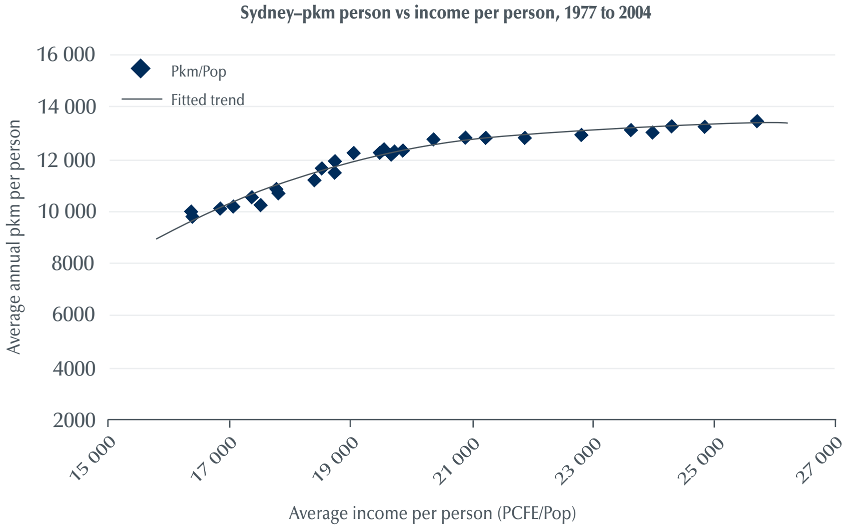


Figure 1.5a Historical trend in Melbourne passenger travel

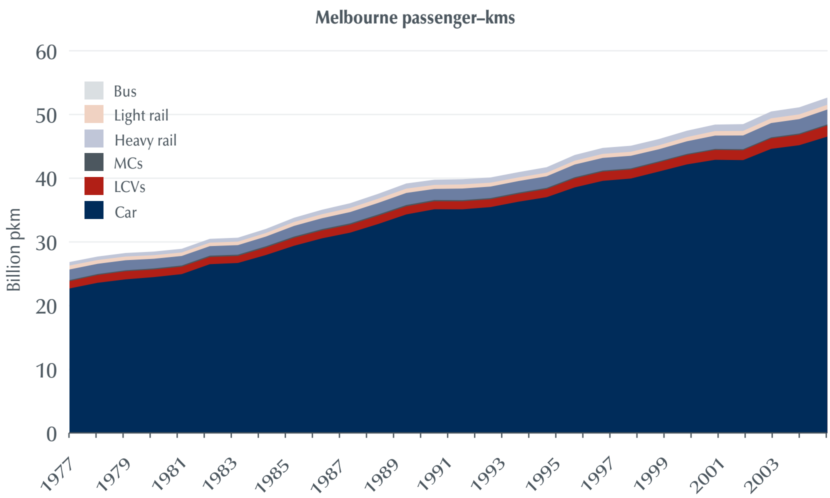


Figure 1.5b Historical trend in Melbourne passenger mode share

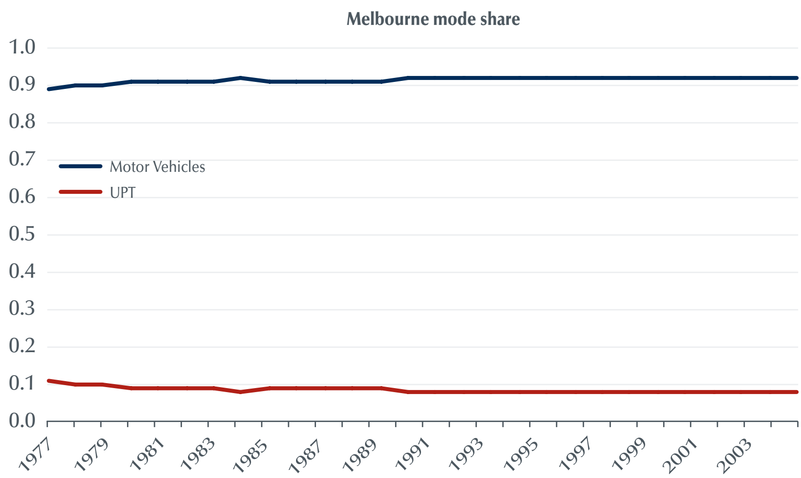


Figure 1.5c Relationship of per capita travel to per capita income, Melbourne

Figure 1.6a Historical trend in Brisbane passenger travel

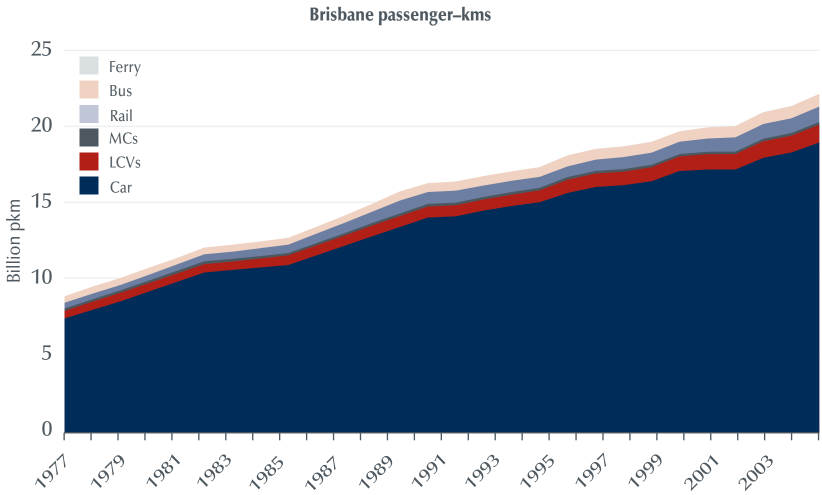


Figure 1.6b Historical trend in Brisbane passenger mode share

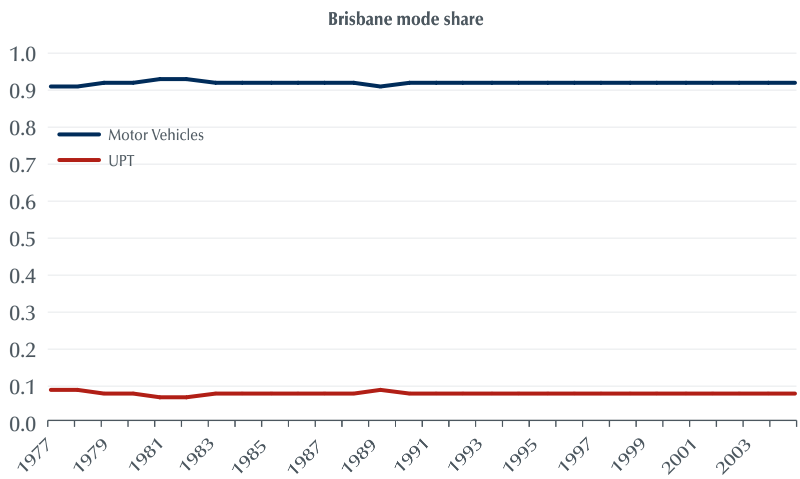


Figure 1.6c Relationship of per capita travel to per capita income, Brisbane

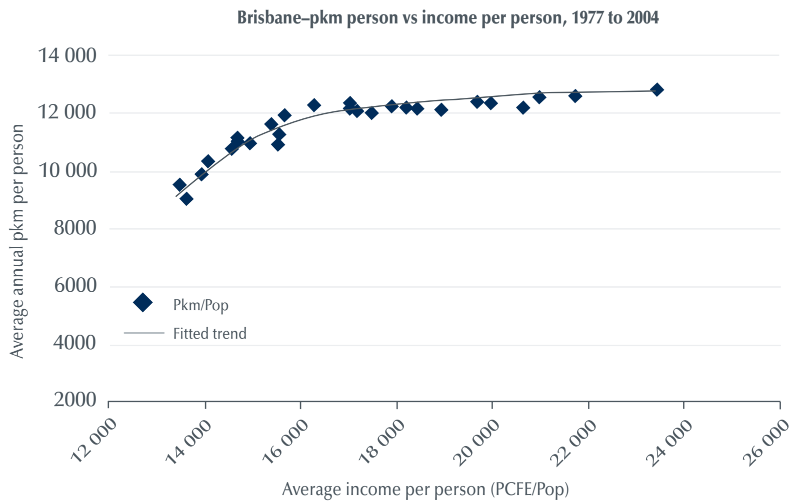


Figure 1.7a Historical trend in Adelaide passenger travel

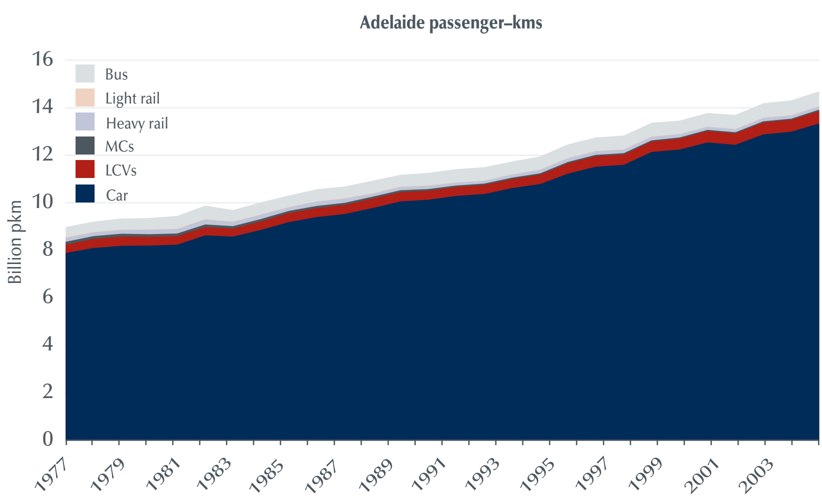


Figure 1.7b Historical trend in Adelaide passenger mode share

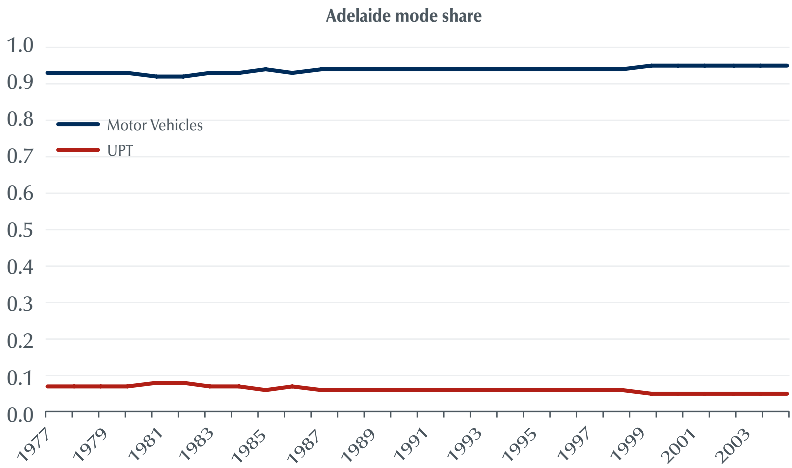


Figure 1.7c Relationship of per capita travel to per capita income, Adelaide

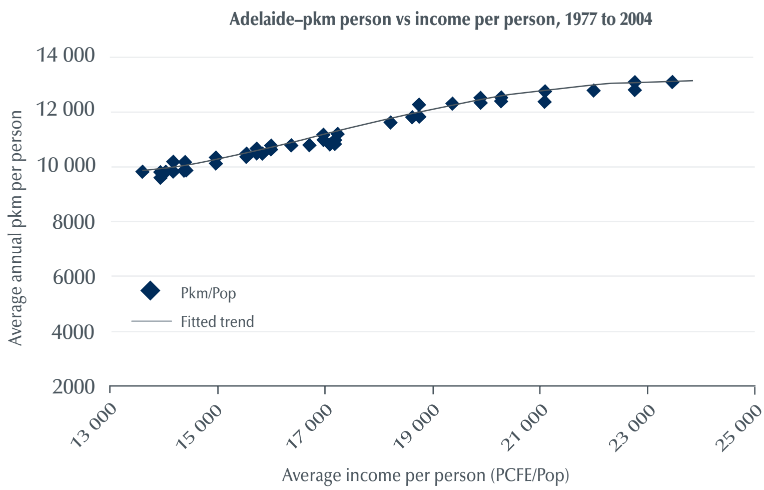


Figure 1.8a Historical trend in Perth passenger travel

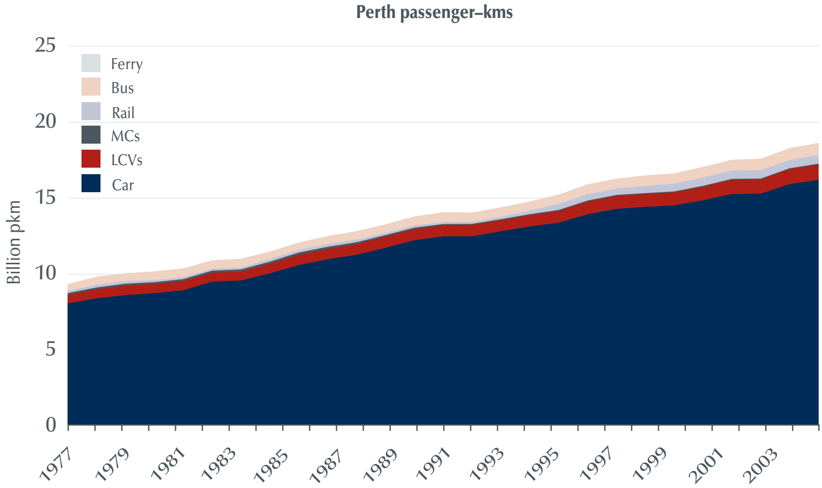


Figure 1.8b Historical trend in Perth passenger mode share

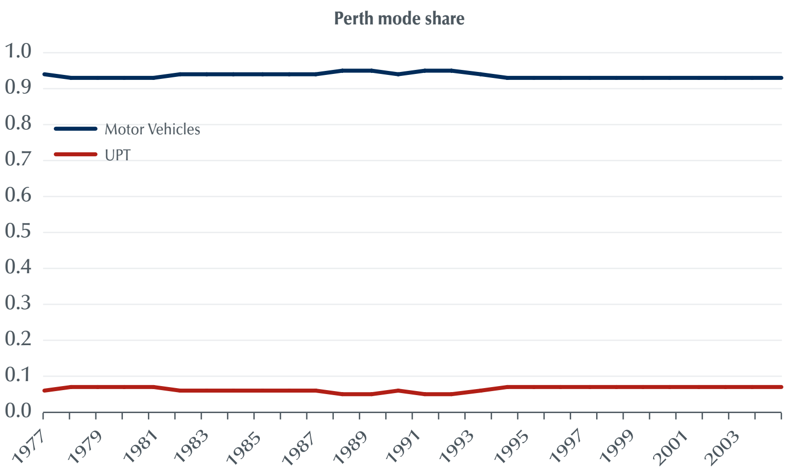


Figure 1.8c Relationship of per capita travel to per capita income, Perth

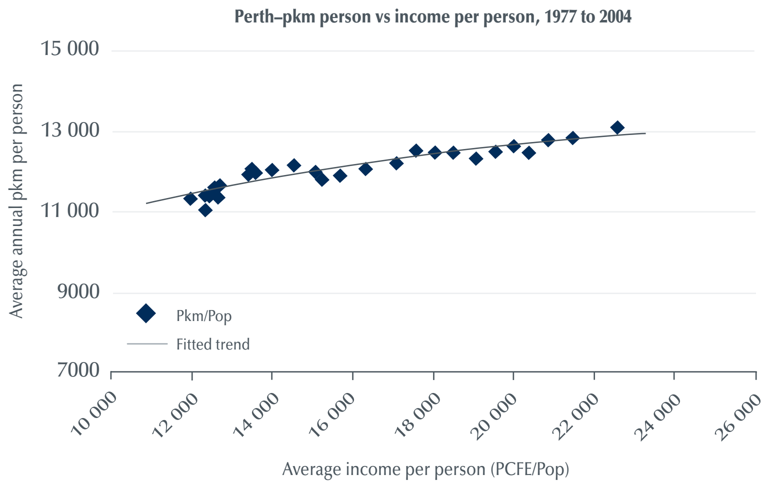


Figure 1.9a Historical trend in Hobart passenger travel

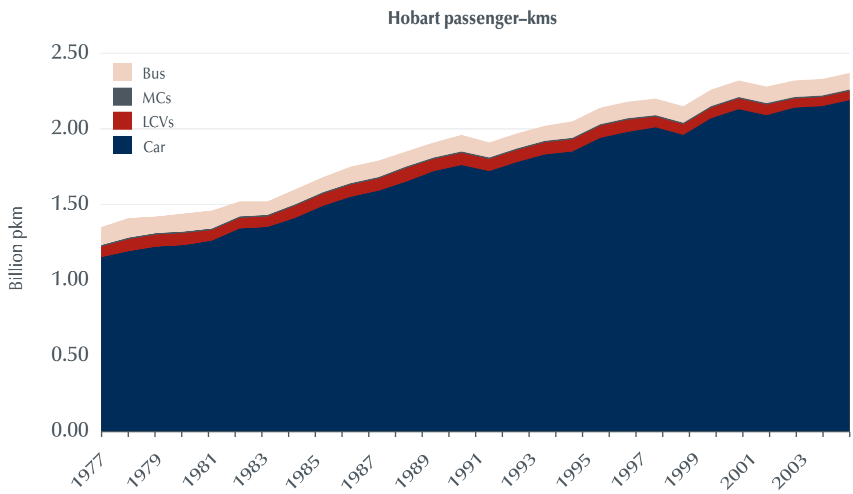


Figure 1.9b Historical trend in Hobart passenger mode share

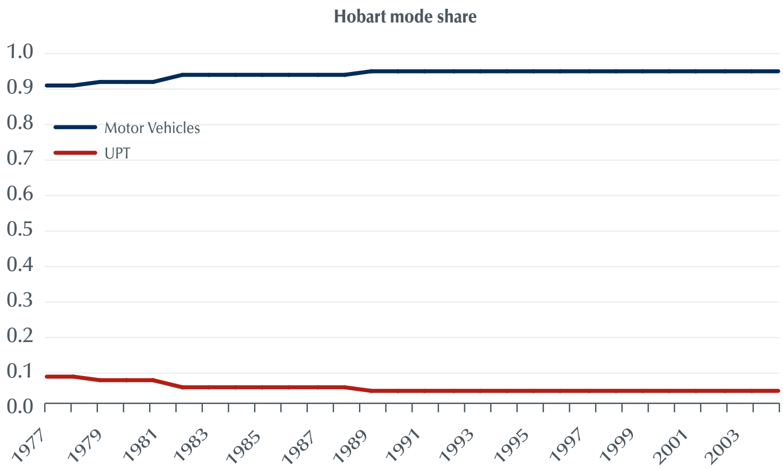


Figure 1.9c Relationship of per capita travel to per capita income, Hobart

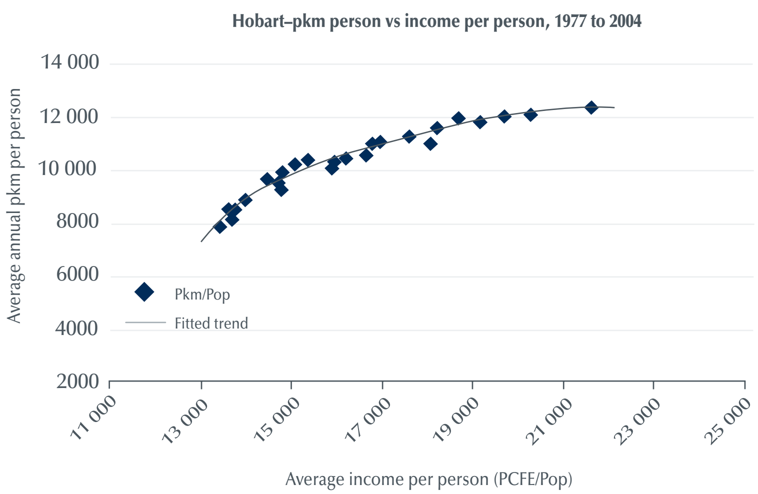


Figure 1.10a Historical trend in Darwin passenger travel

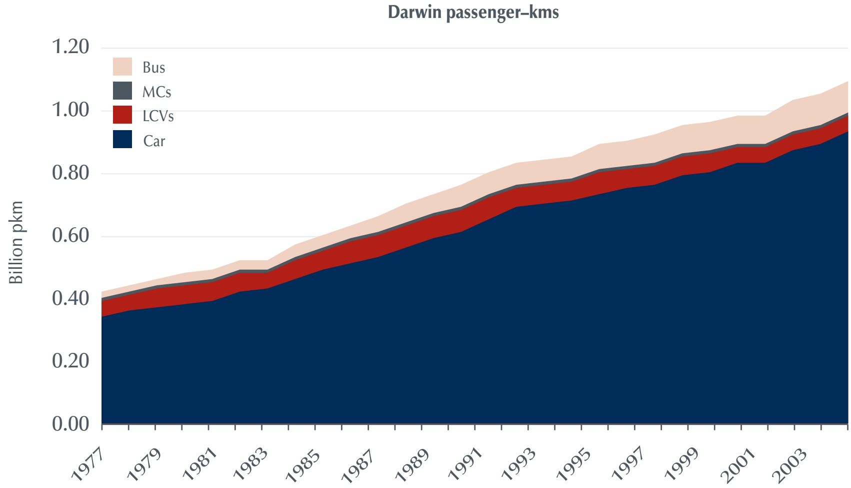


Figure 1.10b Historical trend in Darwin passenger mode share

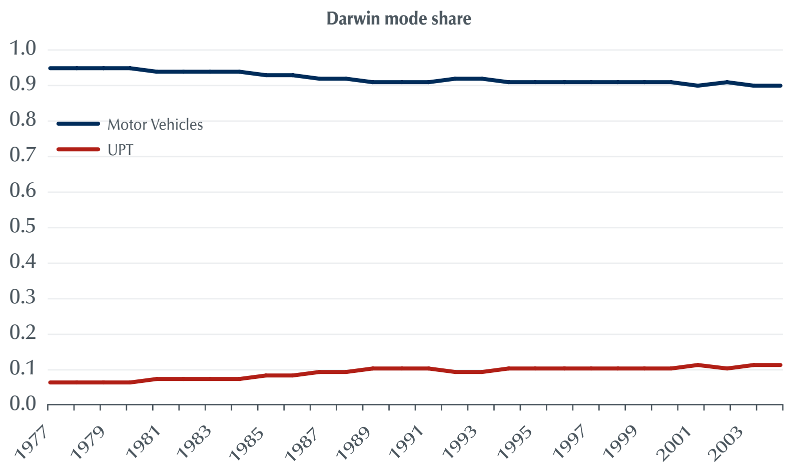
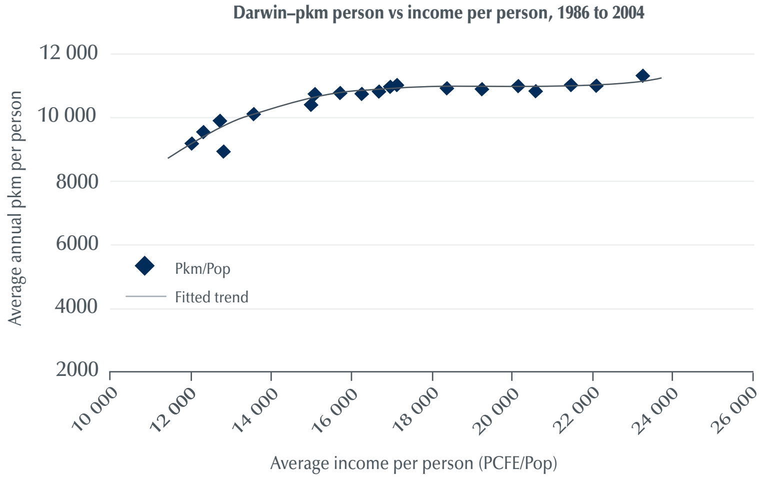


Figure 1.10c Relationship of per capita travel to per capita income, Darwin



Figures 1.11a Historical trend in Canberra passenger travel

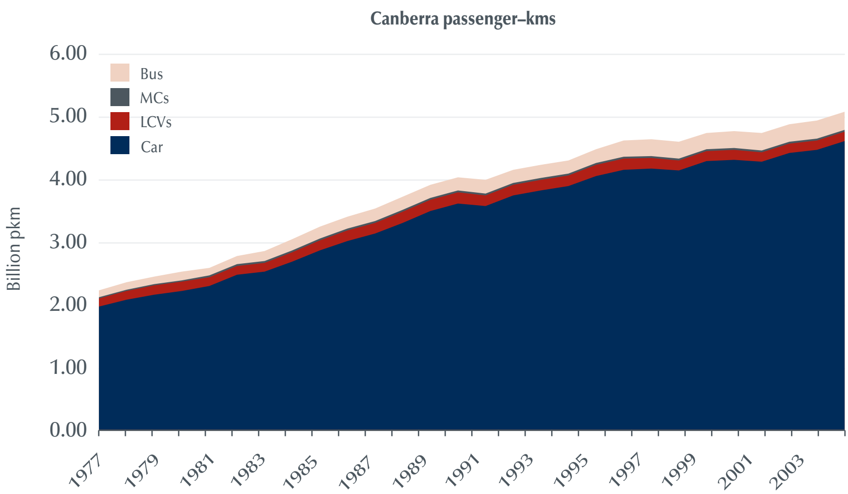


Figure 1.11b Historical trend in Canberra passenger mode share

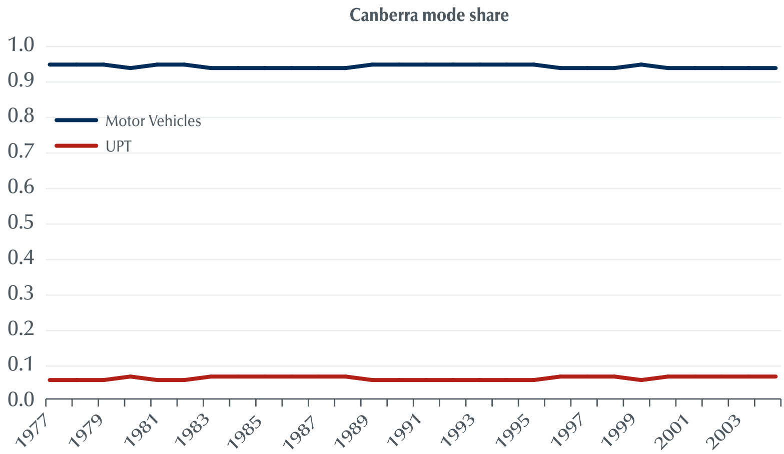
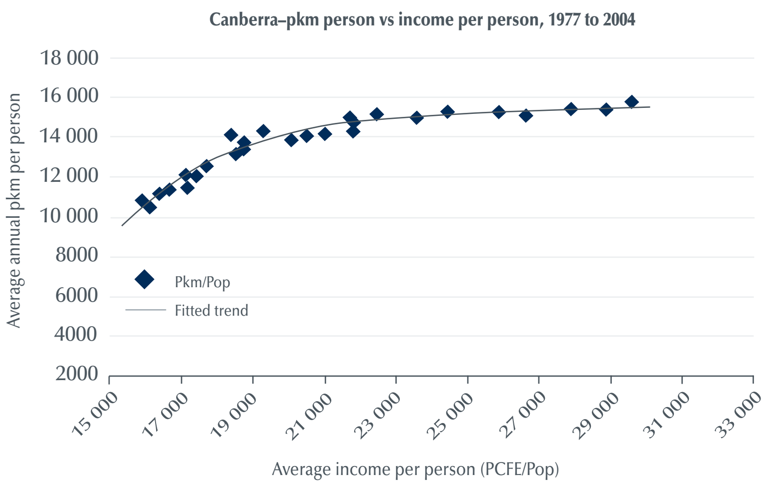


Figure 1.11c Relationship of per capita travel to per capita income, Canberra



Urban freight growth

Growth in the freight task in the capital cities has been estimated in the BTRE's recent publication *Freight Measurement and Modelling* (Report 112, BTRE 2006c—see Chapter 3 and Appendices II and III). The size of the task for the eight capitals combined is shown in figure 1.12. The task grew most rapidly in the 1970s and early 1980s, as real road freight rates declined sharply (see BTRE 2006b, Chapter 8).

Figure 1.12 also plots predicted values from a model of that growth, based on growth in GDP (income elasticity of 1.014) and reductions in real freight rates (real freight rate elasticity of -0.685).

A similar model, incorporating estimates for each capital, gives an income elasticity of 0.960 and a real freight rate elasticity of -0.781. The fit to the data for each city is shown in figure 1.13, together with forecasts from the model using GDP and real freight rates assumptions (detailed in Report 112). Table 1.1 gives the historical estimates of aggregate freight task (tonne-kilometres) for each capital, together with forecasts to 2020. It can be seen that the expected growth for the eight capitals in total is 3.1 per cent per year from 2003 to 2020, resulting in the projected eight-capital freight task growing by 70 per cent over that period.

Projected urban freight growth for most capitals is around that rate, except Hobart and Adelaide (which are estimated to be lower) and Brisbane and Perth (which are higher).

These forecasts of growth in total tonne-kilometre (tkm) task for each city are used to derive forecasts of growth in commercial vehicle traffic using methods described in the section after next.

Table 1.1 Capital city road freight task—trends and projections

(billion tonne-kilometres)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Drw*	*Cbr*	*8 Caps*
1971	2.82	1.96	0.62	0.67	0.78	0.11	0.04	0.10	7.11
1972	2.98	2.09	0.68	0.71	0.84	0.13	0.05	0.11	7.58
1973	3.14	2.21	0.75	0.75	0.89	0.14	0.05	0.11	8.04
1974	3.29	2.34	0.81	0.79	0.94	0.15	0.05	0.12	8.50
1975	3.44	2.47	0.88	0.83	1.00	0.16	0.06	0.13	8.96
1976	3.59	2.60	0.95	0.87	1.05	0.18	0.06	0.13	9.43
1977	3.85	2.83	1.12	0.94	1.15	0.19	0.06	0.14	10.28
1978	4.10	3.06	1.30	1.00	1.24	0.21	0.06	0.16	11.13
1979	4.34	3.29	1.49	1.07	1.34	0.23	0.06	0.17	11.98
1980	4.53	3.47	1.66	1.05	1.41	0.24	0.09	0.18	12.63
1981	4.72	3.66	1.84	1.02	1.49	0.24	0.13	0.18	13.28
1982	4.90	3.84	2.03	0.98	1.56	0.25	0.17	0.19	13.93
1983	5.05	4.00	2.11	1.02	1.60	0.27	0.18	0.20	14.44
1984	5.20	4.16	2.20	1.06	1.64	0.29	0.19	0.21	14.95
1985	5.34	4.32	2.29	1.10	1.68	0.32	0.20	0.21	15.46
1986	5.64	4.64	2.43	1.17	1.79	0.33	0.20	0.23	16.42
1987	5.92	4.96	2.57	1.24	1.90	0.33	0.21	0.24	17.37
1988	6.21	5.28	2.72	1.31	2.01	0.34	0.21	0.25	18.33
1989	6.37	5.51	2.80	1.35	2.09	0.34	0.22	0.26	18.94
1990	6.53	5.73	2.89	1.38	2.18	0.35	0.23	0.27	19.55
1991	6.69	5.96	2.97	1.42	2.27	0.35	0.24	0.28	20.17
1992	6.99	6.30	3.13	1.48	2.38	0.35	0.24	0.27	21.14
1993	7.29	6.64	3.30	1.55	2.50	0.34	0.24	0.26	22.12
1994	7.58	6.99	3.47	1.62	2.62	0.33	0.23	0.26	23.10
1995	7.88	7.34	3.64	1.68	2.74	0.33	0.23	0.25	24.08
1996	8.19	7.67	3.86	1.76	2.86	0.31	0.24	0.25	25.12
1997	8.49	8.00	4.08	1.83	2.98	0.29	0.25	0.24	26.17
1998	8.80	8.33	4.31	1.91	3.10	0.27	0.26	0.24	27.22
1999	8.95	8.61	4.64	1.93	3.17	0.27	0.29	0.24	28.10
2000	9.35	9.20	4.99	2.01	3.40	0.28	0.26	0.25	29.74
2001	9.62	9.45	5.18	2.04	3.52	0.29	0.22	0.24	30.56
2002	10.02	10.06	5.50	2.15	3.75	0.31	0.19	0.25	32.22
2003	10.39	10.28	5.71	2.25	3.87	0.32	0.19	0.26	33.27
Average annual growth rate (per cent)									
1985–2003	3.8	4.9	5.2	4.1	4.7	0.0	-0.3	1.2	4.3

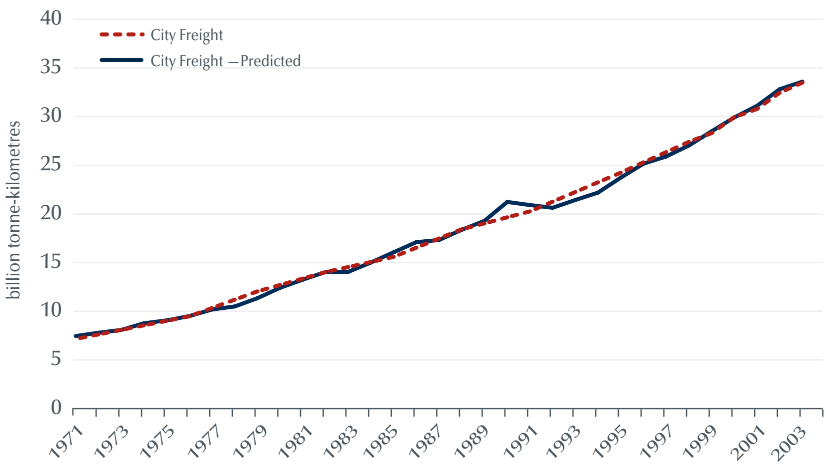
Table 1.1 Capital city road freight task—trends and projections (continued)

(billion tonne-kilometres)

Year	Syd	Mel	Bne	Adl	Per	Hob	Drw	Cbr	8 Caps
2003act	10.39	10.28	5.71	2.25	3.87	0.32	0.19	0.26	33.27
2003pred	10.84	10.21	5.58	2.23	3.91	0.33	0.20	0.28	33.59
2004	11.22	10.58	5.81	2.30	4.07	0.34	0.21	0.29	34.82
2005	11.64	11.00	6.08	2.37	4.24	0.35	0.23	0.30	36.20
2006	12.08	11.43	6.35	2.45	4.41	0.36	0.24	0.31	37.62
2007	12.54	11.86	6.64	2.52	4.60	0.37	0.25	0.32	39.09
2008	12.93	12.23	6.89	2.58	4.77	0.38	0.26	0.33	40.37
2009	13.32	12.61	7.15	2.65	4.92	0.39	0.27	0.34	41.65
2010	13.71	12.99	7.41	2.71	5.09	0.40	0.28	0.35	42.94
2011	14.11	13.36	7.68	2.77	5.27	0.41	0.29	0.36	44.26
2012	14.52	13.75	7.96	2.85	5.44	0.41	0.29	0.37	45.59
2013	14.94	14.15	8.23	2.91	5.62	0.42	0.30	0.38	46.95
2014	15.34	14.54	8.51	2.97	5.79	0.43	0.31	0.39	48.29
2015	15.76	14.93	8.79	3.04	5.97	0.44	0.32	0.40	49.65
2016	16.16	15.31	9.07	3.10	6.14	0.45	0.33	0.41	50.97
2017	16.58	15.71	9.36	3.16	6.33	0.45	0.34	0.42	52.36
2018	17.04	16.14	9.68	3.23	6.52	0.46	0.35	0.43	53.86
2019	17.43	16.51	9.96	3.29	6.70	0.47	0.37	0.44	55.17
2020	17.85	16.92	10.27	3.35	6.89	0.48	0.38	0.45	56.60
Average annual growth rate (per cent)									
2003 pred—2020	3.0	3.0	3.7	2.4	3.4	2.2	3.8	2.8	3.1

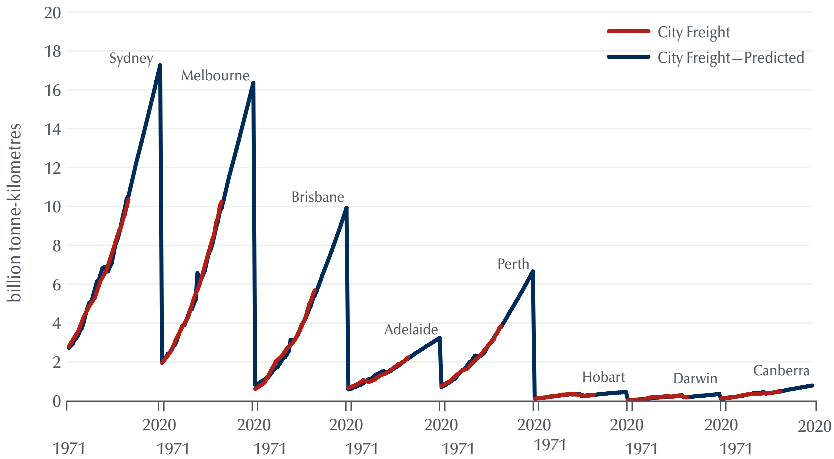
Source: BTRE (2006b).

Figure 1.12 Historical and model fitted data for aggregate freight task



Source: BTRE (2006b).

Figure 1.13 Cross section, time-series data and model fit for city freight tasks



Source: BTRE (2006c).

Car traffic growth

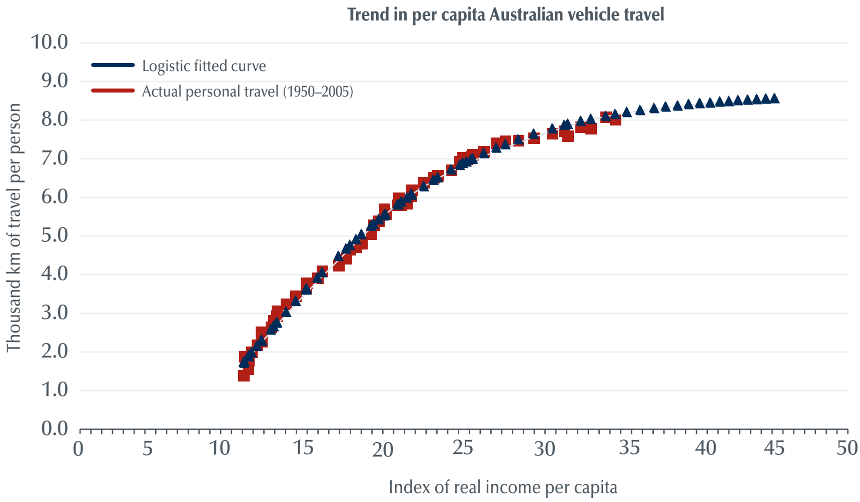
Given the comparative constancy of the expected UPT mode share in each city (including Perth after the addition of the southern railway), essentially one can forecast car traffic growth relatively independently.

A simplifying framework for explaining car traffic (vehicle kilometres travelled or VKT) is the following:

$$\text{Car traffic} = \text{Car travel per person} \times \text{Population}$$

The advantage of this formulation is that, for Australia, it turns out that car travel per person has a simple relationship to economic activity levels. The trend in per capita car travel (kilometres per person) in Australia has in general been following a logistic (saturating) curve against real per capita income—measured here by real Gross Domestic Product (GDP) per person (see figure 1.14).

Figure 1.14 Historical trend in annual per capita passenger vehicle travel versus real Australian income per capita



Source: BTRE (2002, 2003a, 2005), BTRE Estimates.

Here, then, we have the basis for understanding the relationship between car traffic and economic development. As incomes per person increase, personal car travel per person has also tended to increase, but at a slowing rate over time. In other words, more car travel is attractive as incomes rise, but there reaches a point where further increases in per capita income elicit no further demand for car travel per capita. However, even after the virtual saturation of per capita km travelled to per capita income growth, total car traffic continues to respond (in an essentially one-to-one relationship now) to population growth (that other component of aggregate economic activity levels).

Note that even though personal passenger travel exhibits a saturating trend over time, there is, as yet, no sign of approaching saturation in per capita freight movement in Australia. For illustrative purposes, a graph of national per capita passenger and freight movement curves—relative to per capita income—is provided in the Appendix, as figure A.1.

Once again, our formula for understanding the relationship between car traffic growth and economic growth is:

Car traffic = Car travel per person × Population

The assumed base case rate of GDP growth of around 2.7 per cent per annum over the 15 years from 2005 to 2020 (Treasury 2002) implies that Australia-wide per capita car travel should level out at around 8900 kilometres per person by 2020—about a 6 per cent increase on 2005 (and about 10–12 per cent over the somewhat *below trend* 2001–2003 levels). After 2020, growth coming from this first term in the equation will probably effectively cease.

There is still the growth in car travel resulting from population growth to consider. The two main sources of population growth are natural increase and immigration. The contribution each has made to population growth over approximately the last 40 years is shown in Figure 1.15 (where the two components have been stacked). The average growth rate (of both components) has tended to decline over time.

The Australian Bureau of Statistics (ABS) has previously produced several scenarios for population growth—see www.abs.gov.au for details—projecting national population to be between about 22 million and 24 million people by 2020. The following aggregate analysis example uses population projections based on the trends to 2020 of the ABS *Series III* projections (e.g. ABS 2001) and the recent mid-range Series B long-term projections (ABS 2005). 'Series III' projections assume a net immigration level of about 70 000 persons per year and a further decline in the rate of natural increase (due to a fairly rapid ageing of the population, coupled with a fairly low fertility rate).

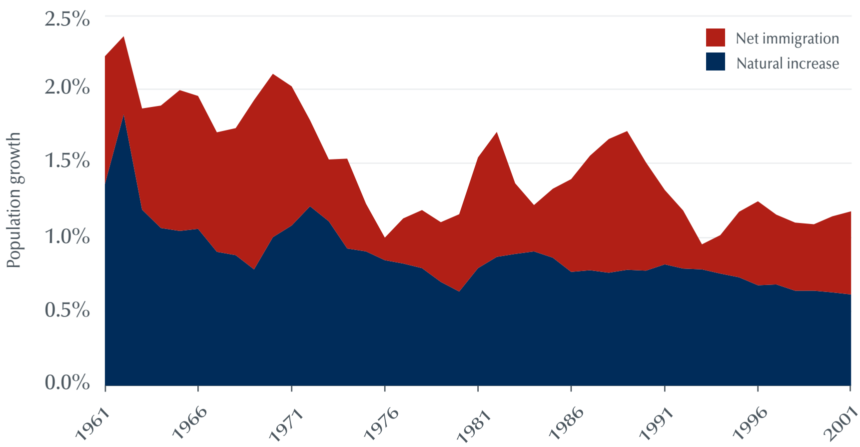
The ABS population projections are also available for each of the Australian capital cities (see the Appendix for tabulated population projection values based on the ABS mid-range values). The following *example* values (e.g. table 1.2) are derived using a rough aggregate approach—to demonstrate the overall trend picture (where final values from the detailed modelling and projection process—that allows for demographic characteristics and state-specific vehicle fleet attributes—are given within tables in Part 2 of this paper). So, for simplicity, if we use *national* car travel per person percentage increases (from figure 1.14) and the capital city population projections, we obtain the VKT values in table 1.2, for this illustration of the car traffic projection method. For example, using a year 2005 baseline, the national (percentage) projected increase in car travel per person is roughly:

(8.87-8.38)/8.38 = 5.8%.

Increasing Sydney's per capita travel (at approximately 7.47 thousand km VKT per person in 2005) by this amount gives an illustrative projected 2020 level of about 7.91 thousand km per person. Multiplying this by Sydney's projected 2020 population of around 5.1 million gives (illustrative) projected 2020 Sydney car VKT of about 40.3 billion km.

It should be noted that the national level of VKT per person is slightly higher than the metropolitan average, but for this example it is assumed that the latter will saturate in a like manner to the national total.

Figure 1.15 Historical trend in components of Australian population increase



Sources: ABS (2001b).

Table 1.2 Example car traffic projections for Australian cities

City	*2005*			*2020*			*Percent change*
	Car VKT/ Person ('000)	Population ('000)	Total Car VKT (million)	Car VKT/ Person ('000)	Population ('000)	Total Car VKT (million)	2005–2020
Sydney	7.47	4 382	32 715	7.91	5 103	40 340	23%
Melbourne	8.60	3 682	31 651	9.10	4 143	37 702	19%
Brisbane	7.30	1 780	12 996	7.73	2 233	17 264	33%
Adelaide	7.96	1 135	9 032	8.43	1 195	10 069	11%
Perth	7.58	1 505	11 411	8.03	1 835	14 731	29%
Hobart	7.59	194	1 474	8.04	192	1 540	5%
Darwin	6.33	99	630	6.71	130	871	38%
Canberra	9.55	328	3 133	10.11	362	3 663	17%
Metro	7.86	13 106	103 041	8.32	15 193	12 6475	23%
Rest of Australia	9.42	7 244	68 265	9.98	8 049	80 308	18%
Total Aust.	8.42	20 350	171 306	8.91	23 241	207 154	21%

Note: The projected Australian aggregate level per cent increase (of 8.38 thousand km per person in 2005 to near saturation at 8.87 by 2020) is assumed here to apply to each city. At the level of the 8 capitals, the increase from car travel per person is about 6%, and from population 16%. The overall increase in Australia Metro car traffic is therefore likely to be of the order of (1.06 × 1.16—1) = about 23% over the 15 years.

Sources: BTRE (2003a, 2006a), BTRE estimates.

The average increase in car traffic in Australian capital cities is projected to be in the order of 23 per cent (close to the Sydney and Melbourne levels of growth, with the most significant in Brisbane, because of its high population growth). Even with a proportion of the total growth occurring at the city fringes, this still implies substantial increases in the level of car traffic on our current city networks.

As mentioned above, this procedure (table 1.2) is a simplification of the final process of forecasting car traffic growth in the cities. The final forecasts for each capital's car VKT are given in tables in Part 2. For now, we turn to forecasting the rest of the traffic stream.

Bus and motorcycle traffic growth

Buses and motorcycles form a small part of passenger vehicle traffic in Australian cities (excluding for the moment the traffic contribution of LCVs and trucks). In most of our cities, they account for only 1–3 per cent of the total VKT by non-business vehicles (i.e. cars routinely account for 97–98 per cent of *passenger vehicle* traffic). This car share has practically saturated. For the bus and motorcycle VKT shares, bus travel has tended, on average, to grow slightly over the last decade and a half, while the motorcycle share reduced during the 1990s—though often with a relatively high year to year variability. Motorcycle use appears to be currently growing again, after many years of decline, and could possibly see its share increase in the future, especially if their manoeuvrability in traffic becomes more attractive as congestion levels grow. Equivalently, if significant numbers of drivers find the hassle of coping with congested driving conditions not worthwhile, as future congestion becomes more widespread, bus patronage could also gain from some possible modal shift, though from a purely *delay* point of view, standard buses will not generally show any benefits over car travel.

BTRE projections of non-car passenger vehicle travel are based on competitiveness models (using generalised costs, which take account of travel time spent as well as direct expenses such as fuel prices and fares). The BTRE base-case projections have the bus and motorcycle share of passenger VKT as remaining essentially constant (only increasing marginally by 2020 from the current combined VKT share of about 1.7 per cent of national metropolitan passenger vehicle kilometres travelled).

As for the metropolitan car VKT projections, (base case or *business-as-usual*) forecasts for bus and motorcycle traffic are presented in Part 2 tables.

Truck traffic growth

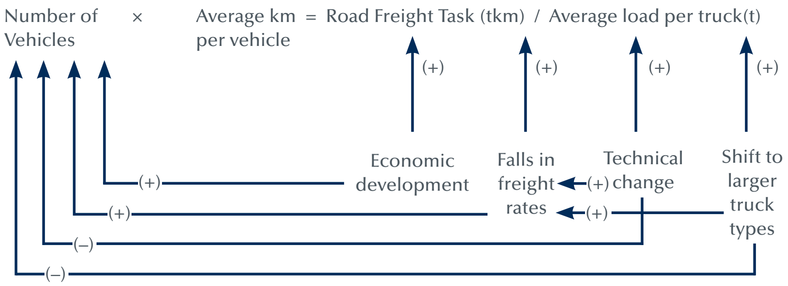
The basic mechanism generating truck traffic can be expressed as follows:

Truck Traffic (VKT) = Road Freight Task / Average Load per Truck

In other words, a certain level of truck kilometres is performed in order to carry out the freight task in each city, where the number of vehicles travelling is determined by the average load of those vehicles. The level of truck traffic (in total VKT terms) can equivalently be derived from the product of *numbers of vehicles* times the yearly *average* VKT they each perform.

The influences of the economy and technological shifts (in improving logistical operation or truck size) can then be illustrated as below:

Total freight vehicle traffic (VKT per annum) =



The main influence of economic development is through increases in the freight task. In the section above on urban freight, tkm growth was found to react proportionally to the growth rate of the economy—at about 1.0 times economic growth. While this relationship cannot continue indefinitely, there are no signs yet of saturation in Australian truck freight use per person (as there are in car travel per person). Similarly, there are no signs of saturation in current levels of United States truck freight per person, and American levels of road freight per person are already much higher than those in Australia. The other influence on the demand for urban freight transport is the real freight rate. Real road freight rates in Australia have fallen dramatically since 1965, mainly driven by the progressive introduction of larger articulated vehicles, but also by technological change which has made possible lighter vehicles, improved terminal efficiencies etc. Real freight rates fell 45 per cent from 1965 to 1990, and then another 3 per cent in the 1990s (BTRE 2002b). In the section above on urban freight, demand was seen to increase 0.7 to 0.8 per cent with a 1.0 per cent reduction in real freight rates.

The other influence of technological change is direct. For example, the same weight-reducing technological change that lowers freight rates also makes possible direct increases in average loads.

However, the main influence on average loads has been the continuing shift to the larger articulated vehicles. This directly increases average load and serves to reduce the overall number of trucks on the road (i.e. from the level of truck traffic that would have been required at the lower average loadings).

Overall, then, the effects of economic development and associated technical change can be summarised as follows:

1. As the economy grows, the urban road freight task grows just as quickly.
2. The shift to larger vehicles makes possible larger loads and therefore less traffic (albeit composed of larger vehicles), but at the same time makes possible lower real freight rates which causes additional demand for freight transport.
3. General technological change has a similar 'double-edged' effect on truck traffic.

The projections in Table 1.1 have already provided the forecasts of the aggregate freight task in tonne-kilometres for each capital. These are turned into traffic forecasts in two steps:

1. The task is split into vehicle types by assumptions about the trend in vehicle type share. The result is projections of tonne-kilometres performed by LCVs, rigid trucks and articulated trucks.
2. The change in average loads per vehicle type is projected, based on past trends and assessments of likely technological or industrial changes.

The result is forecasts for each capital of the VKT performed by LCVs, rigid trucks and articulated trucks.

Projections of total traffic for Australian cities

The forecast growth in total traffic by vehicle type in the various cities is given in detail in the next section of the paper (see tables 2.1 to 2.9 for the VKT projections by vehicle type for each capital city). The following chart (figure 1.16) provides a summary of these projected trends. Table 2.10 weights these VKT projections (in km) by vehicle type to more accurately reflect the traffic-impedance value of each vehicle class. Typical weights versus a passenger car (equal to one), for example, are two for rigid trucks and buses, and three for a six-axle articulated truck. The weighted values are commonly called passenger car equivalent units (PCUs). Figure 1.17 plots the projected VKT trend (aggregate PCU-km, using the BTRE base case scenario) for the Australian capital cities. (For a schematic diagram briefly summarising the demand projection process see Appendix figure A.2.)

Variations in forecast city growth rates for VKT (e.g. the high growth in Brisbane, Perth and Darwin, and the low growth in Hobart) are due mainly to variations in projected population growth. The average metropolitan growth in traffic (total PCU terms, across the eight capitals) is projected to be about 37 per cent over the 15 years from 2005 to 2020. (Though it should be noted that there might be several reasons for traffic growth to be constrained below these forecasts, possibly through a stronger than expected demand response to increasing levels of congestion, through higher than expected changes in demand patterns due to traffic control measures or modal shifts, or from higher than projected fuel prices).

Cars continue to be the largest component of the traffic stream. Their forecast growth of about 24 per cent is, as we have seen, composed of around 6 per cent growth coming from the effect of rising income levels on per person travel, and the rest from the projected increase in population of the eight capital cities. Buses and motorcycles continue to be a small part of the traffic stream.

Articulated truck use is projected to continue growing strongly, but their overall vehicle numbers are relatively small. However, LCVs are a substantial, and quickly growing, part of the traffic stream (with forecast 2005 to 2020 VKT growth of 90 per cent in the base case). Growth in LCV use has averaged between 3 and 4 per cent per annum for well over 20 years, and the base case essentially continues this trend to 2020, with continued (projected) economic growth leading to continued VKT growth.

As mentioned previously, this relatively high level of commercial traffic growth is predicated on the assumption that there will be no decoupling of activity in the freight and service sectors from overall income trends (i.e. GDP per person) during the projection period. If such decoupling does occur in the future (as has already become apparent for the passenger sector), VKT growth for LCVs and trucks will be expected to decelerate, but the evidence so far suggests that such a saturating trend in per capita freight movement is unlikely in the short to medium term (e.g. see Appendix figure A.1). It is primarily the strong projected annual growth in LCV travel that substantially lifts the forecast growth in total metropolitan traffic (PCU-km) between 2005 and 2020 to 37 per cent, from the 24 per cent level for cars. (Though note that even if the current almost exponential growth in commercial VKT slows to, say, a linear growth trend midway during the projection period, then the overall PCU-km growth over the period would not be radically different, changing from around 37 per cent to the order of 33–35 per cent).

PCU values are generally the best ones for gauging the congestion potential of the total traffic stream into the future. Looking at Figure 1.17, two things are clear:

1. The growth in total traffic (in PCU terms) is expected to be approximately linear over the full period from 1990 to 2020.
2. The projected growth rate means that the same absolute volume of traffic (in PCU terms) will likely be added to our capital city roads in the next 15 years as was added in the past 15.

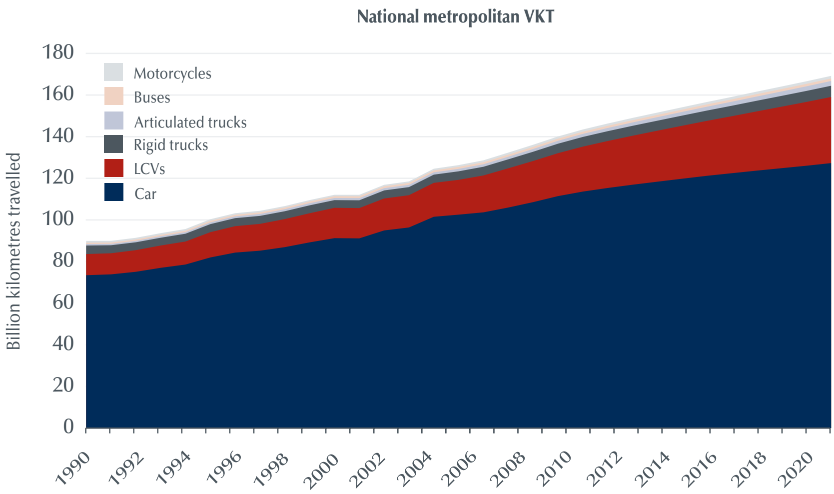
The growth in traffic in the past 15 years has resulted in additional congestion, but the increase has been moderated by three main factors:

1. Significant additions to capacity (in the form of freeways, tunnels etc.) for many cities;
2. Increasing intelligence built into the road network (e.g. loops in the road controlling intersection lights); and
3. Peak spreading.

None of these three factors will cease operating in the next 15 years, but given the extent of their implementation in many areas, obtaining substantial additions to their current moderating influence will likely pose a challenge for some jurisdictions.

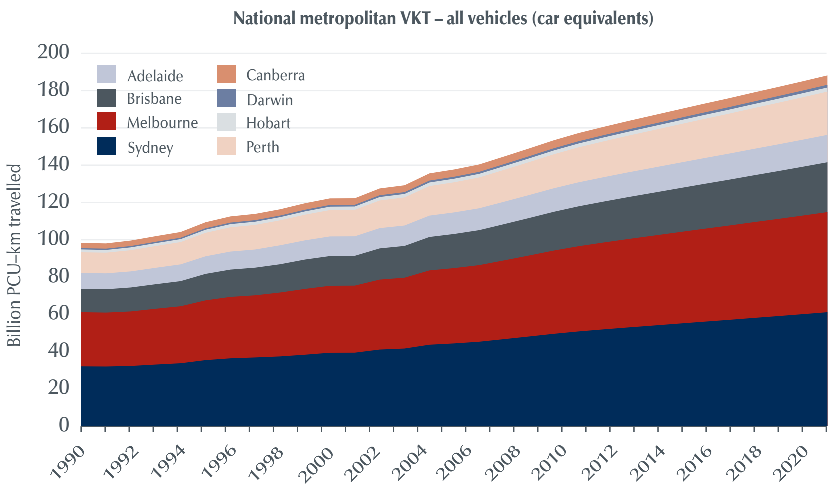
The next part of this report discusses the implications of the large projected increases in traffic in our cities for increases in congestion, and in the associated social costs. Suffice to say, increases in traffic of the size foreseen here will have major implications for mobility and amenity in our cities.

Figure 1.16 Projected travel by motor vehicles, Australian metropolitan total



Source: BTRE estimates.

Figure 1.17 Total projected traffic for Australian capital cities



Source: BTRE estimates.

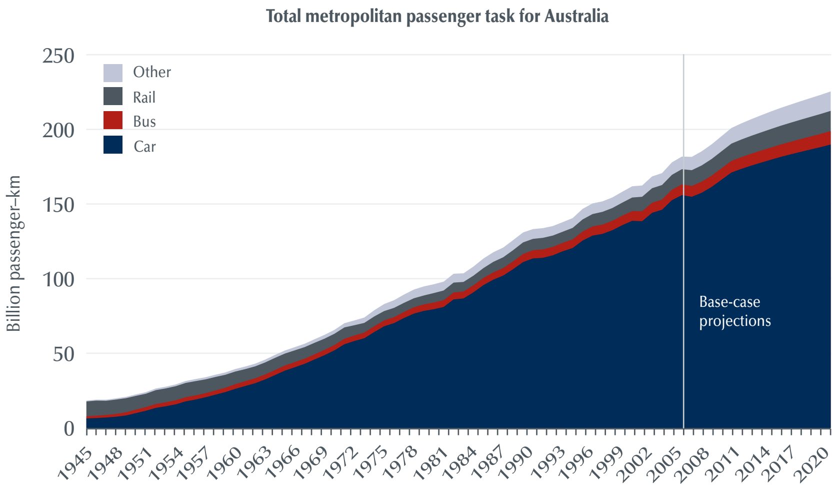
Part 2–Social costs of congestion

Estimation of Avoidable Social Costs for Australian Capital Cities

Increasing traffic trends underlying congestion

Motor vehicle travel within Australian cities has grown enormously over the last 60 years–with current levels of urban kilometres travelled by passenger cars being over 15 times greater than at the start of the 1950s (see figure 2.1 for the long-term trends in urban passenger movement since World War II). Furthermore, as also shown in figure 2.1 (under 'base case' projection assumptions), metropolitan vehicle travel in Australia is expected to continue to grow appreciably over the next decade and a half.

Figure 2.1 Historical and projected urban passenger movement, Australian metropolitan total



Note: 'Other' primarily consists of non-business use of light commercial vehicles (LCVs)–with contributions from motorcycles, non-business use of trucks, and urban ferries.

Sources: BTRE (2003a, 2005), BTRE estimates.

Figures 2.1 and 2.2 nicely summarise the overall modal trends experienced in Australian metropolitan travel over the long term, so they have been reproduced here from Part I of the paper, to introduce our discussion of the impacts of rising traffic levels and consequent congestion effects.

The main 'drivers' of growth in overall transport demand have traditionally been increases in population and average income levels. As demonstrated in Part I of this study, future increases in Australian urban passenger travel are likely to be more dependant on the rate of population increase and less dependent on increases in general prosperity levels. The growth rate in passenger-kilometres (pkm) per person has reduced in recent years, especially compared with the some high growth periods in the past (such as between the 1950s and the 1970s).

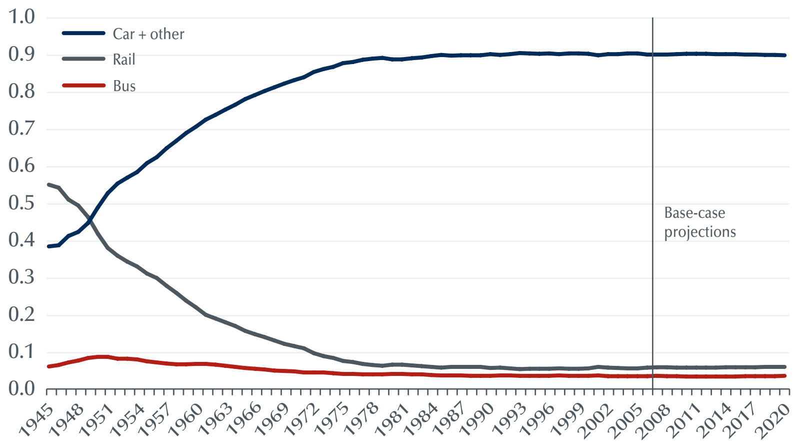
Basically, as income levels and motor vehicle affordability have increased over time, average travel per person has increased. However, there are limits to how far such growth can continue. Eventually, people are spending as much time on daily travel as they are willing to commit and are loath to spend any more of limited time budgets on even more travel, even if average income levels continue to increase. So growth in per capita personal travel is likely to be lower in the future than for the long-term historical trend. However, this decoupling of income level trends from personal travel trends is not apparent in the current freight movement trends. Tonne-kilometres performed per capita are still growing quite strongly, and even though the freight trend curve could possibly also exhibit slowing growth over the longer-term, there is no saturating tendency evident yet (see Appendix figure A.1). Growth in freight and service vehicle traffic is therefore projected to be substantially stronger than for passenger vehicles, over the next decade and a half.

The BTRE base case (or *'business-as-usual'*) projections of Australian transport use are derived from forecasts of population and income levels for each of the relevant regions—allowing for projected trends in fuel prices and other travel expenses (such as fares or vehicle purchase prices) using a variety of aggregate demand models and/or modal competition models. For some background material on the base-case projection process see: BTRE Report 107 (BTRE 2002a), *Greenhouse Gas Emissions from Australian Transport: Base Case*

Projections to 2020 (BTRE 2006a), and *Urban Pollutant Emissions from Motor Vehicles: Australian Trends To 2020* (BTRE 2003a).

Under the base-case scenario settings, the modal share of urban public transport is not projected to vary significantly, from current levels, over the next decade and a half (see figure 2.2). Public transit patronage has reasonably strong growth in the base case (stronger that for total car use) but since over 90 per cent of the total pkm task is done by light vehicles, the portion of mode share that cars lose to buses and rail over the projection period does not make much of a change to their level of dominance. The BTRE projects private travel volumes (averaged across the eight capital cities) to increase by about 1.7 per cent per annum over the period of 2000 to 2020, with a stronger growth trend for the commercial road sector (business kilometres expected to increase by around 3.5 per cent per annum, 2000 to 2020). High levels of traffic and traffic growth lead to significant levels of urban congestion—especially in peak travel periods—which imposes considerable costs on those affected by delays, increased fuel consumption and increased air pollution.

Figure 2.2 Historical and projected modal share, Australian metropolitan passenger travel



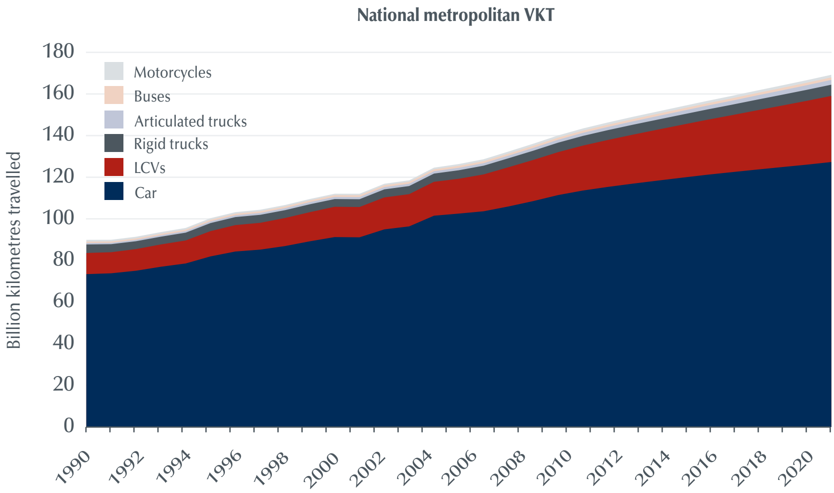
Note: 'Other' primarily consists of non-business use of light commercial vehicles (LCVs).

Sources: BTRE (2003a, 2006a), BTRE estimates.

The total vehicle kilometres travelled (VKT) estimates from the base case projections (displayed previously in figure 1.16) are shown in figure 2.3. (For a schematic diagram briefly summarising the demand projection process see Appendix figure A.2.)

As shown in table 2.1, total metropolitan VKT (all vehicle types) is forecast, in the BTRE base case, to increase by about 34 per cent between 2005 and 2020.

Figure 2.3 Historical and projected travel by motor vehicles, Australian metropolitan total

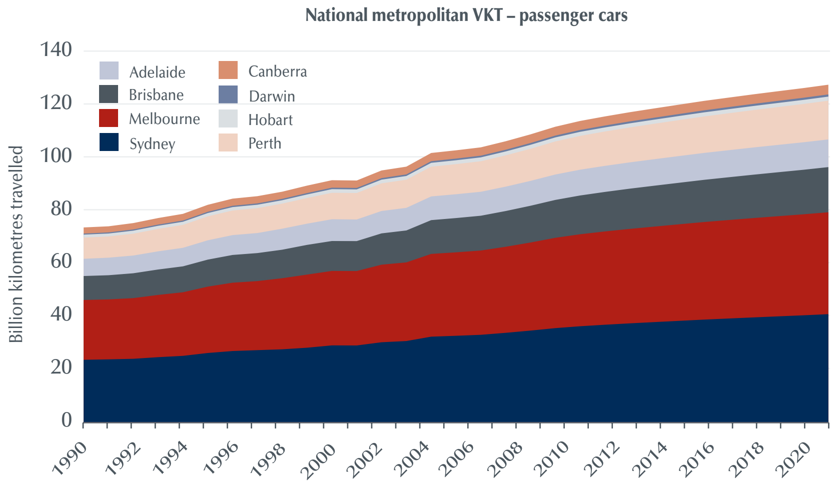


Sources: BTRE estimates.

Australian cities not only vary greatly in size and design (and consequently, in current traffic congestion levels), but also have varying levels of population growth (and consequently, expected congestion growth rates). Figures 2.4 to 2.19 present BTRE projections of motor vehicle traffic for the State and Territory capitals to 2020. Figure 2.11 gives total annual kilometres travelled in passenger car equivalent units (PCU-km).

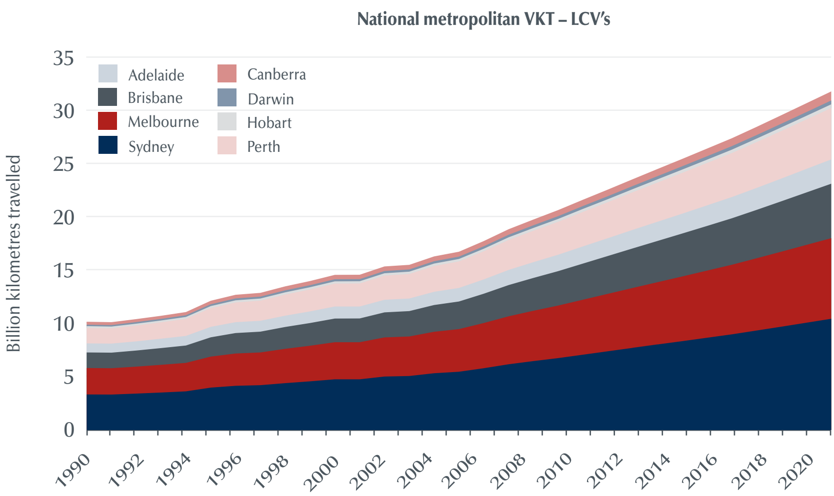
As shown in table 2.10, total metropolitan traffic (in PCU-weighted VKT terms) is projected to increase by close to 37 per cent between 2005 and 2020 (using base case input assumptions to the BTRE transport demand models).

Figure 2.4 Total projected car traffic for Australian capital cities



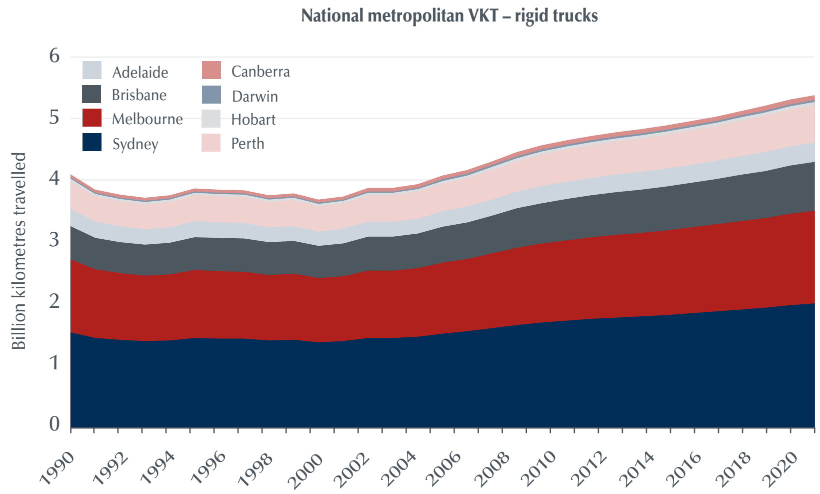
Sources: BTRE estimates.

Figure 2.5 Total projected LCV traffic for Australian capital cities



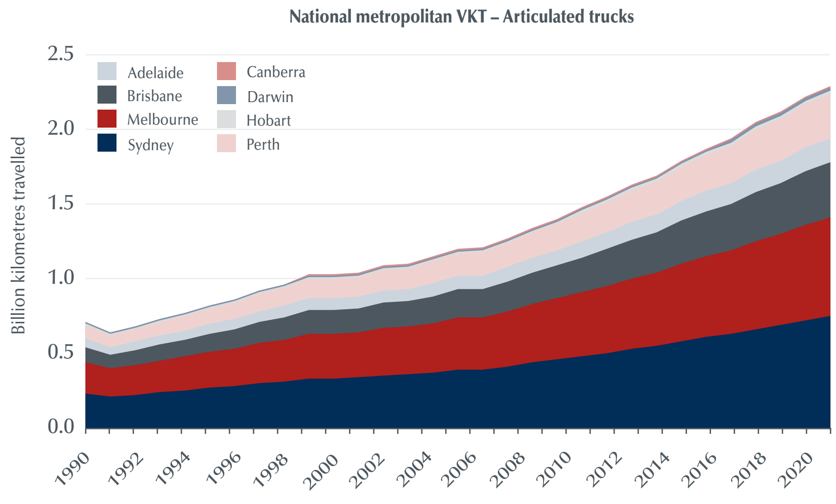
Sources: BTRE estimates.

Figure 2.6 Total projected rigid truck traffic for Australian capital cities



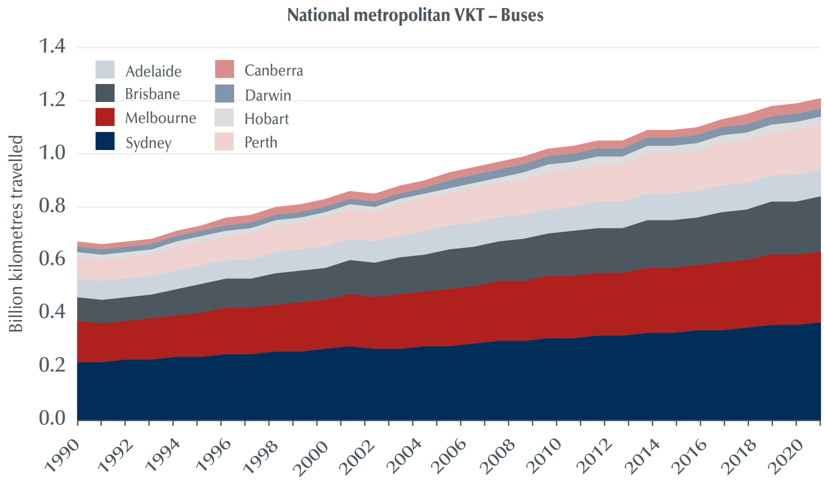
Sources: BTRE estimates.

Figure 2.7 Total projected articulated truck traffic for Australian capital cities



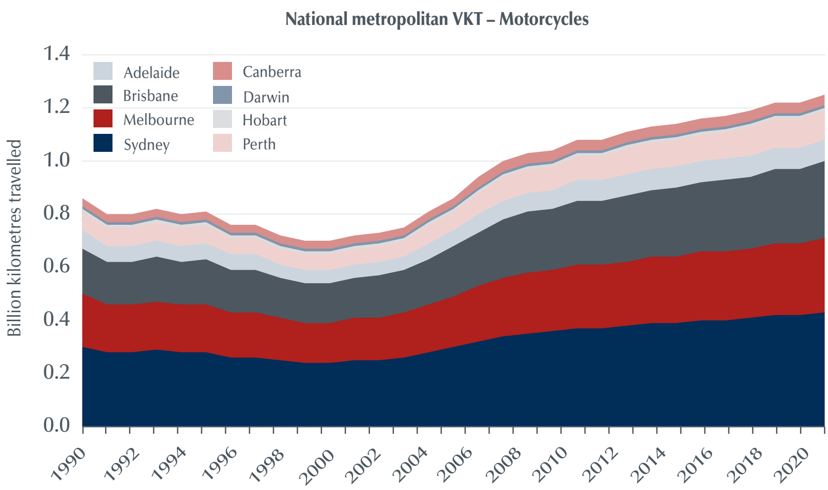
Sources: BTRE estimates.

Figure 2.8 Total projected bus traffic for Australian capital cities



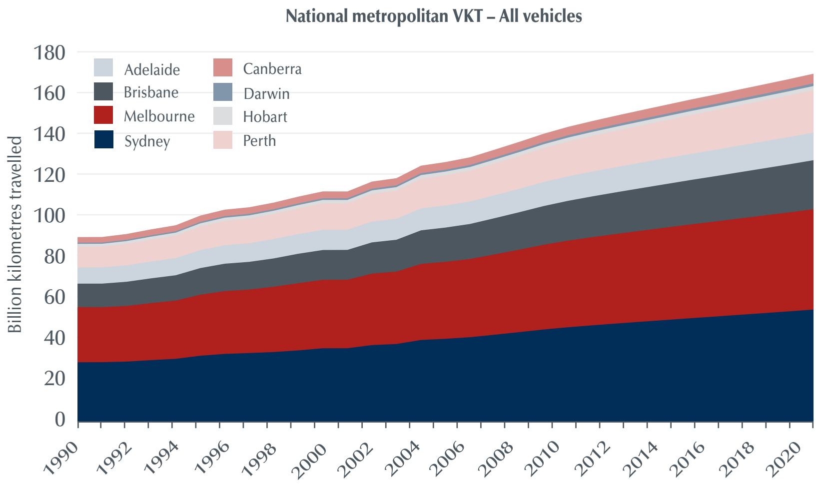
Sources: BTRE estimates.

Figure 2.9 Total projected motorcycle traffic for Australian capital cities



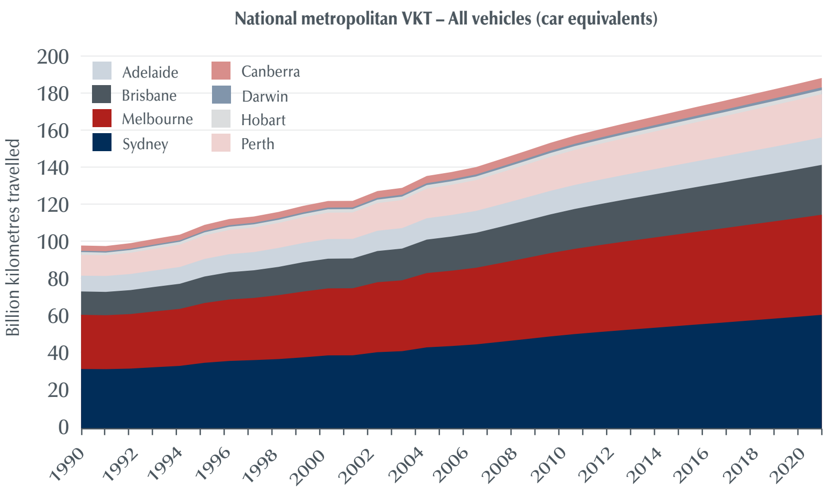
Sources: BTRE estimates.

Figure 2.10 Total projected traffic for Australian capital cities–VKT



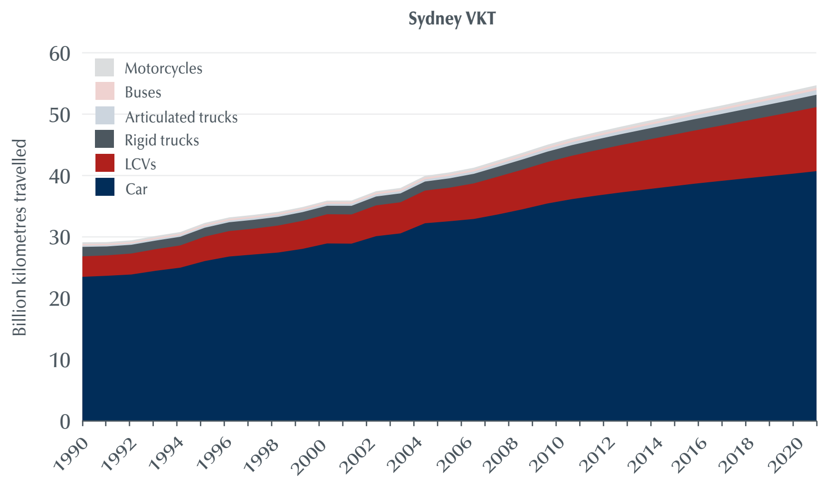
Sources: BTRE estimates.

Figure 2.11 Total projected traffic for Australian capital cities–PCU VKT



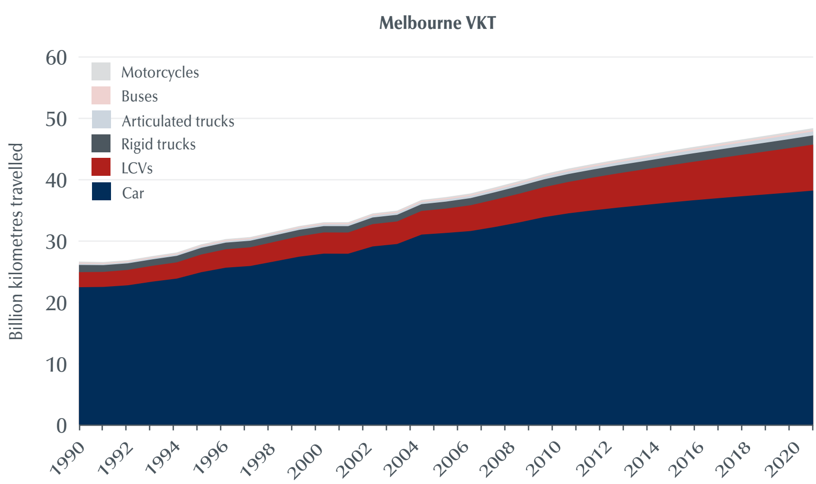
Sources: BTRE estimates.

Figure 2.12 Total projected VKT for Sydney



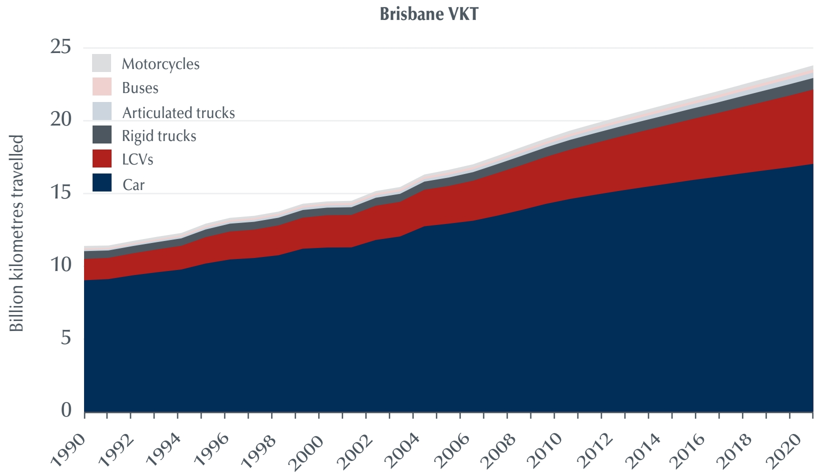
Sources: BTRE estimates.

Figure 2.13 Total projected VKT for Melbourne



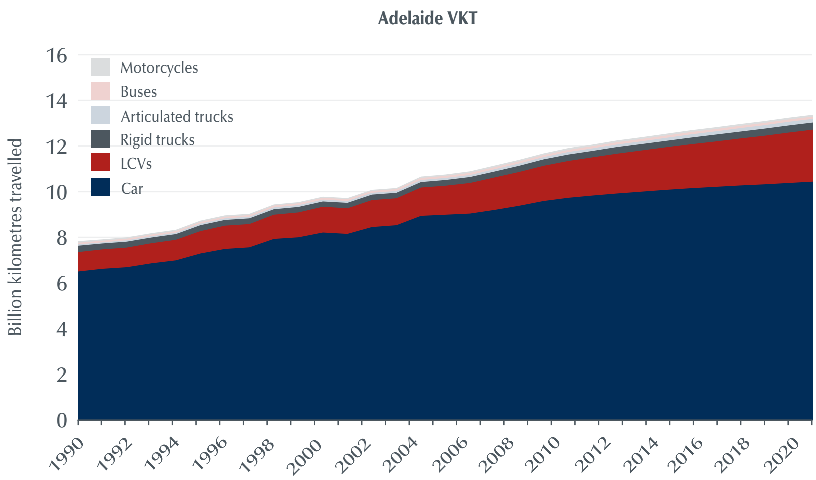
Sources: BTRE estimates.

Figure 2.14 Total projected VKT for Brisbane



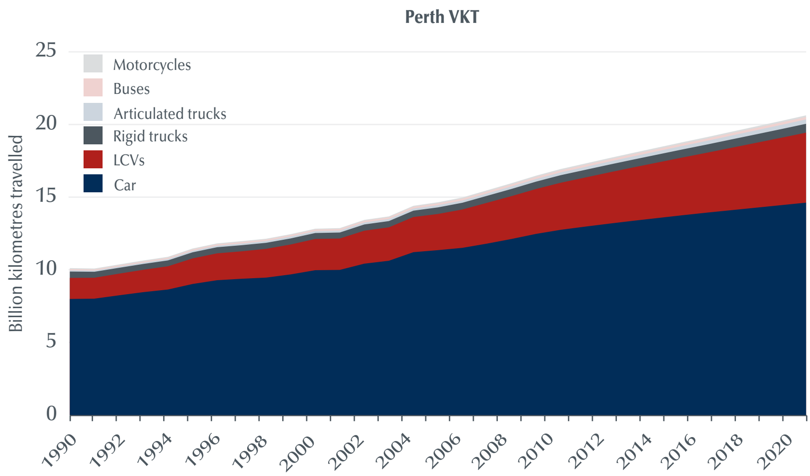
Sources: BTRE estimates.

Figure 2.15 Total projected VKT for Adelaide



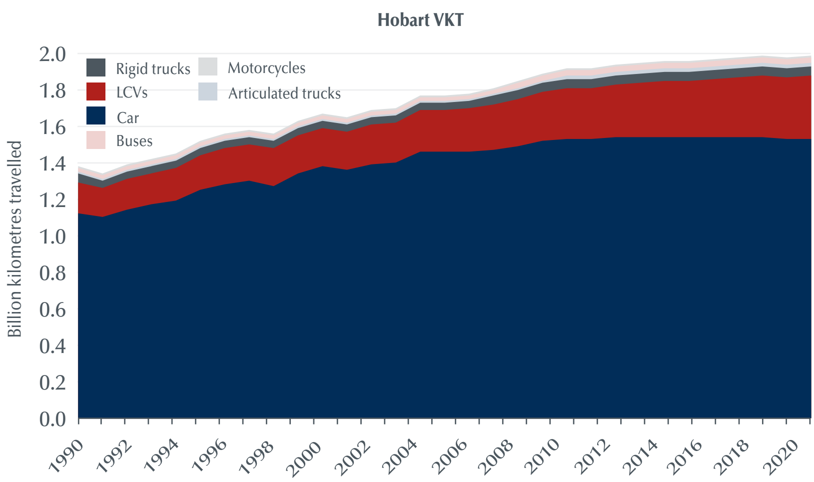
Sources: BTRE estimates.

Figure 2.16 Total projected VKT for Perth



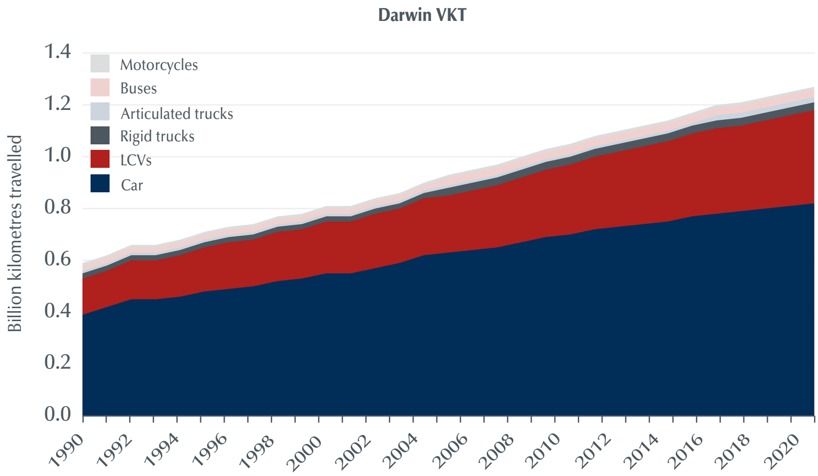
Sources: BTRE estimates.

Figure 2.17 Total projected VKT for Hobart



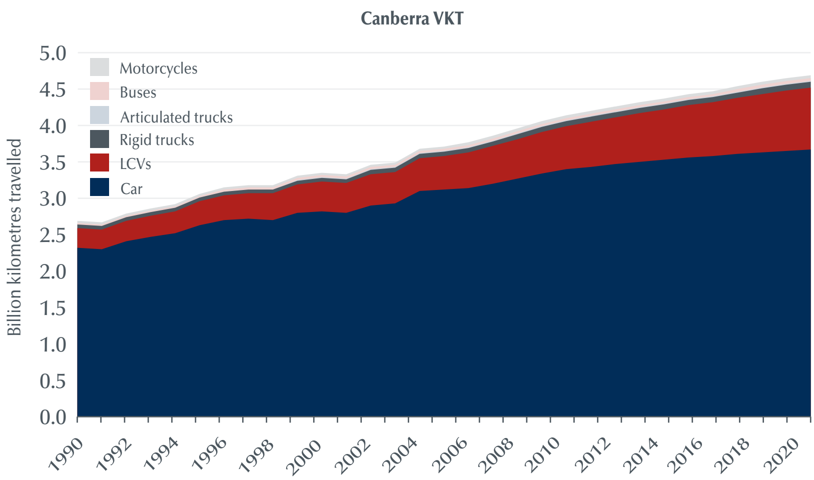
Sources: BTRE estimates.

Figure 2.18 Total projected VKT for Darwin



Sources: BTRE estimates.

Figure 2.19 Total projected VKT for Canberra



Sources: BTRE estimates.

Table 2.1 National base case projections of metropolitan vehicle kilometres travelled by type of vehicle, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	73.43	10.16	4.102	0.698	0.659	0.856	89.90
1991	73.84	10.13	3.864	0.648	0.663	0.799	89.94
1992	75.07	10.40	3.776	0.687	0.666	0.801	91.39
1993	76.98	10.72	3.726	0.725	0.673	0.819	93.64
1994	78.56	11.05	3.748	0.768	0.704	0.805	95.63
1995	81.96	12.14	3.872	0.829	0.733	0.799	100.33
1996	84.30	12.69	3.863	0.851	0.757	0.752	103.21
1997	85.21	12.88	3.845	0.918	0.776	0.749	104.39
1998	86.92	13.48	3.772	0.963	0.798	0.720	106.65
1999	89.21	14.00	3.797	1.031	0.813	0.693	109.54
2000	91.24	14.56	3.709	1.032	0.832	0.701	112.07
2001	91.13	14.56	3.741	1.046	0.861	0.722	112.07
2002	94.94	15.35	3.879	1.095	0.868	0.729	116.86
2003	96.37	15.50	3.890	1.106	0.887	0.751	118.50
2004	101.51	16.29	3.946	1.134	0.906	0.806	124.60
2005	102.53	16.73	4.089	1.187	0.932	0.872	126.33
2006	103.64	17.72	4.176	1.215	0.949	0.938	128.64
2007	105.95	18.85	4.311	1.274	0.973	0.989	132.34
2008	108.54	19.77	4.440	1.342	0.993	1.032	136.12
2009	111.43	20.63	4.552	1.407	1.009	1.050	140.08
2010	113.61	21.60	4.652	1.483	1.025	1.069	143.44
2011	115.34	22.56	4.716	1.552	1.041	1.088	146.30
2012	116.90	23.53	4.771	1.629	1.056	1.107	148.99
2013	118.36	24.49	4.814	1.707	1.071	1.125	151.57
2014	119.79	25.44	4.882	1.784	1.086	1.144	154.13
2015	121.19	26.40	4.947	1.864	1.105	1.162	156.67
2016	122.44	27.38	5.025	1.944	1.125	1.181	159.10
2017	123.67	28.45	5.123	2.036	1.146	1.200	161.62
2018	124.85	29.54	5.194	2.122	1.167	1.219	164.09
2019	126.02	30.65	5.294	2.208	1.188	1.238	166.60
2020	127.30	31.77	5.386	2.292	1.209	1.257	169.21
Growth 2005–2020	24.2%	90.0%	31.7%	93.0%	29.8%	44.2%	33.9%

Note: 'Metropolitan' results refer to all activity within the greater metropolitan areas of the eight State and Territory capital cities.

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.2 Base case projections of vehicle kilometres travelled by type of vehicle for Sydney, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	23.49	3.34	1.540	0.227	0.218	0.300	29.12
1991	23.66	3.33	1.451	0.211	0.224	0.280	29.15
1992	23.87	3.42	1.418	0.224	0.226	0.280	29.44
1993	24.48	3.52	1.398	0.236	0.229	0.285	30.15
1994	24.98	3.63	1.405	0.250	0.237	0.280	30.78
1995	26.06	3.98	1.450	0.269	0.242	0.277	32.27
1996	26.80	4.15	1.444	0.276	0.246	0.261	33.17
1997	27.13	4.21	1.437	0.298	0.252	0.260	33.59
1998	27.45	4.40	1.408	0.312	0.258	0.249	34.08
1999	28.05	4.57	1.417	0.334	0.265	0.240	34.88
2000	28.93	4.76	1.384	0.335	0.267	0.242	35.91
2001	28.90	4.76	1.396	0.339	0.277	0.249	35.92
2002	30.11	5.02	1.446	0.355	0.271	0.252	37.45
2003	30.57	5.07	1.450	0.358	0.272	0.259	37.98
2004	32.22	5.33	1.471	0.368	0.275	0.278	39.93
2005	32.55	5.47	1.523	0.385	0.283	0.300	40.51
2006	32.92	5.80	1.556	0.394	0.288	0.323	41.28
2007	33.67	6.17	1.606	0.413	0.296	0.340	42.49
2008	34.51	6.47	1.655	0.435	0.302	0.355	43.73
2009	35.44	6.75	1.697	0.457	0.307	0.361	45.02
2010	36.15	7.07	1.735	0.481	0.312	0.367	46.12
2011	36.72	7.39	1.759	0.504	0.317	0.373	47.06
2012	37.24	7.71	1.780	0.529	0.321	0.379	47.95
2013	37.72	8.03	1.796	0.554	0.326	0.385	48.81
2014	38.19	8.34	1.822	0.580	0.331	0.391	49.66
2015	38.66	8.66	1.847	0.606	0.336	0.398	50.51
2016	39.08	8.98	1.876	0.632	0.343	0.404	51.32
2017	39.49	9.34	1.913	0.662	0.349	0.410	52.16
2018	39.89	9.70	1.940	0.690	0.356	0.416	52.99
2019	40.28	10.07	1.978	0.718	0.362	0.422	53.83
2020	40.71	10.44	2.013	0.746	0.369	0.428	54.71
Growth 2005–2020	25.1%	90.8%	32.1%	93.6%	30.5%	42.7%	35.0%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.3 Base case projections of vehicle kilometres travelled by type of vehicle for Melbourne, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	22.57	2.48	1.178	0.207	0.146	0.196	26.77
1991	22.62	2.47	1.110	0.192	0.145	0.182	26.72
1992	22.89	2.53	1.081	0.203	0.144	0.181	27.02
1993	23.49	2.60	1.063	0.213	0.146	0.184	27.69
1994	23.99	2.67	1.065	0.225	0.153	0.180	28.28
1995	25.04	2.91	1.096	0.242	0.160	0.177	29.63
1996	25.78	3.03	1.089	0.247	0.165	0.166	30.48
1997	26.06	3.07	1.082	0.267	0.168	0.166	30.82
1998	26.82	3.22	1.061	0.280	0.175	0.159	31.71
1999	27.59	3.34	1.068	0.299	0.179	0.153	32.63
2000	28.09	3.48	1.044	0.300	0.183	0.155	33.25
2001	28.08	3.48	1.053	0.304	0.190	0.160	33.26
2002	29.27	3.67	1.092	0.319	0.194	0.161	34.70
2003	29.67	3.71	1.094	0.322	0.200	0.166	35.16
2004	31.22	3.89	1.109	0.330	0.205	0.178	36.93
2005	31.49	4.00	1.149	0.345	0.210	0.193	37.39
2006	31.80	4.24	1.173	0.353	0.213	0.207	37.98
2007	32.47	4.50	1.210	0.370	0.218	0.218	38.99
2008	33.23	4.72	1.246	0.390	0.222	0.228	40.04
2009	34.08	4.93	1.277	0.409	0.225	0.232	41.15
2010	34.71	5.16	1.305	0.431	0.229	0.236	42.07
2011	35.20	5.39	1.322	0.450	0.232	0.240	42.83
2012	35.64	5.62	1.337	0.472	0.235	0.244	43.54
2013	36.04	5.84	1.349	0.495	0.237	0.248	44.22
2014	36.44	6.07	1.367	0.517	0.240	0.252	44.88
2015	36.82	6.30	1.385	0.540	0.244	0.256	45.54
2016	37.16	6.53	1.406	0.563	0.248	0.260	46.16
2017	37.49	6.78	1.433	0.590	0.252	0.264	46.80
2018	37.80	7.04	1.452	0.614	0.256	0.268	47.43
2019	38.11	7.30	1.480	0.639	0.260	0.272	48.06
2020	38.45	7.56	1.504	0.663	0.264	0.276	48.72
Growth 2005–2020	22.1%	89.2%	31.0%	92.0%	26.1%	43.3%	30.3%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.4 Base case projections of vehicle kilometres travelled by type of vehicle for Brisbane, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	9.04	1.46	0.542	0.101	0.091	0.167	11.40
1991	9.12	1.46	0.510	0.094	0.093	0.157	11.43
1992	9.38	1.51	0.503	0.100	0.093	0.159	11.74
1993	9.59	1.57	0.501	0.107	0.094	0.165	12.03
1994	9.78	1.63	0.509	0.114	0.100	0.165	12.29
1995	10.19	1.81	0.531	0.125	0.109	0.165	12.93
1996	10.47	1.92	0.537	0.130	0.111	0.157	13.32
1997	10.57	1.95	0.536	0.140	0.113	0.157	13.46
1998	10.76	2.05	0.527	0.148	0.118	0.152	13.75
1999	11.21	2.13	0.532	0.159	0.118	0.146	14.30
2000	11.29	2.22	0.521	0.159	0.124	0.149	14.46
2001	11.30	2.23	0.526	0.162	0.129	0.154	14.50
2002	11.81	2.35	0.547	0.170	0.133	0.156	15.17
2003	12.05	2.38	0.550	0.172	0.137	0.161	15.46
2004	12.75	2.51	0.559	0.177	0.142	0.174	16.31
2005	12.93	2.59	0.580	0.186	0.148	0.189	16.62
2006	13.13	2.75	0.594	0.191	0.150	0.204	17.01
2007	13.48	2.93	0.615	0.200	0.155	0.216	17.59
2008	13.87	3.08	0.635	0.211	0.159	0.226	18.18
2009	14.29	3.23	0.653	0.222	0.162	0.231	18.79
2010	14.63	3.39	0.669	0.235	0.166	0.236	19.32
2011	14.91	3.55	0.680	0.246	0.169	0.241	19.80
2012	15.18	3.71	0.689	0.259	0.172	0.246	20.25
2013	15.43	3.87	0.697	0.272	0.176	0.251	20.69
2014	15.67	4.03	0.709	0.285	0.179	0.257	21.13
2015	15.92	4.19	0.720	0.299	0.183	0.262	21.58
2016	16.14	4.36	0.733	0.312	0.188	0.267	22.00
2017	16.37	4.54	0.749	0.328	0.192	0.272	22.45
2018	16.59	4.73	0.761	0.343	0.196	0.278	22.89
2019	16.80	4.92	0.778	0.357	0.201	0.283	23.34
2020	17.04	5.11	0.793	0.372	0.206	0.288	23.80
Growth 2005–2020	31.7%	97.4%	36.7%	100.3%	39.1%	52.9%	43.2%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.5 Base case projections of vehicle kilometres travelled by type of vehicle for Adelaide, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	6.50	0.85	0.279	0.058	0.066	0.068	7.82
1991	6.62	0.85	0.263	0.054	0.067	0.064	7.91
1992	6.69	0.86	0.256	0.057	0.068	0.063	7.99
1993	6.86	0.88	0.250	0.059	0.067	0.064	8.18
1994	6.99	0.90	0.250	0.062	0.070	0.063	8.34
1995	7.29	0.98	0.256	0.067	0.072	0.062	8.73
1996	7.49	1.02	0.254	0.068	0.074	0.057	8.96
1997	7.56	1.02	0.250	0.073	0.075	0.057	9.03
1998	7.93	1.06	0.243	0.076	0.077	0.054	9.45
1999	8.00	1.09	0.242	0.080	0.078	0.052	9.55
2000	8.21	1.13	0.235	0.080	0.080	0.052	9.79
2001	8.15	1.12	0.235	0.080	0.082	0.053	9.72
2002	8.45	1.18	0.243	0.084	0.083	0.053	10.09
2003	8.53	1.18	0.242	0.084	0.085	0.055	10.18
2004	8.94	1.24	0.245	0.086	0.087	0.059	10.65
2005	8.99	1.27	0.252	0.090	0.088	0.063	10.75
2006	9.04	1.34	0.257	0.091	0.090	0.067	10.89
2007	9.20	1.42	0.264	0.095	0.091	0.071	11.14
2008	9.38	1.48	0.271	0.100	0.092	0.074	11.40
2009	9.59	1.54	0.277	0.105	0.093	0.074	11.67
2010	9.73	1.61	0.282	0.110	0.094	0.075	11.90
2011	9.83	1.67	0.284	0.114	0.095	0.076	12.07
2012	9.92	1.74	0.287	0.120	0.096	0.077	12.24
2013	10.00	1.80	0.288	0.125	0.097	0.078	12.39
2014	10.08	1.86	0.291	0.130	0.097	0.079	12.54
2015	10.15	1.93	0.294	0.135	0.098	0.080	12.69
2016	10.21	1.99	0.298	0.141	0.099	0.081	12.82
2017	10.27	2.06	0.302	0.147	0.101	0.082	12.96
2018	10.32	2.13	0.305	0.153	0.102	0.083	13.10
2019	10.38	2.21	0.310	0.158	0.103	0.084	13.24
2020	10.44	2.28	0.315	0.164	0.104	0.085	13.39
Growth 2005–2020	16.1%	79.9%	24.6%	82.6%	18.0%	34.6%	24.5%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.6 Base case projections of vehicle kilometres travelled by type of vehicle for Perth, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	7.99	1.45	0.437	0.086	0.081	0.070	10.12
1991	8.01	1.44	0.412	0.080	0.079	0.065	10.09
1992	8.24	1.49	0.404	0.085	0.079	0.065	10.36
1993	8.46	1.54	0.401	0.090	0.081	0.067	10.64
1994	8.64	1.60	0.405	0.096	0.086	0.066	10.89
1995	9.02	1.76	0.421	0.104	0.091	0.066	11.46
1996	9.28	1.85	0.422	0.107	0.095	0.062	11.82
1997	9.38	1.89	0.422	0.116	0.101	0.062	11.96
1998	9.46	1.98	0.415	0.122	0.101	0.060	12.14
1999	9.68	2.06	0.418	0.131	0.104	0.058	12.46
2000	9.97	2.15	0.410	0.132	0.106	0.059	12.83
2001	9.99	2.16	0.414	0.134	0.110	0.061	12.86
2002	10.42	2.27	0.429	0.140	0.113	0.062	13.44
2003	10.62	2.30	0.431	0.142	0.117	0.064	13.67
2004	11.21	2.42	0.438	0.145	0.121	0.069	14.40
2005	11.35	2.49	0.454	0.153	0.124	0.075	14.65
2006	11.51	2.64	0.464	0.156	0.127	0.080	14.98
2007	11.80	2.81	0.480	0.164	0.131	0.085	15.47
2008	12.12	2.95	0.495	0.173	0.134	0.089	15.96
2009	12.47	3.09	0.508	0.182	0.137	0.091	16.47
2010	12.75	3.24	0.520	0.192	0.139	0.093	16.93
2011	12.97	3.38	0.527	0.201	0.142	0.095	17.32
2012	13.18	3.53	0.534	0.211	0.145	0.096	17.70
2013	13.38	3.68	0.539	0.221	0.147	0.098	18.07
2014	13.57	3.83	0.548	0.232	0.150	0.100	18.43
2015	13.76	3.98	0.556	0.242	0.153	0.102	18.80
2016	13.94	4.13	0.565	0.253	0.156	0.104	19.15
2017	14.11	4.30	0.577	0.265	0.159	0.106	19.52
2018	14.28	4.47	0.585	0.277	0.163	0.108	19.88
2019	14.45	4.64	0.597	0.288	0.166	0.110	20.25
2020	14.62	4.82	0.608	0.300	0.170	0.112	20.63
Growth 2005–2020	28.8%	93.5%	33.9%	96.3%	36.6%	49.7%	40.8%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.7 Base case projections of vehicle kilometres travelled by type of vehicle for Hobart, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	1.13	0.17	0.047	0.009	0.020	0.011	1.38
1991	1.11	0.16	0.045	0.009	0.019	0.010	1.35
1992	1.15	0.17	0.043	0.009	0.019	0.010	1.40
1993	1.18	0.17	0.042	0.009	0.019	0.010	1.43
1994	1.20	0.18	0.042	0.010	0.020	0.010	1.46
1995	1.26	0.19	0.044	0.011	0.021	0.010	1.53
1996	1.29	0.20	0.044	0.011	0.022	0.009	1.58
1997	1.31	0.20	0.043	0.012	0.022	0.009	1.59
1998	1.28	0.21	0.042	0.012	0.022	0.008	1.57
1999	1.35	0.21	0.042	0.013	0.022	0.008	1.64
2000	1.39	0.21	0.041	0.012	0.023	0.008	1.69
2001	1.37	0.21	0.041	0.012	0.023	0.008	1.66
2002	1.40	0.22	0.042	0.013	0.023	0.008	1.71
2003	1.41	0.22	0.042	0.013	0.024	0.008	1.71
2004	1.47	0.23	0.043	0.013	0.024	0.009	1.78
2005	1.47	0.23	0.044	0.013	0.024	0.009	1.79
2006	1.47	0.24	0.045	0.013	0.025	0.010	1.80
2007	1.48	0.25	0.045	0.014	0.025	0.010	1.83
2008	1.50	0.26	0.046	0.014	0.025	0.010	1.86
2009	1.53	0.27	0.046	0.015	0.025	0.011	1.89
2010	1.54	0.28	0.047	0.015	0.025	0.011	1.91
2011	1.54	0.28	0.047	0.016	0.026	0.011	1.93
2012	1.55	0.29	0.047	0.016	0.026	0.011	1.94
2013	1.55	0.30	0.046	0.017	0.026	0.011	1.95
2014	1.55	0.31	0.046	0.017	0.026	0.011	1.96
2015	1.55	0.31	0.046	0.018	0.026	0.011	1.97
2016	1.55	0.32	0.046	0.018	0.026	0.011	1.97
2017	1.55	0.33	0.046	0.019	0.026	0.011	1.98
2018	1.55	0.34	0.046	0.020	0.027	0.011	1.98
2019	1.54	0.34	0.047	0.020	0.027	0.011	1.99
2020	1.54	0.35	0.047	0.020	0.027	0.011	2.00
Growth 2005–2020	5.2%	52.3%	5.4%	54.5%	10.6%	16.2%	11.7%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.8 Base case projections of vehicle kilometres travelled by type of vehicle for Darwin, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	0.39	0.14	0.025	0.006	0.016	0.009	0.59
1991	0.42	0.14	0.023	0.006	0.015	0.008	0.61
1992	0.45	0.15	0.023	0.006	0.015	0.008	0.65
1993	0.45	0.15	0.022	0.007	0.016	0.009	0.66
1994	0.46	0.16	0.023	0.007	0.017	0.009	0.67
1995	0.48	0.17	0.023	0.008	0.017	0.009	0.71
1996	0.49	0.18	0.024	0.008	0.018	0.008	0.73
1997	0.50	0.18	0.023	0.008	0.019	0.008	0.74
1998	0.52	0.19	0.023	0.009	0.020	0.008	0.76
1999	0.53	0.19	0.023	0.009	0.021	0.008	0.78
2000	0.55	0.20	0.023	0.009	0.021	0.008	0.81
2001	0.55	0.20	0.023	0.009	0.022	0.008	0.81
2002	0.57	0.21	0.024	0.010	0.023	0.008	0.84
2003	0.59	0.21	0.024	0.010	0.023	0.008	0.86
2004	0.62	0.22	0.024	0.010	0.024	0.009	0.90
2005	0.63	0.22	0.025	0.010	0.025	0.010	0.92
2006	0.64	0.23	0.026	0.010	0.026	0.010	0.94
2007	0.65	0.24	0.026	0.011	0.026	0.011	0.97
2008	0.67	0.25	0.027	0.011	0.027	0.011	1.00
2009	0.69	0.26	0.027	0.012	0.028	0.012	1.03
2010	0.70	0.27	0.028	0.012	0.028	0.012	1.06
2011	0.72	0.28	0.028	0.013	0.028	0.012	1.08
2012	0.73	0.29	0.028	0.013	0.029	0.012	1.10
2013	0.74	0.30	0.028	0.014	0.029	0.012	1.12
2014	0.75	0.31	0.028	0.014	0.030	0.013	1.15
2015	0.77	0.32	0.028	0.015	0.030	0.013	1.17
2016	0.78	0.33	0.028	0.015	0.031	0.013	1.19
2017	0.79	0.33	0.028	0.016	0.031	0.013	1.21
2018	0.80	0.34	0.029	0.016	0.032	0.013	1.23
2019	0.81	0.35	0.029	0.017	0.032	0.014	1.25
2020	0.82	0.36	0.029	0.017	0.033	0.014	1.28
Growth 2005–2020	30.8%	64.9%	14.2%	67.4%	30.9%	42.9%	39.1%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.9 Base case projections of vehicle kilometres travelled by type of vehicle for Canberra, 1990–2020

(billion kilometres)

Fin. Year	Cars	LCVs	Rigid trucks	Articulated trucks	Buses	Motor cycles	Total
1990	2.32	0.27	0.053	0.003	0.021	0.035	2.70
1991	2.30	0.27	0.050	0.003	0.022	0.033	2.68
1992	2.41	0.28	0.049	0.003	0.021	0.033	2.80
1993	2.47	0.29	0.048	0.003	0.021	0.034	2.87
1994	2.52	0.30	0.049	0.004	0.021	0.033	2.92
1995	2.63	0.33	0.050	0.004	0.022	0.033	3.06
1996	2.70	0.34	0.051	0.004	0.025	0.031	3.15
1997	2.72	0.35	0.052	0.004	0.027	0.030	3.19
1998	2.70	0.37	0.052	0.005	0.027	0.029	3.19
1999	2.80	0.39	0.053	0.005	0.026	0.028	3.30
2000	2.82	0.41	0.053	0.005	0.027	0.028	3.34
2001	2.80	0.41	0.054	0.005	0.028	0.029	3.32
2002	2.90	0.43	0.056	0.005	0.028	0.029	3.45
2003	2.93	0.43	0.057	0.005	0.029	0.030	3.49
2004	3.10	0.45	0.058	0.006	0.030	0.031	3.67
2005	3.12	0.46	0.061	0.006	0.030	0.034	3.71
2006	3.14	0.49	0.062	0.006	0.030	0.036	3.76
2007	3.20	0.52	0.064	0.006	0.031	0.038	3.86
2008	3.27	0.54	0.065	0.007	0.031	0.039	3.95
2009	3.34	0.57	0.067	0.007	0.032	0.039	4.05
2010	3.40	0.59	0.068	0.007	0.032	0.040	4.13
2011	3.43	0.62	0.069	0.008	0.033	0.040	4.20
2012	3.47	0.64	0.070	0.008	0.033	0.040	4.26
2013	3.50	0.67	0.070	0.008	0.033	0.041	4.32
2014	3.53	0.69	0.071	0.009	0.034	0.041	4.38
2015	3.56	0.72	0.072	0.009	0.034	0.041	4.43
2016	3.58	0.74	0.073	0.009	0.035	0.042	4.48
2017	3.61	0.77	0.074	0.010	0.035	0.042	4.54
2018	3.63	0.80	0.075	0.010	0.036	0.042	4.59
2019	3.65	0.83	0.076	0.011	0.036	0.043	4.64
2020	3.67	0.85	0.078	0.011	0.037	0.043	4.70
Growth 2005–2020	17.9%	84.2%	27.5%	86.9%	23.7%	27.0%	26.6%

Sources: ABS (2003 and earlier), BTE (1999), BTRE (2002a, 2003a, 2006a), BTRE estimates.

Table 2.10 National base case projections of total metropolitan vehicle travel–passenger car equivalents, 1990–2020

(billion PCU-km)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	32.07	29.07	12.53	8.47	11.15	1.51	0.68	2.83	98.3
1991	31.99	28.92	12.52	8.54	11.08	1.47	0.70	2.81	98.0
1992	32.29	29.24	12.86	8.63	11.37	1.52	0.73	2.93	99.5
1993	33.04	29.93	13.17	8.81	11.67	1.55	0.75	3.00	101.9
1994	33.74	30.57	13.48	8.99	11.96	1.59	0.76	3.06	104.1
1995	35.41	32.06	14.21	9.42	12.61	1.66	0.80	3.21	109.4
1996	36.38	32.95	14.65	9.67	13.01	1.71	0.83	3.31	112.5
1997	36.85	33.34	14.83	9.75	13.18	1.73	0.84	3.35	113.9
1998	37.40	34.29	15.16	10.17	13.39	1.71	0.87	3.35	116.3
1999	38.32	35.30	15.76	10.29	13.76	1.78	0.89	3.48	119.6
2000	39.37	35.93	15.94	10.53	14.14	1.83	0.92	3.52	122.2
2001	39.41	35.97	15.99	10.47	14.19	1.80	0.92	3.50	122.2
2002	41.08	37.53	16.74	10.87	14.83	1.86	0.96	3.64	127.5
2003	41.63	38.00	17.04	10.96	15.07	1.86	0.98	3.68	129.2
2004	43.68	39.86	17.94	11.45	15.85	1.93	1.02	3.87	135.6
2005	44.38	40.41	18.31	11.57	16.15	1.94	1.04	3.91	137.7
2006	45.28	41.10	18.76	11.73	16.53	1.95	1.07	3.97	140.4
2007	46.67	42.25	19.43	12.02	17.10	1.99	1.10	4.08	144.6
2008	48.08	43.44	20.10	12.32	17.66	2.02	1.14	4.18	148.9
2009	49.53	44.67	20.78	12.62	18.24	2.06	1.17	4.29	153.4
2010	50.81	45.72	21.40	12.88	18.77	2.08	1.20	4.38	157.2
2011	51.91	46.60	21.95	13.08	19.23	2.10	1.23	4.45	160.6
2012	52.96	47.44	22.49	13.28	19.68	2.11	1.25	4.52	163.7
2013	53.96	48.23	23.01	13.46	20.11	2.13	1.28	4.59	166.8
2014	54.98	49.02	23.53	13.64	20.55	2.14	1.30	4.65	169.8
2015	55.99	49.81	24.05	13.82	20.98	2.15	1.33	4.72	172.8
2016	56.97	50.56	24.57	13.99	21.41	2.16	1.35	4.77	175.8
2017	58.01	51.35	25.11	14.16	21.86	2.17	1.38	4.84	178.9
2018	59.02	52.11	25.64	14.34	22.30	2.18	1.41	4.90	181.9
2019	60.06	52.89	26.19	14.51	22.75	2.19	1.43	4.96	185.0
2020	61.12	53.70	26.75	14.69	23.21	2.20	1.46	5.03	188.2
Growth 2005–2020	37.7%	32.9%	46.1%	27.0%	43.8%	13.4%	40.2%	28.5%	36.6%

Note: PCU-km estimates calculated using traffic contribution values (relative to passenger car = 1) of: LCV = weighted sum of standard light commercials (PCU=1) and large vans (PCU=1.5); Rigid truck = 2; Articulated truck = weighted sum of standard 6-axle semi-trailer (PCU=3) and B-doubles (PCU=4); Motorcycle = 0.5; and Bus = 2.

Source: BTRE (2003a, 2006a), BTRE estimates.

The costs of congestion

Congestion imposes significant social costs with interruptions to traffic flow lengthening average journey times, making trip travel times more variable and making vehicle engine operation less efficient. The cost estimates presented here include allowances for:

- extra travel time (e.g. above what would have been incurred had the vehicle been travelling under more freely flowing conditions),
- extra travel time variability (where congestion can result in trip times becoming more uncertain, leading to travellers having to allow for an even greater amount of travel time than the average journey time, in order to avoid being late at their destination),
- increased vehicle operating costs (primarily higher rates of fuel consumption), and
- poorer air quality (with vehicles under congested conditions emitting higher rates of noxious pollutants than under free-flow conditions, leading to even higher health costs).

Most studies that give congestion cost estimates are not entirely suitable for assessing the real impacts of congestion on society—or for valuing the *avoidable* social costs of congestion (i.e. those costs that could be saved under appropriate policy or operational intervention). This is because they are usually based on the *total* time costs for congestion delay—which refer to the differences in costs (borne by society) between average travel at the current congested traffic levels and travel under *totally uncongested* conditions. However, some level of delay is practically unavoidable if there are a reasonable number of interacting vehicles on a particular road link—that is, under real-world traffic conditions, it is typically not practicable (nor desirable on social or economic efficiency grounds) to reduce congestion to zero. To enable a *particular* vehicle to travel at free-flow speeds during a time of peak underlying demand would essentially require the suppression of most of that demand, and consequent high social costs to those not able to travel then.

'Total cost of congestion delay' estimates are derived by the BTRE methodology but only as intermediate values. Since total delay values are based on the value of the excess travel time compared with travel under completely free-flow conditions—an unrealisable situation for actual road networks—they are rather poor measures of the social gains that could be obtained through actual congestion reduction, and are only given in this paper for comparison purposes. A preferable set of values to use for the *'social costs of congestion'* are the estimated deadweight losses (DWLs) associated with a particular congestion level, which basically gives a measure of the *cost of doing nothing about current congestion* or the *avoidable costs of traffic congestion levels*.

That is, DWL valuations give an estimate of how much total costs (for time lost and other wasted resources) could be reduced if traffic volumes were reduced to the economically optimal level (which is defined as the level of traffic beyond which the full social costs of any further travel would outweigh the benefits of that extra travel). For most urban travel, including in times of peak demand, motorists only make an allowance for the time costs they are likely to face personally (i.e. the current *average* generalised cost) and do not also take into account all the extra delay that their entry into the already congested traffic stream is likely to impose on other motorists (i.e. allow for the *marginal* generalised cost for current traffic levels). If a pricing mechanism could be put in place that obliged all motorists to base their travel decisions not only on their private costs (represented by the current average cost values) but also on the additional costs imposed on others (the *external* costs—represented by the difference between the average and marginal costs), then transport choices would alter. Some trips would be deferred or not taken, others would be re-routed or taken on alternative modes. The resulting traffic flow (commonly termed the socially or economically *optimal quantity of travel*) would involve a somewhat lower vehicle density than before—but nowhere near as low as that required for free-flow speeds—and would theoretically have significantly lower congestion delay.

This BTRE study first estimates total delay costs, and then derives the DWL portion of those costs—and gives the final results for estimated social costs of congestion in terms of the deadweight losses associated with a respective congestion intensity and its level of total delay. (DWLs appear to be in the order of half total delay costs for typical peak traffic conditions—where their proportion would be much lower for light traffic and grow rapidly for severely congested areas).

The calculation of generalised costs requires the conversion of estimates of hours lost due to congestion into dollars—that is, a unit *value of time*. The unit cost rates used in the BTRE congestion estimation process (described in the following sections) were derived from standard Austroads values for road user costs (*Economic Evaluation of Road Investment Proposals—Unit Values for Road User Costs at June 2002*, Austroads 2004). The Austroads report gives different estimated values of travel time for different vehicle types, with private vehicle travel incurring costs in order of $9 per person-hour and business travel in the order of $20–$30 per person-hour. Freight vehicles get a further cost rate in terms of dollars per vehicle-hour (e.g. with a 6-axle articulated truck having an additional travel value of around $28 per vehicle-hour).

The BTRE analyses also include estimates of health/damage costs for urban air pollution, requiring the use of unit costs for motor vehicle emissions (e.g. in terms of dollars per tonne emitted). The unit cost rates used in this BTRE study are based on estimates of the health impacts of Australian air pollution by Paul Watkiss (*Fuel Taxation Inquiry: The Air Pollution Costs of Transport in Australia*). The Watkiss (2002) values for the costs of environmental damage due to air pollution vary greatly between the different emission species, ranging from $3 per tonne for carbon monoxide up to high costs of $342 000 dollars per tonne for particulate matter (for inner-city areas of the larger capitals). These unit costs imply that urban traffic contributes, on average, around 3.6 cents per vehicle kilometre travelled to the total social costs of air pollution (with about 2.5 c/km for cars and over 20 c/km for heavy vehicles).

The Bureau has also recently published a study on the costs of air pollution (BTRE 2005, *Health Impacts of Transport Emissions in Australia: Economic Costs*, Working Paper 63). The total (mortality and morbidity) cost values derived in Working Paper 63 are of a comparable magnitude to the Watkiss damage valuations, with metropolitan totals using Watkiss unit costs coming out higher than Working Paper 63's 'central' estimate for motor vehicle air pollution costs, but within the uncertainty/sensitivity range given around this central estimate. Unit values derived from the Working Paper 63 total costs were not suitable for this current congestion study—since that report 'estimated the long-term health impacts of ambient air pollution using particulate matter of less than 10 microns as a surrogate for all air pollutants'. The contribution of congestion to total emission costs requires the use of speed versus emission rate curves. And since the different emission species have reasonably different engine load versus emission response relationships, separate unit costs are needed for each individual emission type included in the analysis. This meant that the Watkiss (speciated) unit values were more useful for this study than a solely PM_{10} unit rate derived from Working Paper 63 costings.

BTRE modelling (e.g. see BTCE 1996b, BTRE 2003a) implies that traffic interruptions due to road congestion account for around 15 to 35 per cent of the emissions generated by urban motor vehicles, depending on the emission species, by increasing emission rates to higher than average levels during interrupted travel conditions. With congestion growing, this percentage is projected to increase by 2020. This current study attributes a congestion share of estimated total health costs from motor vehicle pollution according to calculated percentage ratios (for the proportional contribution of various levels of congestion, based on the various speed-emission rate curves).

An important point to stress is that the current BTRE approach is basically an *aggregate* modelling one—that is, it does not use detailed network models (which separately model traffic flows on all the cities' major roads), but aims to roughly estimate the scale of a city's congestion situation using aggregate indicators of a city's overall average traffic conditions. The main advantages of this aggregate approach relate to the ability to generate congestion cost estimates and projections with relatively slight computational and data resources. (Network models tend to require extensive data input and a considerable level of computational and maintenance support.) The main disadvantages relate to congestion being such a non-linear, inhomogeneous (in fact, so location-specific that certain bottlenecks can account for an inordinate amount of an area's total delay) and stochastic process that highly accurate assessments of its impacts can really only be accomplished using detailed network models.

The following congestion cost estimates are therefore provided as 'order of magnitude' evaluations—to help with considerations dealing with the likely aggregate costs of urban transport externalities, and their likely future trends. Detailed assessments of each of the cities' congestion impacts, especially analyses at the level of particular major city roads or thoroughfares, should be pursued using the appropriate network modelling frameworks and the Bureau firmly encourages the potential of various jurisdictions undertaking more congestion modelling on the network (and whole of day) scale, particularly using micro-simulation techniques. (Especially now that more powerful and less computationally resource hungry micro-simulation models are emerging and becoming more prevalent in the transport modelling arena, though it should be noted that wide-scale micro-simulation models are still highly data and calibration intensive responsibilities, e.g. see Austroads 2006a). Conducting such modelling on consistent bases will also allow more comparisons to be made between studies done in the various cities.

Furthermore, additional (network modelling) work dealing with the separation of total congestion delay into recurrent and incident-based components would also be useful. Incidents, such as road accidents and bad weather, contribute to a significant element of total delay; and their analysis is often best handled using traffic microsimulation approaches.

BTRE congestion work has typically used speed-flow relationships of the form:

$$ATT = T\ (1+a\{(x-1)+((x-1)^2 + bx)^{0.5}\})$$

where

ATT = Average travel time per kilometre,

T = Free speed travel time per kilometre,

x = volume-capacity ratio, and

a and b are adjustable parameters;

following the derivations of Kimber and Holis (1979) and Akcelik (1978, 1991).

Figure 1.20 plots some examples of typical speed-flow curves for a variety of road types, and an area *averaged* curve that results from aggregating delay over a set of road links and intersections (derived using network models). Though the current analysis does not entail *running* network models, the methodology does rely on previous Bureau results using network models for Australian metropolitan traffic assessment (see BTCE Report 92 for some details of analyses using the TRANSTEP trip assignment model). Part of the Bureau network modelling work allowed the semi-empirical derivation of aggregate speed-flow response curves, by averaging over sets of links and intersections within a defined area.

To derive the current BTRE congestion cost estimates, a set of aggregate speed-flow curves were used for the analysis, using aggregate data on traffic flows for the Australian capital cities (i.e. relating average vehicle travel speeds to the average road network volume-to-capacity ratios for the major road types and areas of the city). The functional forms were partly calibrated using data on average speeds over the cities' arterial and major road networks (from the *Austroads National Performance Indicators*) and BTRE estimates of urban VKT by the various vehicle types (as shown in figures 2.3 to 2.19). The BTRE base case projections (of city-by-city VKT growth, along with assumptions about likely trends in road capacity growth) then allow estimates of likely average speed reductions for future traffic levels.

A sample of some of the vehicle speed response curves used within the BTRE models, for fuel consumption and vehicle emission rates, are given in figures 2.21 and 2.22.

Figure 2.20 Representative functional forms for normalised speed-flow relationships for various road types

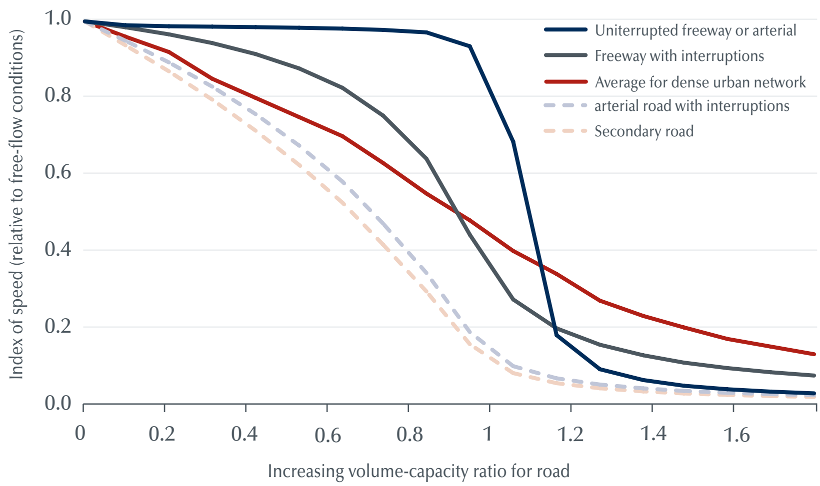


Figure 2.21 Typical response curves for average fuel consumption to variation in vehicle speed

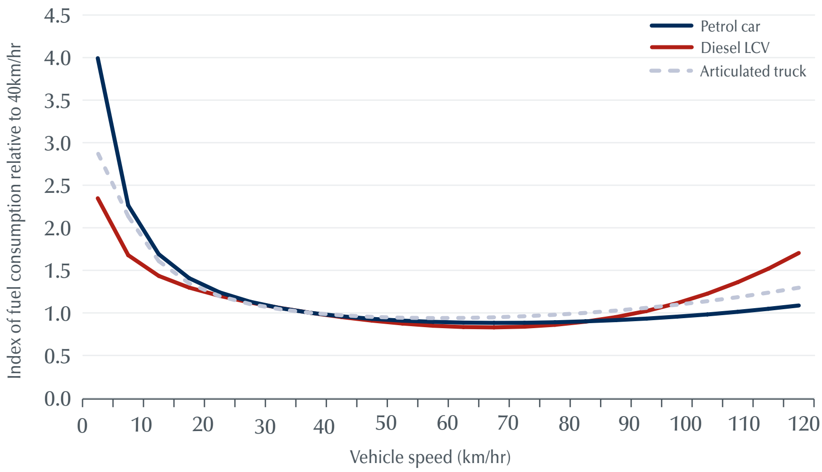
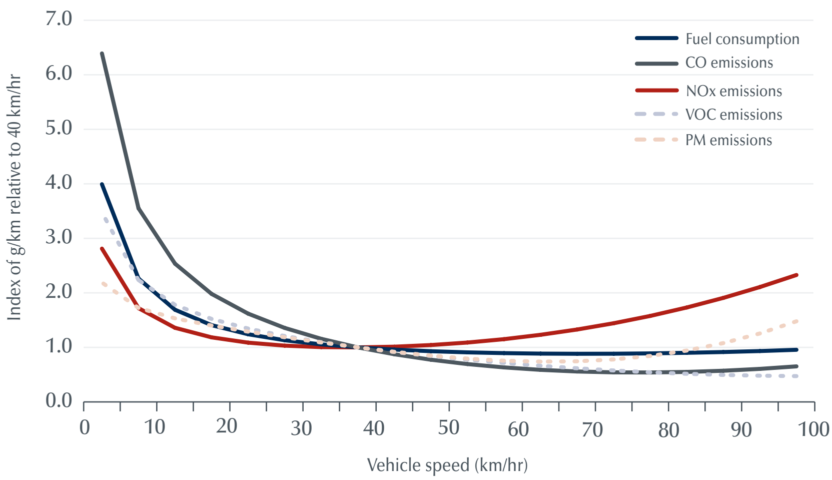


Figure 2.22 Typical response curves for petrol car emission rates to variation in speed, by pollutant type

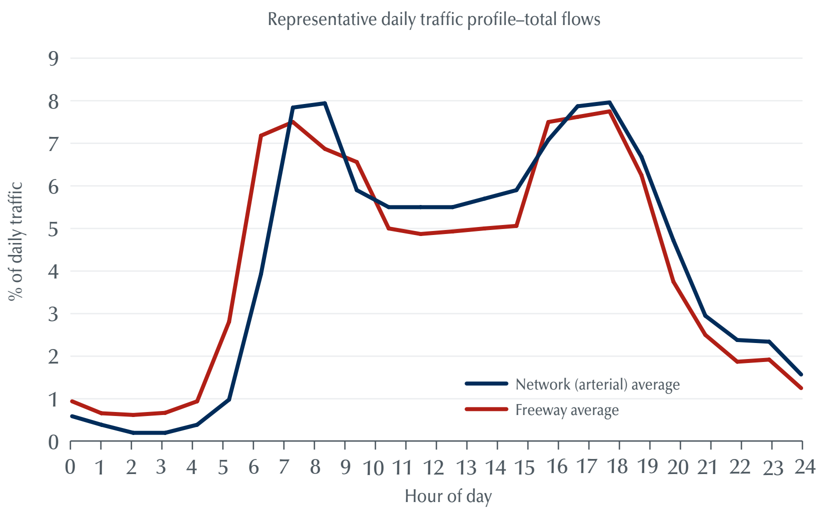


The following section outlines the current BTRE methodology, giving a primarily graphical overview of the steps involved in the congestion cost estimation process, using the various functional forms derived (relating aspects of congestion and overall network performance to average levels of traffic using the network at various times of the day). For a schematic diagram briefly summarising the cost estimation process see Appendix figure A.3.

Total congestion cost estimation

BTRE estimates of total metropolitan VKT for a particular city (e.g. as shown in figures 2.12 to 2.19) are first used to derive an average daily traffic level for the entire network, which is then subdivided into VKT on each of the main road types for each hour of the day, using average daily traffic profiles for the current city networks.

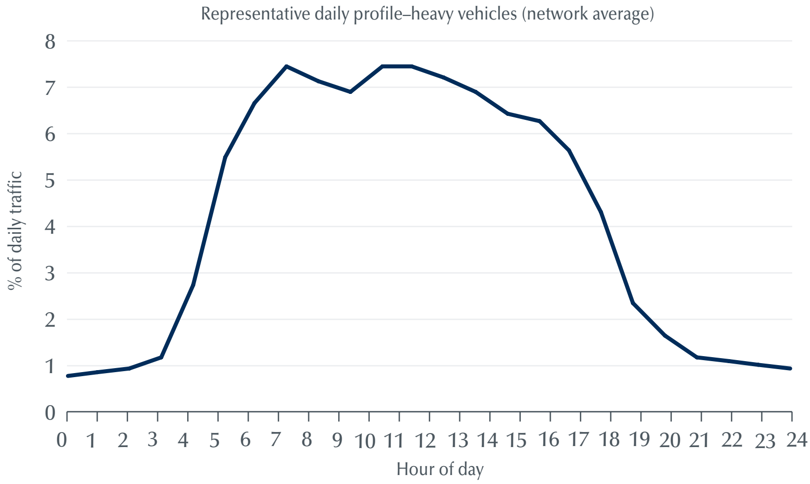
Figure 2.23 Hourly traffic volumes for typical metropolitan travel



The hourly VKT levels are then subdivided between the various vehicle types (according to the total vehicle-specific utilisations given in figures 2.12 to 2.19) using average daily profiles derived for the major components of overall traffic.

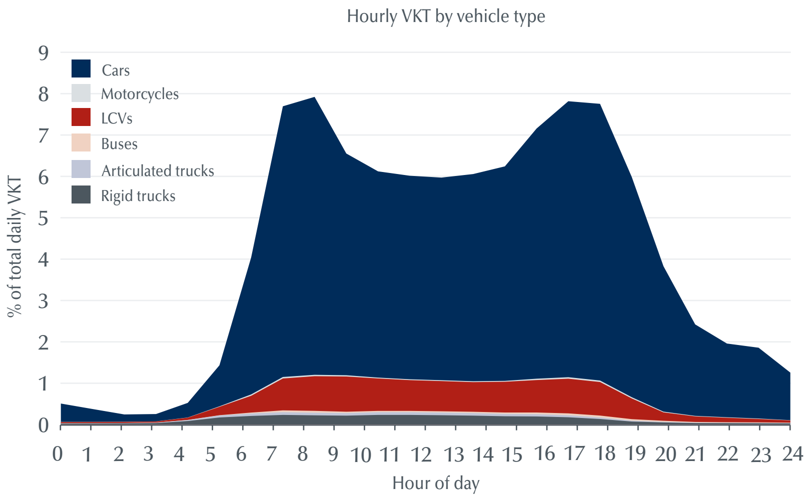
For example, the hourly pattern of private car use is very close to the average profile shown above, while that for freight vehicles tends to involve a greater proportion of travel outside of the traditional peak periods (where a representative profile for trucks is given in Figure 2.24).

Figure 2.24 Typical daily traffic profile for commercial vehicles



Using the various road type and vehicle-specific daily profile curves gives the following (figures 2.25a and 2.25b) general shapes for hourly distributions of average Australian metropolitan traffic throughout the day (for a typical weekday).

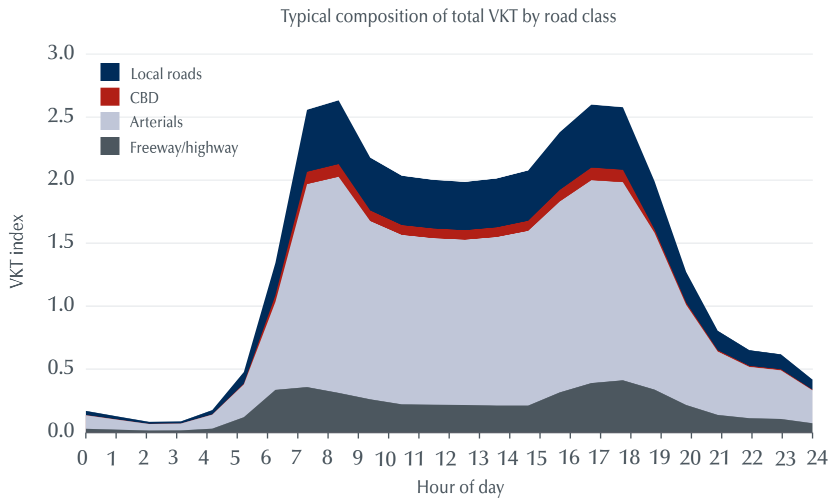
Figure 2.25a Typical daily VKT profile by vehicle type



The application of average vehicle occupancy rates to these VKT profiles then allows the pattern of daily passenger-kilometres to be estimated (with the occupancies also varying by time of day, e.g. average bus loading levels being much higher during peak periods than during the off-peak).

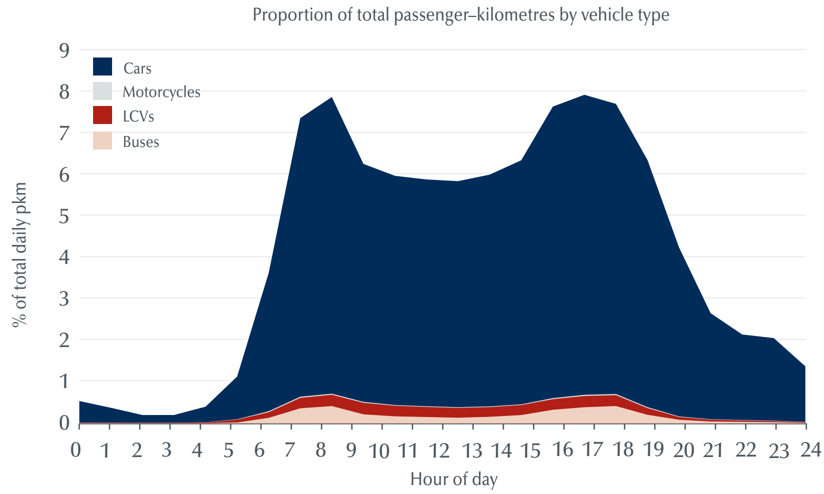
Note: for estimating passenger tasks of LCVs and trucks (i.e. as opposed to freight or service uses), the non-business portion of total VKT is used.

Figure 2.25b Typical daily VKT profile by road type



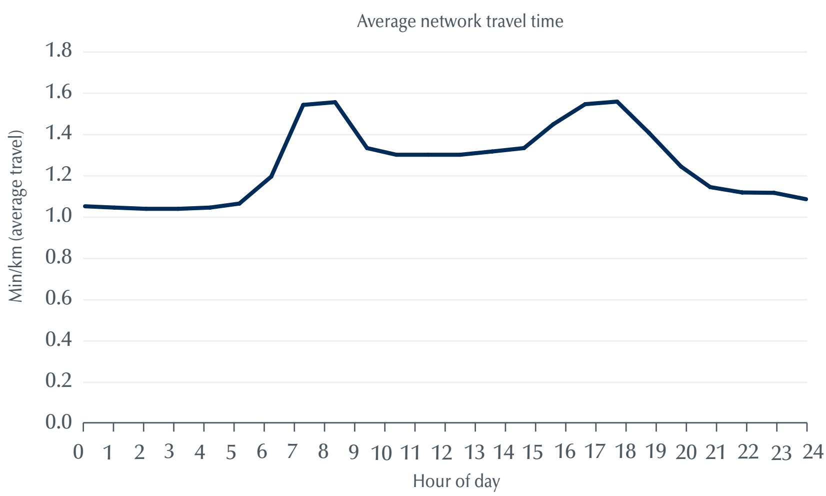
Applying occupancy rates to the VKT pattern plotted in figures 2.25a and 2.25b, after allowing for the variation of average vehicle occupancy rates over the hours of the day, results in the following estimated profile for metropolitan passenger task (pkm) by time of day.

Figure 2.26 Typical daily passenger task profile by vehicle type



Using the appropriate aggregate speed-flow curves for the various road types and city areas, and summing over the resulting estimates of average travel speeds (weighted by the VKT distributions derived above) for each hour of the day then gives an estimate for the network-wide average travel time pattern over the day.

Figure 2.27 Average urban traffic performance by time of day

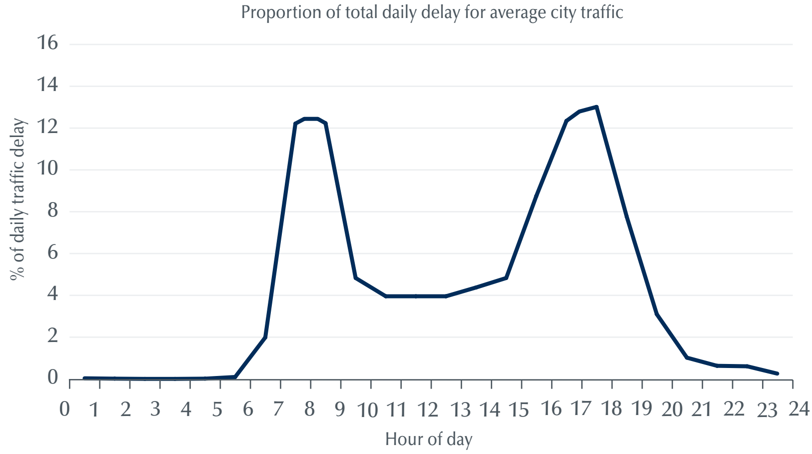


Using estimated or assumed 'free' speeds (i.e. average traffic speeds encountered under totally uncongested conditions) for each major road type then allows average *delays* (free speed minus actual traffic speed) to be calculated. A significant part of the uncertainty associated with this type of congestion estimation methodology relates to the setting of the *free* speed values, since they are typically not precisely known for most real-world travel. The values used in the current analyses are a combination of floating-car values for off-peak travel (when available), estimates of likely free speed levels based on the measured differences between peak speeds and traffic volumes versus inter-peak speeds and volumes (when fully off-peak values not available), estimated network free speeds from the Bureau TRANSTEP modelling work, and literature values for various cities (which are typically derived from network models, calibrated to floating-car records, or traffic monitoring data).

Several cities report annual averages for their posted speed limits (i.e. traffic weighted averages across the whole city's major road network, including all arterials and freeways, of the speed limits on each road link) to Austroads' *National Performance Indicators*. These values tend to vary somewhat from city to city, and typically fall in the range of between 65 to 75 kilometres per hour. Due to road lay-out and design factors (such as the density and control of intersections), actual traffic on these city networks will not generally be able to travel at the posted speed limits even during uncongested traffic conditions. The current BTRE model specification has input values for approximate network-wide free speeds typically ranging between about 56 to 65 kilometres per hour.

The resulting pattern for average delay over the day (for an average week-day), summed over the road types, for a typical major metropolitan area is shown in the next graph (figure 2.28).

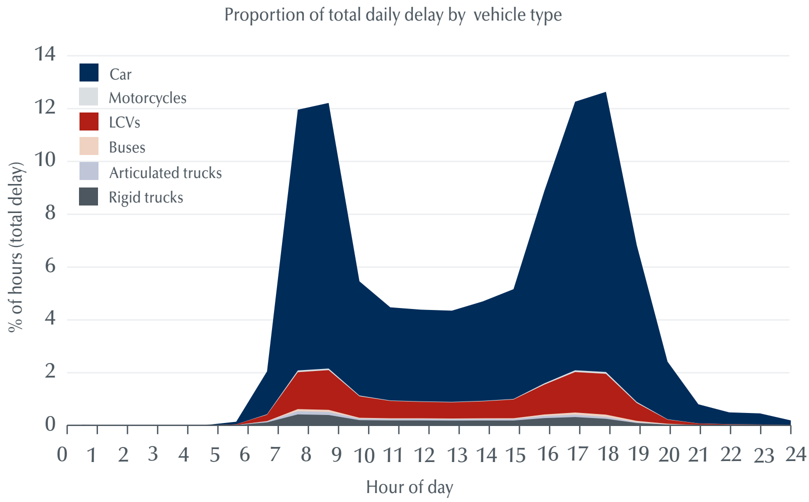
Figure 2.28 Typical delay profile



Note: Total delay refers to the comparison of trip times at average recorded traffic speeds and at free-flow speeds for the network.

The total delay is spread over the main vehicle types as shown in Figure 2.29 (estimated using the vehicle-specific daily profiles discussed previously).

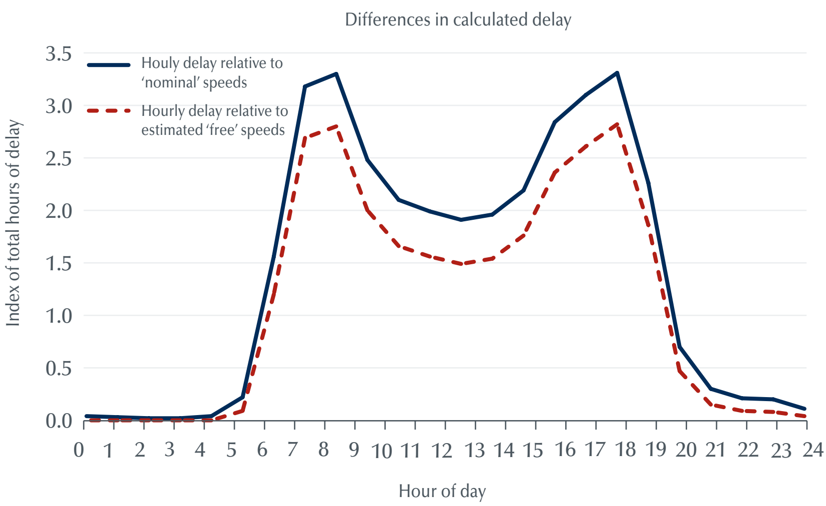
Figure 2.29 Typical daily delay profile by vehicle type



Some literature values (and a variety of congestion indicators often used by road authorities) are based on delay values relative to *'nominal'* speeds (i.e. based on average posted speed limits) rather than comparisons to estimated 'free' speeds. This practice has the advantage of nominal speeds being more precisely defined than free speeds, and tending to be much easier to estimate than free speed values. However, such comparisons to nominal speeds are not as useful for congestion cost estimation since travel at nominal speeds is often not possible for many actual road links, even in times of zero congestion. Free-flow speeds for many roads are typically dependent on the particular road design, especially its number of intersections (and other signalised or unsignalised impedances), and therefore, realistic *free* speeds are often (particularly for inner-city streets) considerably below posted or nominal speeds.

For example, if the previous delay calculations (as shown in figure 2.28) were done using average nominal speeds, as opposed to estimated free speeds, the total daily delay calculated would be significantly higher, simply due to the chosen comparison speed for defining 'delay'. The typical order of magnitude for this definitional divergence is illustrated in the next graph (figure 2.30).

Figure 2.30 Divergence in estimated delay depending on comparison speeds



Using the previously discussed unit values for travel time (based on the Austroads standards) then gives estimates for the dollar values of total delay (i.e. travel time lost, relative to free speeds) due to congestion. The estimates assume that since around 10 per cent of urban journeys are under 2–3 kilometres in length, that a portion of total trips will not tend to take long enough on average to incur noticeable delay. The current model setting is for an assumed five per cent of trips to be below the threshold of incurring noticeable delay–and are allocated zero delay costs. It is also assumed that average delays incurred on local roads are considerably below those encountered on major metropolitan arterials and freeways (especially during peak periods).

Another adjustable parameter in the model relates to the proportion of trips that (due to particular trip purposes, origin-destinations or individual user preferences) are likely to be less time-sensitive than average. The current assumption (input to the base case scenario) has around 10 per cent of light vehicle travel and around 5 per cent of heavy vehicle travel as being less time-sensitive trips (with the parameter value varying throughout the day, such that time insensitivity is more likely outside of business hours than during them), which are allocated a unit time delay cost of half the standard rate. All these parameters are adjustable, as better data on trip distributions and travel time valuations become available.

Note that the congestion cost values derived by this study, even though given in *dollar* terms, are not directly comparable to aggregate income measures (such as GDP). Some elements involved in the costings have GDP implications (e.g. the timeliness and reliability of freight and service deliveries will impact on business productivity levels). However, a major proportion of the derived cost values refer to elements that play no part in the evaluation of GDP, such as private travel costs.

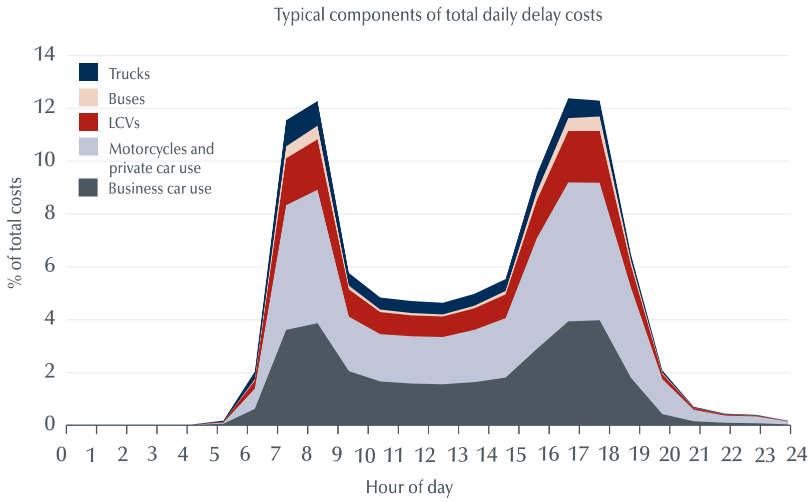
Any reduction in congestion delay due to some traffic management measure will typically have some time savings benefits for road users; but the size of those benefits (in dollar terms, using *generalised* costings)—especially with regard to private individuals—will not give a direct estimate of the size of any GDP changes that happen to flow from the congestion reduction.

Total delay cost values

BTRE preliminary analyses give an Australian total of $11.1 billion for total (i.e. relative to free-flow) annual delay costs over the Australian capitals for 2005 (comprising $5.7 billion in private vehicle delay and $5.4 billion in business vehicle delay)—with Sydney (at $3.9 billion), Melbourne (at $3.6 billion) and Brisbane (at $1.44 billion) comprising a major portion of this total. The other cities contributed $0.78 billion for Adelaide, $1.05 billion for Perth, $80 million for Hobart, $27 million for Darwin, and $182 million for Canberra.

The average distribution of these costs over the day, by vehicle type, is displayed in the following graph (figure 2.31).

Figure 2.31 Distribution of total delay costs by vehicle type



The base case demand projections (coupled with the speed-flow and daily profile functions in the BTRE models) have this value of total metropolitan delay rising to $23 billion by 2020 (with private travel incurring $10.9 billion and business vehicle use $12.1 billion). The city specific levels rise to $8.3 billion for Sydney, $7.0 billion for Melbourne, $3.4 billion for Brisbane, $1.4 billion for Adelaide, $2.4 billion for Perth, $0.11 billion for Hobart, $50 million for Darwin, and $0.3 billion for Canberra.

To these total delay costs, the methodology then adds an (additional) allowance for trip variability (as a measure of system reliability). Trip variability in uncongested traffic conditions tends to be quite low, but variability in travel time grows as the traffic level increases toward the road's rated capacity. Over a fairly congested road link, the travel times will tend to exhibit quite a large spread, with the maximum time taken to cover the link often being several times larger than the minimum time.

The current BTRE variability assessment uses measures of the spread of travel times over different trips for a certain time of the day–based on Austroads *National Performance Indicators* data for average network travel variability and on analyses of the slopes of the derived travel time functional forms (described above, with regards to figure 2.20). The extra travel time required by a certain level of speed variability then has dollar values attached to it, again using the Austroads unit values of time. With respect to the unit values for delay (e.g. in terms of minutes lost per km), an elasticity of 0.8 for private travel and of 1.2 for business travel (where many businesses tend to value trip reliability very highly for product deliveries and service distribution) is applied to one standard deviation (SD, in min/km) around the mean travel time for the relevant period.

These expanded time costs thus make some allowance for:

- the extra time lost due to travellers having to leave earlier than they would otherwise choose (if they could rely on average trip times being fairly constant) to avoid being late at their destinations; and
- the costs to individuals and businesses of not only having their average travel take substantially longer in peak traffic conditions, but that trip times are also more likely to be unpredictable, and that they will often fail to meet schedules.

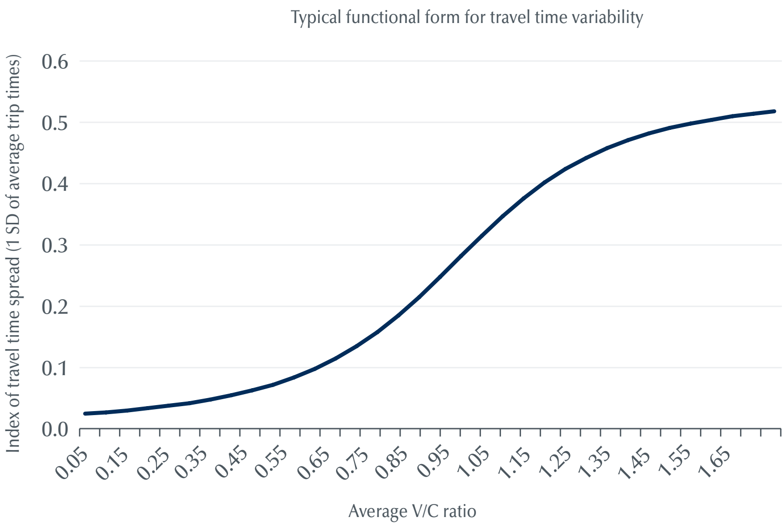
A representative functional form (for the dependence of trip variability on increasing traffic levels), derived from the average trip time functions presented earlier, is shown in figure 2.32. The functional expressions for such curves (e.g. see Ensor 2002) are typically of the form:

$$Var = S_0 + S_1/(1 + \exp(-c(x - d)))$$

where

Var = the standard deviation in average trip times (mins/km);
x = volume-capacity ratio of the road's traffic level;
S_0, S_1, c and d are adjustable (positive) parameters depending on the road type.

Figure 2.32 Representative variation of trip reliability with traffic volume



Each period's average trip variability value—in terms of the extra minutes taken per kilometre that slower travel (at one standard deviation above the mean travel time for that period) entails—is calculated from the relevant traffic volume estimates. The difference is then taken between estimated free-flow trip variability and the estimated trip variability values for the various time periods (and vehicle types). These differences are multiplied by the VKT for that period, summed over the hours of the day, and multiplied by the relevant vehicular value of time, thus giving an estimate for the total cost of trip variability due to congestion.

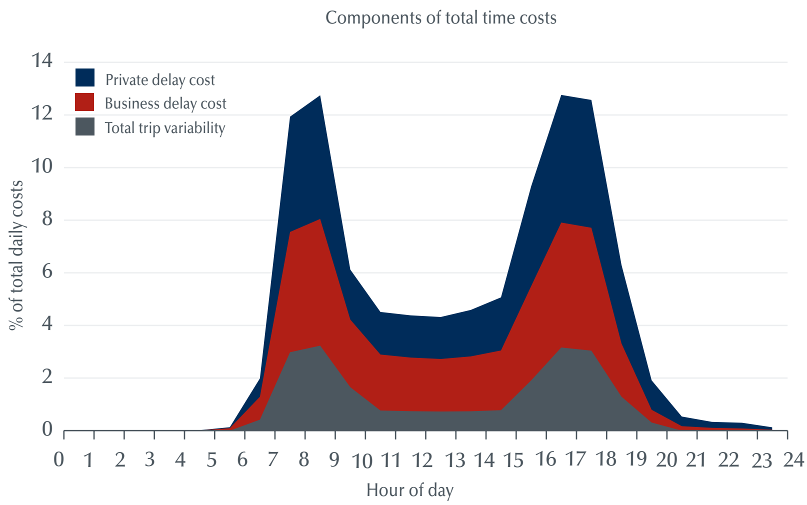
This method of valuing trip variability may tend to somewhat underestimate the total actual costs to businesses since it does not allow for wider economic effects than those directly related to congestion delay for their operating vehicles. Some other impacts congestion can have on businesses include possible reductions in market accessibility; restrictions on locations, inventory practices and specialised labour (or input materials) reducing possible economies of scale; and possibly increased labour costs (associated with wage rates tended to having to compensate workers for their higher commuting costs). Assessing such costs is beyond the scope of this study though they are likely to be substantial in magnitude. Some studies suggest that these broader economic costs to business could be comparable in size to the direct travel costs due to congestion (and, based on this, a rough sensitivity result for their possible impact on the total estimated costs is derived in a following section of the report).

The chosen parameters for the variability costings could be considered conservative–since they are based on a single standard deviation in travel time (i.e. covering variation in travel times to about the 68th percentile, if normally distributed) and an elasticity of approximately one (for the value of time lost due to trip variability versus the value of time lost due to standard delay). However, the engineering definitions of trip variability are commonly based upon 85th percentile travel times (i.e. approximately 1.44 standard deviations from the mean), and some literature values imply that surveyed travellers often express a significantly higher value of time for trip variability losses, as opposed to time losses from expected levels of (recurrent) delay.

This current method of valuing trip variability adds around 25 per cent to the total delay costs. For example, the total time cost for Australian metropolitan areas—i.e. the value of total hours of delay (due to average travel times being above free flow times) plus the extra hours for trip variability (above free-flow levels of variability)—for 2005 has been estimated by our model to be around $14.1 billion dollars. The base case projections push this to around $30 billion for 2020.

The average distribution typical of current total time costs (due to congestion-related delay and travel time variability) over the hours of the day is displayed in figure 2.33.

Figure 2.33 Typical daily profile of total time costs

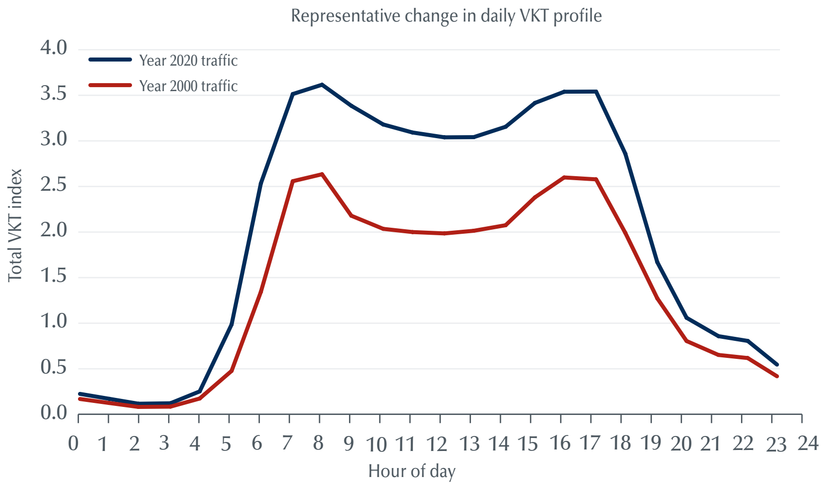


Notes: Costs here refer to on-road travel times compared with free-flow conditions.
Costs calculated using VKT data for a base year of 2000.

When projecting the congestion costs into the future, the BTRE models allow for some travel time substitution effects. If increasing traffic levels lead to a period's generalised travel costs rising sharply enough (as will tend to happen in peak periods where travel times are already much longer than average, and where the marginal costs of travel are particularly high), then a portion of the increasing VKT has its trip timing decision deferred or brought forward, into a period of lesser generalised cost. This leads to a certain amount of peak-spreading in the projected daily profiles, with the amount of traffic in the *shoulder* periods (around the main peak times) and in the *inter-peak* period tending to increase by a greater percentage than for the peak volumes.

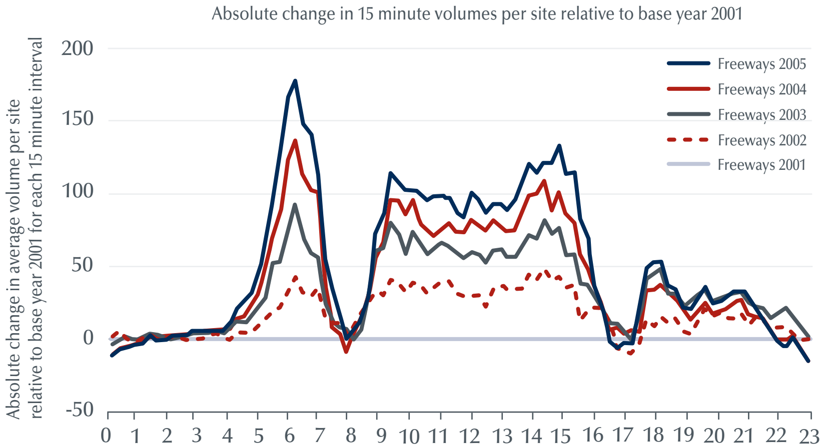
Figure 2.34 displays how the shape of the daily VKT profile alters over the term of the projection period (for average metropolitan travel in the base case), where even though there is still significant growth in the peak periods, there is substantially greater proportional growth in the hours around the standard peak hours.

Figure 2.34 Projected daily VKT profile



This pattern of limited growth in peak periods, while growth in periods around the peak remains strong, is already apparent in recent yearly data for particular city links (due to many major metropolitan roads already operating close to their rated capacity at certain times of day). For example, the following growth patterns (figure 2.35, reproduced from VicRoads *Traffic Systems Performance Monitoring* Information Bulletin) have been reported for Melbourne's freeway traffic over the last few years–where practically all the growth in traffic volume has occurred outside of the times of highest total volume (i.e. the peaks at 8 am and 5:30 pm).

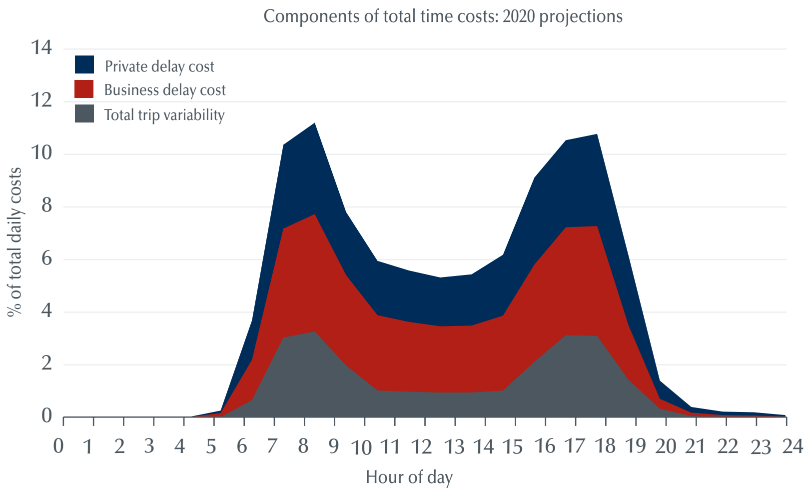
Figure 2.35 Growth in Melbourne freeway volumes



Source: VicRoads Information Bulletin, Traffic Systems Performance Monitoring 2004/2005

The projected peak spreading leads to the forecast daily profile for total time costs (associated with congestion) to flatten somewhat, over the course of the day, by 2020. For example, if the shape of the daily cost profile curve representative of year 2000 average traffic volumes (presented in figure 2.33) is compared to the 2020 projected curve (given in figure 2.36), then it is apparent that the contributions of the peaks are much less prominent by 2020.

Figure 2.36 Projected daily profile of total time cost



Note: Costs here refer to travel compared to free-flow conditions

Congestion estimation method–avoidable social costs

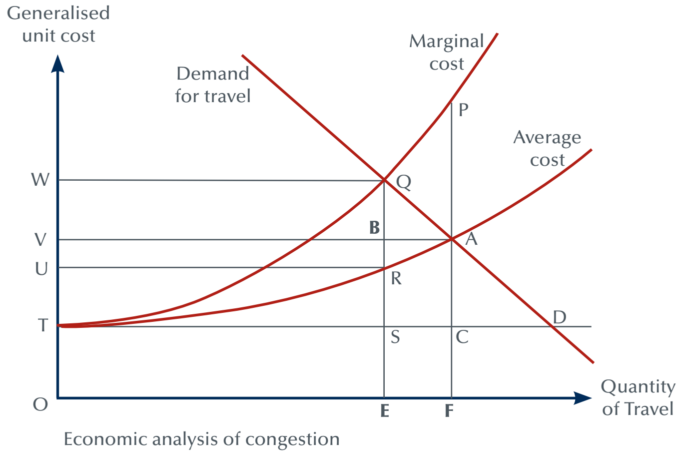
The cost estimates given in the above section (i.e. *total* time costs for congestion delay) are not actually very useful for assessing the impacts of congestion on society–or for valuing the *avoidable* social costs of congestion (i.e. those costs that could potentially be saved under appropriate policy or operational intervention).

As already mentioned, estimates of the 'total cost of congestion delay' are based on the value of the excess travel time (and other external or resource costs) incurred by the actual traffic over those that would have occurred had that traffic volume operated under completely *free-flow* conditions. Such conditions are of course an unrealisable hypothetical situation for actual road systems. So the congestion cost values given so far are really only useful as trend indicators, when comparing totals over time, rather than a direct measure of actual savings in social costs that may possibly be made through congestion-reduction measures.

A better set of values to use are the estimated deadweight losses (DWLs) associated with a particular congestion level–essentially giving a measure of the **'cost of doing nothing about congestion'** or the **'avoidable social costs of congestion'**. That is, DWL values give an estimate of how much total social costs could be reduced if traffic volumes were reduced (either by appropriate pricing mechanisms or other demand management techniques) to the economically optimal level (i.e. to traffic volumes beyond which the full social costs of any further travel would outweigh the social benefits of that extra travel–given by the intersection of the travel demand curve and the generalised marginal travel cost curve).

For a brief overview of the theory behind the DWL valuation, and what portion of total congestion costs that the DWLs account for, refer to figure 2.37 below (reproduced BTCE 1995).

Figure 2.37 Basic economic theory of congestion costs



Source: BTCE (1995a).

The average cost curve in the diagram represents the unit cost of travel as perceived by individual road users and is essentially the basis for individual trip decision making. This curve is generally comprised of vehicle operating costs (such as maintenance and fuel expenses) and travel time costs (i.e. the average trip time, at that level of congestion, multiplied by a dollar value of time). Since the costs include dollar values for non-financial quantities (i.e. travel time) they are *generalised* costs.

This 'Average Cost' curve is given by averaging the total generalised travel cost for all road users (for the traffic level on the network link under consideration) across the number of those users (i.e. the product of the generalised unit cost at point **A**, equal to value **V**, by the quantity of travel for point **A**, equal to value **F**, gives the total cost incurred by all road users at that level of traffic). The marginal (social) cost curve is given by the derivative of this total cost (with respect to quantity of travel). That is, the 'Marginal Cost' curve gives the contribution to total travel costs for the marginal unit of travel, where the distance between the marginal and average cost curves represents the additional costs imposed on others (but not typically taken into account) by an extra motorist entering the traffic.

The **total** cost of congestion is equal to the size of the area bounded by the points **VACT**—or equivalently the area under the marginal cost curve less the generalised costs at free flow (i.e. the area **TPC**). A better measure of congestion impacts is the *'external'* costs of congestion—i.e. the costs that road users impose on others, through not having to personally meet the total costs caused by their travel decisions—given by the difference between the area under the marginal cost curve and the average cost curve, equal to area **TPA**. Though somewhat more sound than total delay costs (as an indicator of congestion's actual social impact), the external costs of delay still tend to overstate the actual problems associated with congestion since they are still relative to the unrealisable situation of free flow travel speeds.

Theoretically, a better measure of congestion's social costs is given by the deadweight loss of the current congestion level. The problem with a currently congested situation is that it includes a quantity of travel (in the range between the points **E** to **F** along the x-axis of Figure 2.37) for which the total travel costs exceed the social benefits of undertaking that travel. The net loss on this travel (the DWL of current congestion) is given by the area between the marginal cost curve and the demand curve (within the external cost area)–i.e. the area **PAQ**. Avoiding this loss (e.g. through the use of congestion charging or other transport demand management) thus provides a net social benefit of this amount (i.e. **PAQ**, evaluated in dollars), giving an estimate of the 'cost of doing nothing about congestion' or alternatively the 'net benefit from optimal congestion reductions'. DWL estimates (termed here the **'avoidable'** costs of congestion) have the advantage of not being the costs relative to the unfeasible situation of total free-flow, but rather are costs relative to the economically most efficient level of traffic for the road network.

Another (essentially equivalent) way viewing of the definition of such social costs (that is independent of any considerations of required pricing or traffic management mechanisms) consists of considering two of the main cost components that change as the traffic gets heavier. Referring again to Figure 2.37, consider the case of the traffic situation at point **R** (with quantity of travel **E** and average travel cost **U**) increasing to the level at point **A** (with traffic intensity **F** and average travel cost **V**). The two main changes to net social welfare involve:

- an increase in consumer surplus for the extra travellers (whose overall utility improves) by an amount given by the area **BAQ**; and

- an increase in total travel costs for all existing users (due to the higher congestion at point **A**), given by the area **VBRU**.

The net increase in costs from the increased traffic congestion is therefore equal to area **VBRU** less area **BAQ**, which given the geometry of the marginal cost curve, is equal to area **PAQ**. Thus if point **R** is taken as a suitable benchmark for congestion comparisons (since as it is defined here by the intersection of the travel demand curve and the marginal cost curve, the benefits of any extra travel beyond this point are outweighed by the extra costs to society), then area **PAQ** becomes the most economically appropriate value to take for the social costs of that congestion.

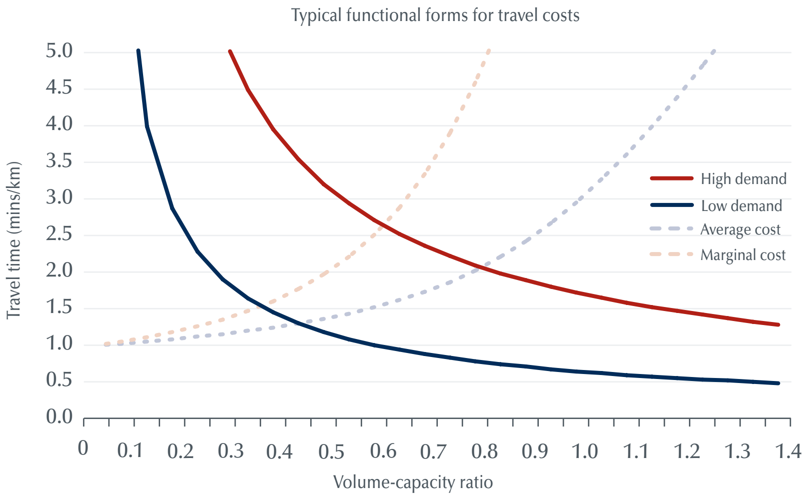
It should also be noted that even though these cost levels are *theoretically* avoidable, they do not directly relate to any net savings that may be possible under any particular congestion abatement policies. A DWL valuation gives an (order-of-magnitude) estimate of the worth society places on the disadvantages of current congestion-related delays and transport inefficiencies, relative to travel under less-dense traffic conditions (i.e. at economically optimal traffic levels). It does not allow for any of the wide range of costs that would be associated with actually implementing specific traffic management measures. The introduction of any measure aimed at congestion reduction will typically incur both set-up and ongoing operating costs, which will have to be considered separately from any benefits arising from changes in overall consumer utility (estimated here by the DWL reductions).

Also, remember that the derived congestion costs (dollar amounts) are not directly attributable to some equivalent proportion of GDP, since a major share of the congestion cost values refer to elements that play no part in the evaluation of GDP, such as private travel costs.

For the current analyses, average cost curve functions (and their associated marginal cost curves) have been derived for the various components of the cost calculations (largely based on the Bureau TRANSTEP modelling work, suitably calibrated for more recent aggregate network performance data). The calculation of the various cost elements (especially those given by the different areas just discussed with regards to figure 2.37) then proceeds using constant elasticity demand functions (derived from results given in BTCE Report 92) and typical aggregate relationships between the cost elements (again discussed in Report 92).

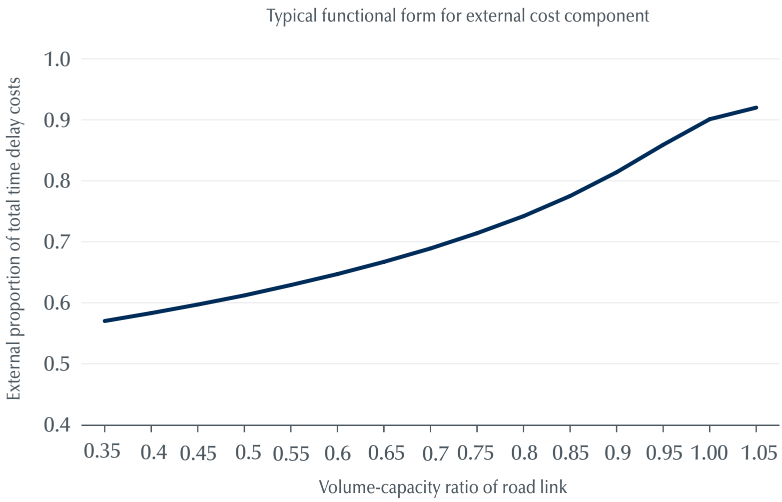
The resulting functional forms (in the current BTRE methodology) typically have the general shapes displayed in the following illustration (figure 2.38, which displays two different examples of possible demand curves). It should be noted that the current aggregate methodology relies on the assumption of constant demand elasticities—where the characteristic elasticity (with respect to total generalised travel cost) of the demand curves is taken to be -1.2, based on analyses described in Chapter 5 of Bureau Report 92 (BTCE 1996b). Other parts of the demand analyses use elasticities with respect to just the fuel price component of total travel costs, and these elasticities range between -0.1 to -0.3, depending on the type of vehicle use and the term over which the demand response is calculated. The estimated results would differ somewhat if the chosen demand elasticity was changed in value–or if the elasticity actually varies considerably between different periods of the day and different groups of travellers (i.e. the elasticity is highly non-constant).

Figure 2.38 Modelled average and marginal cost curves



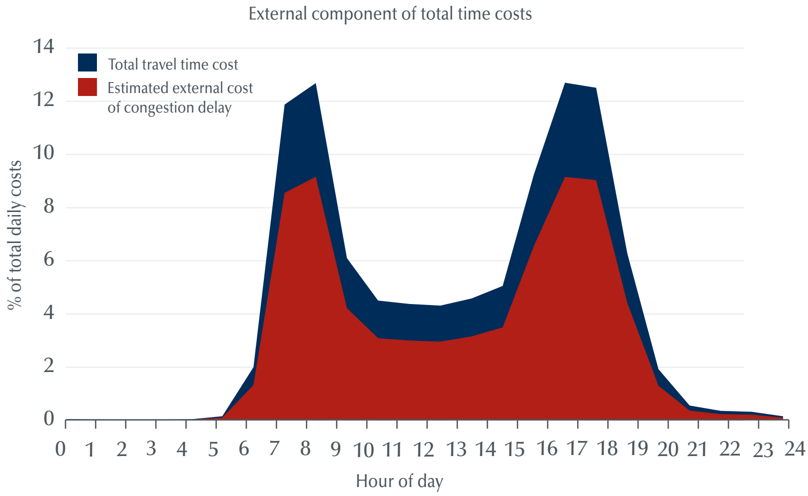
For each road type in the model, the chosen speed-flow relationships (using the formula given on page 81 of the report) allow the calculation of average cost curves, which are then differentiated to obtain marginal cost curves. The derived cost functions are then integrated, to derive the various areas under the curves (corresponding to the cost elements discussed with regards to figure 2.37). For example, consider the following graph (figure 2.39), which plots the result of calculating the areas **TPA** and **TPC** (again referring to the elements of figure 2.37) for the functional form of a typical divided arterial (given by using the parameter values of a = 16.7, b = 0.004 and T = 1 min/km in the formula given on page 81). The values in figure 2.39 are equal to the division of area **TPC** by area **TPA**, which provides an estimate of the proportion of the total costs that are external costs, for this example road link.

Figure 2.39 Proportion of external costs for a typical divided arterial



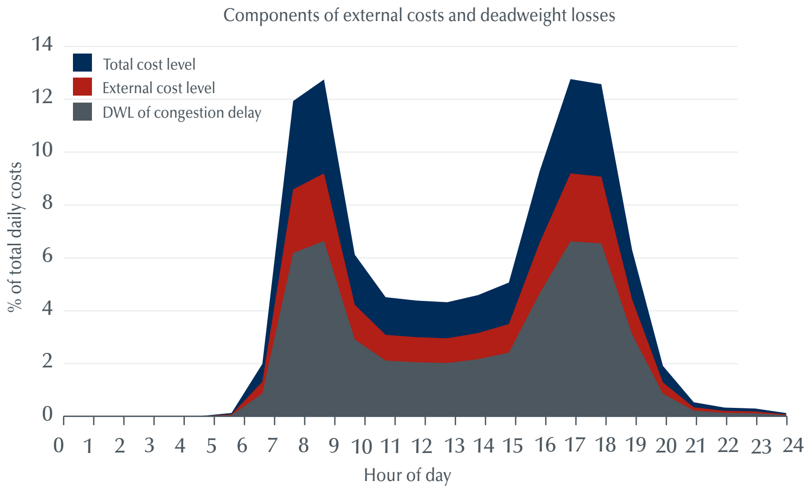
The next figure (2.40) then shows the typical proportion of total time costs that are external costs for the estimated network as a whole, over the hours of a typical week-day—i.e. after summing components from the major road types in the model, each divided according to their relevant external-proportion curves, such as given in Figure 2.39—again based on the results of the Bureau TRANSTEP modelling work and integration of the derived aggregate functional forms (e.g. those shown in figure 2.38).

Figure 2.40 Proportion of external costs



The demand curves (with the assumed constant elasticity) are then calibrated to pass through their relevant point **A** (again referring to the diagram of figure 2.37), so that their intersection with the derived marginal cost curve fixes the placement of point **Q** (and thus the size of area **PAQ**). Proceeding with a similar (numerical) integration to that for figure 2.39 yields a similar relationship for the DWL component (i.e. for what proportion area **PAQ** is of area **TPA**, depending on the volume-capacity ratio of the road link). Using this proportional relationship on the external cost values previously calculated (e.g. Figure 2.40) for each road type, and summing across all the modelled components yields, an aggregate estimate of the DWL fraction, and thus the following proportional makeup of total costs (figure 2.41), where the Figure shows the relative amounts typically accounted for by the *external costs* and the *deadweight losses* for current traffic profiles.

Figure 2.41 Proportion of external costs and deadweight losses

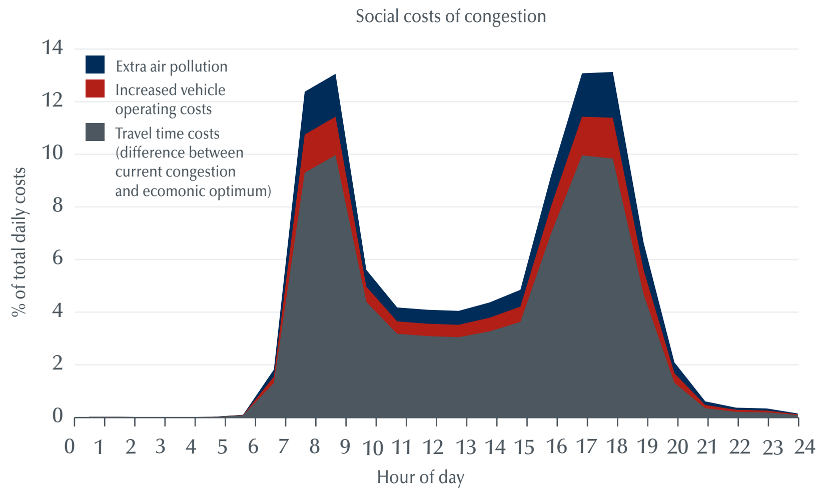


The resulting average proportions from this estimation process (using the current model specification) are for aggregate external costs to be approximately 70 per cent of total costs (typically ranging between about 60 to 75 per cent) and for the deadweight losses to be around 50 per cent of total costs (typically ranging between about 30–55 per cent). It should be noted that this part of the estimation process is quite approximate, and is reliant on several input assumptions (e.g. the demand curve elasticity), and could introduce an additional element of uncertainty into the final cost estimates, perhaps of the order of 10–20 per cent.

Once the DWL values have been calculated for each city network (for each year), estimates of the full (avoidable) social costs of congestion are derived by adding in the appropriate cost estimates for extra vehicle operating cost (VOC) and for extra air pollution (using the types of functions displayed in figures 2.21 and 2.22).

The resulting daily composition of these aggregate avoidable costs (which essentially comprise the *possible net benefit from optimal congestion reductions*) is shown in figure 2.42.

Figure 2.42 Typical daily profile for avoidable costs of congestion



Avoidable social cost values

BTRE base case results give a total of about **$9.39 billion** for national *social costs of congestion* (i.e. potentially avoidable costs, calculated on a DWL of current congestion basis) over the Australian capitals for 2005. This total value is comprised of approximately $3.5 billion in private time costs (DWL of trip delay plus variability), $3.6 billion in business time costs (DWL of trip delay plus variability), $1.2 billion in extra vehicle operating costs, and $1.1 billion in extra air pollution costs. The national total is spread over the capital cities with Sydney the highest (at about $3.5 billion), followed by Melbourne (with about $3.0 billion), Brisbane ($1.2 billion), Perth ($0.9 billion), Adelaide ($0.6 billion), Canberra ($0.11 billion), Hobart ($50 million) and Darwin ($18 million).

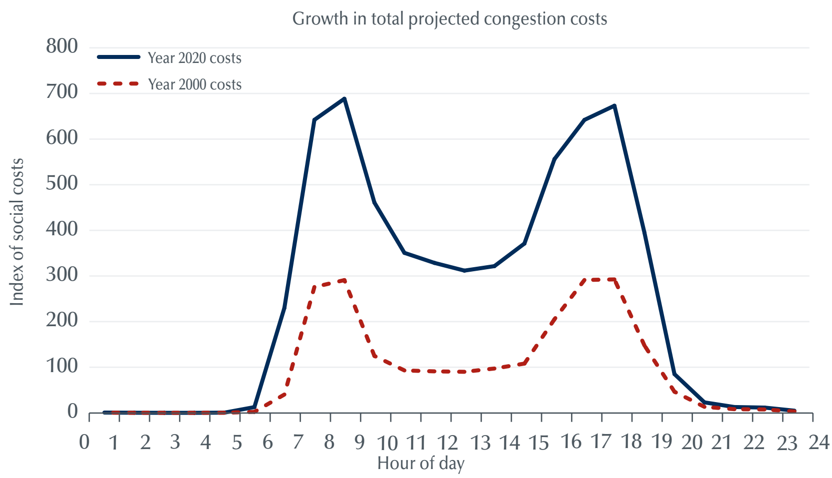
Projections of congestion costs

Using the base case projections for metropolitan VKT, in the congestion models described in the previous sections, then yields forecast values for the congestion cost estimates—taken to the year 2020 in the current study.

The base case demand projections (coupled with the speed-flow, daily profile and marginal cost functions in the BTRE models) have the value of national metropolitan costs rising to an estimated **$20.4 billion** by 2020 (on an avoidable cost of congestion basis). Of this total, private travel is forecast to incur time costs of approximately $7.4 billion (DWL of trip delay plus variability), and business vehicle use $9 billion (DWL of trip delay plus variability). Extra vehicle operating costs contribute a further $2.4 billion and extra air pollution damages a further $1.5 billion. The city specific levels rise to approximately $7.8 billion for Sydney, $6.1 billion for Melbourne, $3.0 billion for Brisbane, $1.1 billion for Adelaide, $2.1 billion for Perth, $0.07 billion for Hobart, $35 million for Darwin, and $0.2 billion for Canberra.

The manner in which the average daily profile (for the avoidable social costs of congestion) changes over the projection period is shown in the figure 2.43.

Figure 2.43 Projected daily cost profile



Note: The congestion-delay elements of these plotted costs relates to the DWL component of total time costs.

The following tables (2.11 to 2.13) give the base case estimates for (avoidable) social costs, average network traffic performance, and average unit social costs due to urban traffic congestion (in the 8 Australian capital cities). The national social costs of metropolitan congestion for Australia (on a DWL basis) are also illustrated in the two charts following the time-series tables (figures 2.44 and 2.45).

Table 2.11 Base case projected estimates of social costs of congestion for Australian metropolitan areas, 1990–2020

(billion dollars)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	2.045	1.797	0.545	0.350	0.433	0.032	0.009	0.061	5.272
1991	2.042	1.773	0.530	0.353	0.420	0.030	0.009	0.060	5.218
1992	2.074	1.808	0.556	0.360	0.439	0.032	0.010	0.065	5.342
1993	2.149	1.881	0.582	0.372	0.461	0.033	0.010	0.068	5.556
1994	2.222	1.949	0.609	0.383	0.482	0.034	0.010	0.070	5.760
1995	2.381	2.056	0.682	0.411	0.539	0.038	0.011	0.077	6.195
1996	2.489	2.103	0.731	0.423	0.578	0.040	0.012	0.082	6.460
1997	2.568	2.050	0.680	0.430	0.592	0.041	0.012	0.084	6.457
1998	2.599	2.214	0.750	0.463	0.614	0.040	0.013	0.085	6.777
1999	2.818	2.170	0.852	0.467	0.674	0.043	0.014	0.091	7.129
2000	2.860	2.229	0.944	0.494	0.694	0.045	0.014	0.093	7.374
2001	2.764	2.218	0.900	0.484	0.691	0.044	0.014	0.092	7.207
2002	2.961	2.495	0.907	0.513	0.726	0.046	0.016	0.098	7.762
2003	3.009	2.533	1.010	0.526	0.753	0.046	0.016	0.101	7.994
2004	3.405	2.919	1.135	0.580	0.839	0.050	0.018	0.112	9.057
2005	3.531	3.019	1.190	0.596	0.875	0.050	0.018	0.114	9.394
2006	3.692	3.125	1.256	0.616	0.919	0.051	0.019	0.117	9.796
2007	3.967	3.340	1.361	0.652	0.991	0.053	0.020	0.124	10.507
2008	4.259	3.571	1.472	0.690	1.065	0.055	0.021	0.131	11.265
2009	4.577	3.826	1.593	0.731	1.145	0.057	0.023	0.138	12.090
2010	4.871	4.054	1.709	0.767	1.223	0.059	0.024	0.145	12.852
2011	5.133	4.253	1.817	0.799	1.294	0.060	0.025	0.151	13.531
2012	5.392	4.447	1.926	0.829	1.365	0.061	0.026	0.156	14.202
2013	5.649	4.637	2.040	0.858	1.440	0.062	0.027	0.161	14.874
2014	5.915	4.832	2.160	0.888	1.517	0.063	0.028	0.167	15.571
2015	6.189	5.032	2.286	0.919	1.598	0.064	0.029	0.172	16.289
2016	6.463	5.227	2.414	0.949	1.680	0.065	0.030	0.177	17.005
2017	6.762	5.442	2.557	0.982	1.772	0.066	0.031	0.183	17.794
2018	7.068	5.653	2.702	1.014	1.864	0.067	0.032	0.189	18.590
2019	7.401	5.880	2.859	1.048	1.963	0.068	0.034	0.195	19.447
2020	7.755	6.123	3.027	1.084	2.068	0.069	0.035	0.201	20.362

Note: Time costs are based on deadweight losses for current congestion. That is, social costs refer here to the estimated aggregate costs of delay, trip variability, vehicle operating expenses and motor vehicle emissions—associated with traffic congestion—being above the economic optimum level for the relevant network.
'Total' column values refer to weighted averages over all metropolitan travel.

Source: BTRE estimates.

Table 2.12 Base case projections for average network delay due to congestion for Australian metropolitan areas, 1990–2020

(minutes per km)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	0.285	0.281	0.185	0.216	0.177	0.115	0.061	0.107	0.243
1991	0.288	0.279	0.180	0.219	0.174	0.110	0.062	0.104	0.243
1992	0.290	0.282	0.185	0.222	0.179	0.114	0.065	0.109	0.246
1993	0.293	0.287	0.190	0.225	0.184	0.116	0.066	0.112	0.250
1994	0.295	0.291	0.195	0.229	0.189	0.118	0.067	0.114	0.253
1995	0.298	0.291	0.209	0.235	0.202	0.125	0.071	0.120	0.258
1996	0.301	0.288	0.217	0.235	0.210	0.128	0.073	0.124	0.260
1997	0.304	0.274	0.193	0.234	0.212	0.129	0.074	0.125	0.255
1998	0.306	0.291	0.213	0.247	0.218	0.126	0.076	0.125	0.265
1999	0.323	0.273	0.234	0.246	0.235	0.132	0.078	0.130	0.270
2000	0.318	0.276	0.264	0.257	0.236	0.136	0.081	0.130	0.274
2001	0.306	0.276	0.245	0.249	0.232	0.132	0.080	0.128	0.266
2002	0.319	0.298	0.234	0.256	0.235	0.136	0.084	0.134	0.277
2003	0.317	0.298	0.259	0.262	0.239	0.135	0.085	0.135	0.280
2004	0.345	0.332	0.280	0.280	0.256	0.141	0.090	0.143	0.306
2005	0.350	0.335	0.286	0.283	0.261	0.141	0.091	0.143	0.310
2006	0.358	0.342	0.294	0.288	0.267	0.142	0.093	0.145	0.317
2007	0.374	0.356	0.308	0.299	0.279	0.145	0.096	0.150	0.331
2008	0.390	0.370	0.323	0.309	0.291	0.148	0.099	0.154	0.345
2009	0.407	0.386	0.338	0.321	0.304	0.151	0.101	0.159	0.359
2010	0.421	0.399	0.352	0.330	0.315	0.153	0.104	0.163	0.372
2011	0.433	0.409	0.364	0.338	0.325	0.155	0.106	0.166	0.382
2012	0.444	0.419	0.375	0.344	0.333	0.156	0.108	0.169	0.392
2013	0.454	0.428	0.385	0.351	0.342	0.157	0.110	0.171	0.401
2014	0.464	0.436	0.396	0.357	0.350	0.158	0.112	0.174	0.410
2015	0.475	0.445	0.407	0.363	0.359	0.158	0.113	0.176	0.419
2016	0.484	0.453	0.418	0.369	0.367	0.159	0.115	0.179	0.427
2017	0.495	0.462	0.429	0.375	0.376	0.160	0.117	0.181	0.437
2018	0.505	0.470	0.440	0.381	0.384	0.161	0.118	0.184	0.445
2019	0.516	0.479	0.452	0.388	0.393	0.161	0.120	0.186	0.455
2020	0.527	0.488	0.464	0.393	0.402	0.162	0.122	0.188	0.464

Note: Relative to estimated free speeds.

Sources: Austroads (2006a), BTCE (1996a, b), BTRE estimates.

Table 2.13 Base case projections for average unit costs of congestion for Australian metropolitan areas, 1990–2020

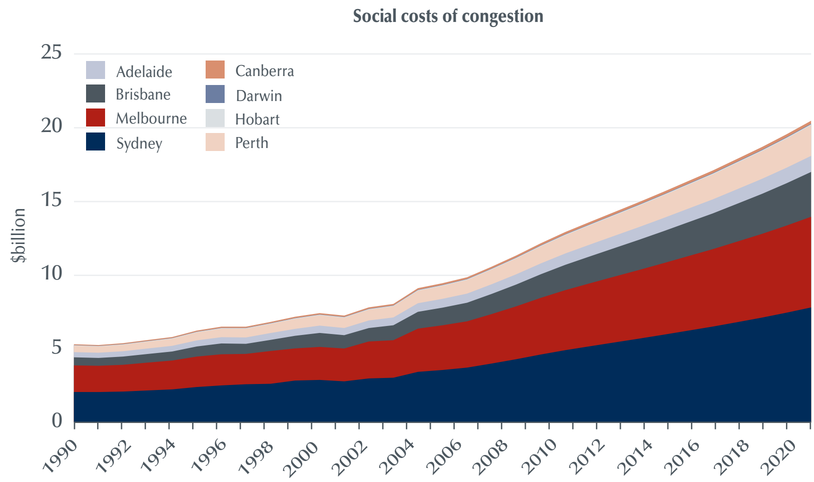
(cents per PCU-km)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	6.4	6.2	4.3	4.1	3.9	2.1	1.3	2.2	5.4
1991	6.4	6.1	4.2	4.1	3.8	2.0	1.3	2.1	5.3
1992	6.4	6.2	4.3	4.2	3.9	2.1	1.3	2.2	5.4
1993	6.5	6.3	4.4	4.2	3.9	2.1	1.3	2.3	5.5
1994	6.6	6.4	4.5	4.3	4.0	2.2	1.4	2.3	5.5
1995	6.7	6.4	4.8	4.4	4.3	2.3	1.4	2.4	5.7
1996	6.8	6.4	5.0	4.4	4.4	2.3	1.5	2.5	5.7
1997	7.0	6.1	4.6	4.4	4.5	2.4	1.5	2.5	5.7
1998	6.9	6.5	4.9	4.6	4.6	2.3	1.5	2.5	5.8
1999	7.4	6.1	5.4	4.5	4.9	2.4	1.5	2.6	6.0
2000	7.3	6.2	5.9	4.7	4.9	2.5	1.6	2.6	6.0
2001	7.0	6.2	5.6	4.6	4.9	2.4	1.6	2.6	5.9
2002	7.2	6.6	5.4	4.7	4.9	2.5	1.6	2.7	6.1
2003	7.2	6.7	5.9	4.8	5.0	2.5	1.7	2.7	6.2
2004	7.8	7.3	6.3	5.1	5.3	2.6	1.7	2.9	6.7
2005	8.0	7.5	6.5	5.2	5.4	2.6	1.8	2.9	6.8
2006	8.2	7.6	6.7	5.2	5.6	2.6	1.8	3.0	7.0
2007	8.5	7.9	7.0	5.4	5.8	2.7	1.8	3.0	7.3
2008	8.9	8.2	7.3	5.6	6.0	2.7	1.9	3.1	7.6
2009	9.2	8.6	7.7	5.8	6.3	2.8	1.9	3.2	7.9
2010	9.6	8.9	8.0	6.0	6.5	2.8	2.0	3.3	8.2
2011	9.9	9.1	8.3	6.1	6.7	2.9	2.0	3.4	8.4
2012	10.2	9.4	8.6	6.2	6.9	2.9	2.1	3.5	8.7
2013	10.5	9.6	8.9	6.4	7.2	2.9	2.1	3.5	8.9
2014	10.8	9.9	9.2	6.5	7.4	3.0	2.1	3.6	9.2
2015	11.1	10.1	9.5	6.7	7.6	3.0	2.2	3.7	9.4
2016	11.3	10.3	9.8	6.8	7.8	3.0	2.2	3.7	9.7
2017	11.7	10.6	10.2	6.9	8.1	3.0	2.3	3.8	9.9
2018	12.0	10.8	10.5	7.1	8.4	3.1	2.3	3.8	10.2
2019	12.3	11.1	10.9	7.2	8.6	3.1	2.4	3.9	10.5
2020	12.7	11.4	11.3	7.4	8.9	3.1	2.4	4.0	10.8

Note: Time costs here are based on deadweight losses for current congestion. That is, these unit social costs refer to the estimated aggregate costs of delay, trip variability, vehicle operating expenses and motor vehicle emissions—associated with traffic congestion above the economic optimum level for the relevant networks—divided by the total (PCU-weighted) VKT on the network.

Source: BTRE estimates.

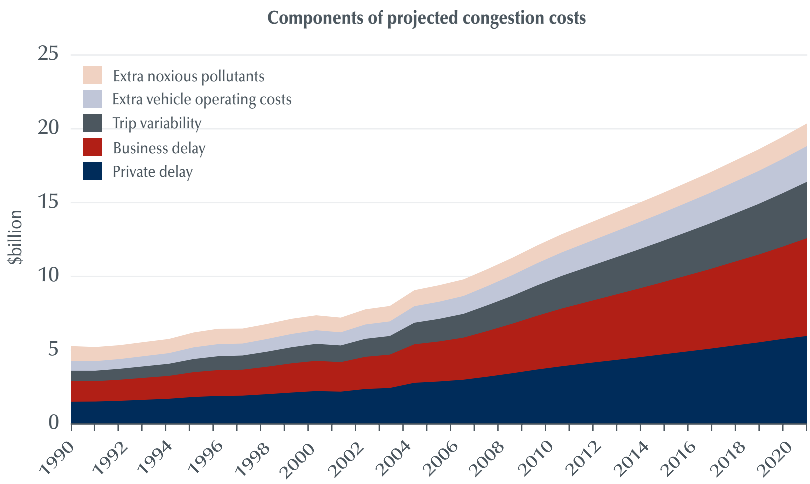
Figure 2.44 Projected avoidable costs of congestion by city



Note: Avoidable social costs are based on the deadweight losses associated with urban congestion levels (compared with the economically optimal traffic levels).
Costs include congestion-related delays, trip variability, increased vehicle operating expenses and increased air pollution damages.

Sources: BTCE (1996b), BTRE estimates.

Figure 2.45 Composition of projected avoidable costs of congestion



Note: Avoidable social costs are based on the deadweight losses associated with urban congestion levels (compared with the economically optimal traffic levels).
Costs include congestion-related delays, trip variability, increased vehicle operating expenses and increased air pollution damages.

Sources: BTCE (1996b), BTRE estimates.

Uncertainty and sensitivity of estimation process

Estimating the 'costs of congestion' is typically a very approximate procedure. Due to a variety of methodological constraints and data limitations, any such cost estimates are far from definitive, forming more a rough (order of magnitude) picture, rather than an exact statement. In addition, the estimates will vary depending on the precise definitions used for the various 'congestion' effects—and to which conditions the *congested* traffic streams are considered relative. For example, current congested travel conditions could be compared to travel at average off-peak speeds, to hypothetical travel at posted speed limits or at free flow speeds, or to travel conditions at the economically optimal traffic level (which is determined by the intersection of the travel demand curve with the marginal generalised cost curve).

Therefore, the estimate of how much total time is lost due to congestion—i.e. the exact value of delay that is derived—will depend directly on the '*free*' speed values that the actual travel speeds of the congested traffic are compared with. Accurate details of free speeds (or average speeds for non-congested conditions) can be difficult to obtain–and different studies will often use quite different values for these comparison speeds (for evaluating delay).

As already pointed out, the current BTRE estimates use an **aggregate** methodology for estimating the *costs of congestion* (where the costs are based on the value of the excess travel time, and other external or resource costs, incurred by actual traffic levels over those that would have occurred had that traffic volume operated under more economically optimal conditions). Note that aggregate estimates of congestion delays (as used here) will generally underestimate the scale of the congestion problem (see BTCE Report 92, page 39, for some quantitative details on this issue). Traffic congestion typically occurs in a non-linear fashion—with only slight additions to vehicle numbers having the potential to radically lengthen travel times if the traffic stream is close to the road's capacity—and aggregate methods will almost always have difficulty adequately capturing such responses.

It should be reiterated that accurate estimation of these effects typically requires the use of detailed traffic generation/assignment models, with all of a city's main streets and traffic volumes encoded within the model. Given the extensive resources required to run (and continually update) such models for all of Australia's capital cities, an aggregate method has been developed for this study, with the aim of deriving reasonable order-of-magnitude estimates for the national costs. However, such aggregate estimates should always be accompanied with the caveat that detailed network models (especially when used in combination with micro-simulation techniques) are far superior tools for calculating congestion effects and should be used whenever practicable. (See Austroads 2006a for a recent assessment of micro-simulation model use in Australia.)

Another source of possible cost underestimation relates to the question of how complete an enumeration of congestion externality effects is attempted. The costs presented in this report primarily relate to estimated externality values for excess travel time for road users (with some allowance for the inefficiency of vehicle engine operation under stop-start conditions, leading to higher rates of fuel consumption and pollutant emissions). However, there will tend to be a series of other flow-on effects from urban congestion, ranging from some businesses having to re-locate or close (due to restrictions on their operations from congestion delays), to widespread psychological stress and irritation from coping with heavy traffic levels, to reducing the efficiency of public transit and the attractiveness of transit or non-motorised transport options. External costs of these wider effects will not be fully reflected in the current estimates and any attempt to include them would have been extremely approximate. Accurate valuations of such externalities are very difficult and there is, as yet, not a great deal in the literature covering suitable quantification methods. There is even considerable debate in the literature over the level that should be attached to the value of time lost, and the valuation techniques for '*$/hr*' figures (generally based on average wage rates) are much more refined and accepted than those for such flow-on effects.

As well as these sources of possible model underestimation, there is also an issue of possible systematic ov*erestimation*. This has to do with the application of a standard, uniform value of time to practically all trips—whatever their origin-destination, purpose and possible level of urgency. The methodology does allow for some trips to be less time sensitive than others (about 10 per cent of trips in the base case assumptions), but it could actually be a much higher proportion. Some surveys suggest that many travellers (and in fact, possibly the bulk of off-peak travel and a substantial portion on non-business peak travel) do not place significant value on their delay time, as long as their chosen mode of transport is comfortable.

In summary, several of the largest sources of uncertainty (for delay cost estimates such as those of the present study) appear to concern:

- the level of free speeds used;
- the standard dollar value of time used;
- how many externalities, apart from delay costs, are included in the valuations; and
- how does the value of delay vary between different road users and their various trip purposes, times of travel or travel distances, especially regarding how much of urban travel is actually fairly time-sensitive.

As a guide to how widely the level of the derived congestion cost estimates are likely to vary, depending on model input values or methodological assumptions, a few sensitivity analyses are provided in this section of the report.

Firstly, a set of values significantly greater than the base case scenario ('High Scenario 1') is calculated:

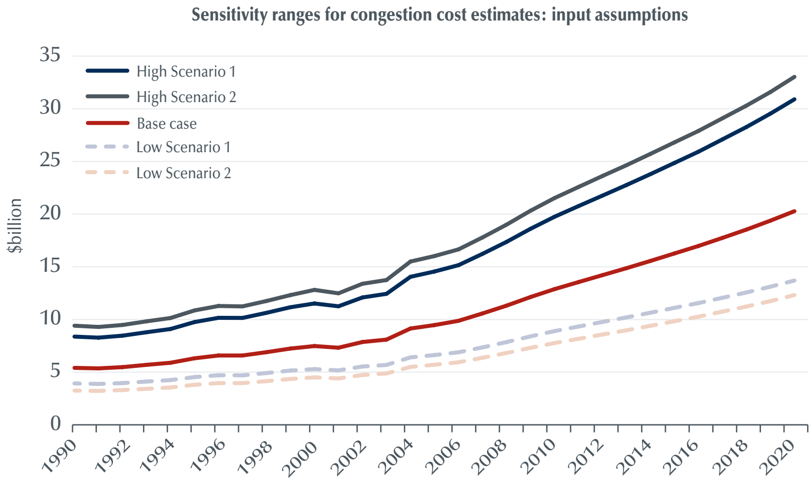
- by including a rough allowance for the wider economic and social effects of congestion (based on the limited literature values available in this area), such as:
  - costs to businesses (related to reductions in market accessibility, location choices, inventory practices, possible economies of scale, and labour/material supply options); and
  - costs to non-car travellers (related to so-called *'barrier effects',* where vehicle traffic and traffic congestion impose delays and discomfort on non-motorised modes (pedestrians and cyclists) and public transit (especially for trips involving a non-motorised component). Heavy traffic levels tend to reduce the viability of non-motorised travel, possibly leading to less than optimal modal choices, with associated external costs
- by removing the allowance for a proportion of total trips to be less time-sensitive than average (that is, the current base case setting, of approximately 10 per cent of trips assumed to have only half the standard value of time lost, is re-set to zero).

Then an even higher level scenario ('High Scenario 2') is obtained, by using the 'High Scenario 1' settings, and increasing assumed 'free' speeds for the networks by 10 per cent. These scenarios are shown in the figure 2.46.

Two related scenarios with lower cost levels than the base case have also been derived and are presented on the same graph (figure 2.46):

- 'Low Scenario 1' raises the proportion of total trips assumed to be less time-sensitive (to approximately half of all trips); and
- 'Low Scenario 2' is obtained from 'Low Scenario 1' by additionally decreasing assumed 'free' speeds for the networks by 10 per cent.

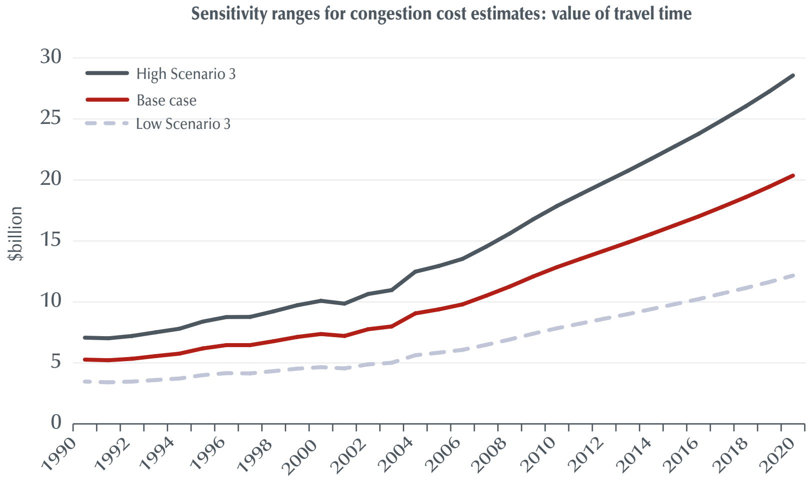
Figure 2.46 Sensitivity scenarios for major parameter variations



Note: 'High Scenario 1' adds a rough allowance for the wider economic and social costs of congestion (such as the costs to businesses related to reductions in possible economies of scale and the costs to non-motorised travel of barrier effects) and reduces the assumed proportion of time-insensitive trips.
'High Scenario 2' furthermore increases 'free' speeds assumed for the networks by 10 per cent.
'Low Scenario 1' raises the proportion of total trips assumed to be less time-sensitive.
'Low Scenario 2' furthermore decreases assumed 'free' speeds by 10 per cent.

Sources: NCHRP (2001), VTPI (2006), BTRE estimates.

Figure 2.47 Sensitivity scenarios for variation in the value of time lost



Note: High sensitivity based on unit costs for value of time 50 per cent higher than base case. Low sensitivity based on unit costs for value of time 50 per cent lower than base case.

Source: BTRE estimates.

Probably the single greatest source of uncertainty in estimating social congestion costs relates to the assumed **value of time**—where there is considerable debate over exactly what 'dollar per hour' rate is actually most appropriate, for valuing the average traveller's time lost to traffic delay, and how much that rate varies between different road users and different trip purposes. As an indicator of the possible uncertainty due to the value of time question, a further sensitivity test was performed by alternately raising the standard value of time—to be 50 per cent above the unit costs used in the base case (for 'High Scenario 3')—and then by lowering it to 50 per cent below the base value ('Low Scenario 3'). These sensitivity tests are plotted in figure 2.47.

Yet another sensitivity test was conducted, to investigate the models' responsiveness to input parameters concerning public transport patronage. A theoretical scenario was run on the model that assumed all non-motorised travel (walking and cycling) and all Urban Public Transit (UPT) passengers (rail and bus) were moved into private cars (for both past and projected urban travel).

Surveys suggest that walking accounts for the order of 20 per cent of *unlinked* urban trips (that is, of all trip segments making up full journeys), since a walking portion is involved in much of urban travel (particularly at the start or end of a multi-modal journey). Yet trips mode-switchable to cars, such as those purely by walking or with walking segments involving a length greater than a kilometre, typically account for less than half of total walking distance. Since the average trip length for walking is quite short (typically in the range of 1 to 1.5 kilometres), walking trips substitutable by vehicle travel probably account for only around 1 per cent of total urban passenger-kilometres.

Figure 2.48 illustrates how the model's cost estimates vary under the assumed response scenario for no (substitutable) trips by cycling, walking or urban public transport (i.e. all such trips are mode shifted to private road vehicles). The basic result of this rough analysis has the assumed mode shift (which moves approximately 12–13 per cent of aggregate urban pkm into private vehicles) increasing aggregate congestion costs by around a third (with about a 29 per cent increase in 2000, rising to about a 33 per cent divergence from the base case by 2020).

Figure 2.48 also plots the other side of this sensitivity test—that is, a model response scenario for a theoretical doubling of non-motorised and UPT travel. For this scenario, it was assumed that walking and cycling mode share could be doubled throughout the entire day—but that UPT travel would be subject to capacity constraints during the workday peak hours. The assumption was made that peak hour travel into the centre of the city, in the absence of extra UPT infrastructure provision, would typically only have around 20 per cent spare capacity. It was assumed that for all other times of the day, and for other trip types, that capacity constraints would not be a problem—and that the appropriate routing and marketing problems could be overcome, allowing a doubling of transit pkm task to be applied. The basic result of this further rough analysis sees the assumed mode shift (which has approximately 12 per cent of aggregate urban pkm *switching out of cars*) decreasing aggregate congestion costs by approximately 25 per cent in 2000, and approximately 27 per cent by 2020.

Figure 2.48 Sensitivity scenarios for UPT share variation

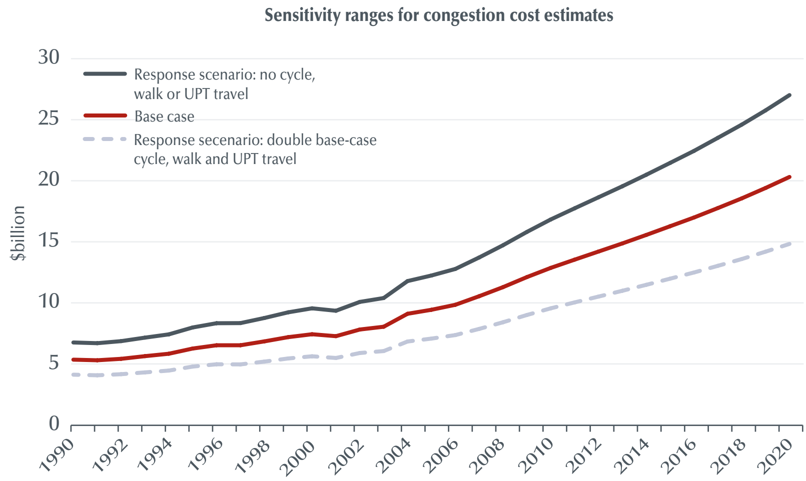


Figure 2.49 Sensitivity scenarios for travel demand variation

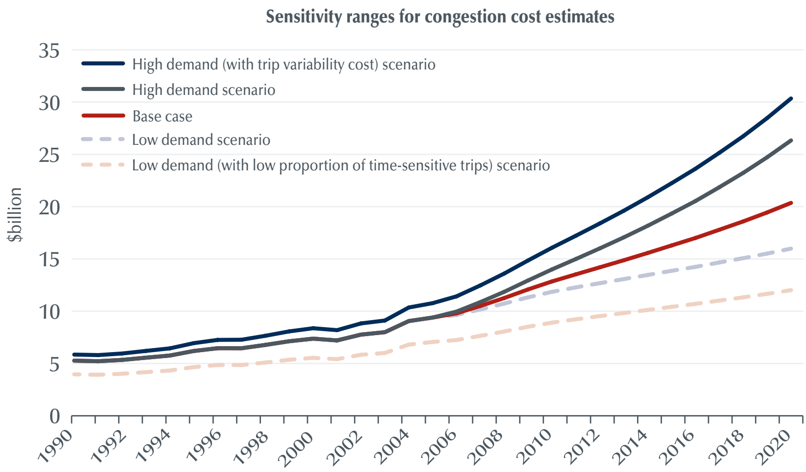


Figure 2.49 illustrates the final series of sensitivity tests conducted–primarily concerning input assumptions to the underlying transport demand modelling. The above chart (figure 2.49) shows the results for:

- a 'High demand scenario', which is based on inputting the highest likely population and economic growth over the projection period, coupled with minimal levels of future traffic peak spreading.
- a 'Low demand scenario' (based on the lowest likely population and economic growth over the projection period, coupled with maximal levels of future traffic peak spreading). The different peak-spreading assumptions make in the order of ±10 per cent difference to the 2020 aggregate cost levels.
- a 'High demand (with high trip variability cost) scenario', which is again based on inputs to the demand models of the highest likely population and economic growth over the projection period, coupled with minimal levels of future traffic peak spreading; along with significantly higher trip variability costs. The trip variability increase in this scenario results from using an 85th percentile for travel time spread (i.e. approximately 1.44 standard deviations from the mean, as opposed to 1 SD for the base case), and an elasticity of 2 for the value of time lost due to trip variability versus the value of time lost due to mean delay levels (as opposed to an elasticity value close to 1 for the base case).
- a 'Low demand (with low proportion of time-sensitive trips) scenario'—again based on the lowest likely population and economic growth over the projection period, coupled with maximal levels of future traffic peak spreading; with the addition of a change to the assumption about average trip time urgency. Specifically, the base case assumption that only around 10 per cent of urban trips are relatively time-insensitive (and incur a value of time lost at half the standard dollar rate) is strengthened to allow for approximately 50 per cent of private trips to not incur appreciable time delay costs.

Current data deficiencies and possible future directions

The impacts of urban road congestion (vehicle delays and higher than average rates of fuel consumption and pollutant emissions) have been steadily increasing over time (due to the growing demand for vehicle travel in our cities), with BTRE (base case) aggregate projections having the social costs of congestion possibly more than doubling over the 15 years between 2005 and 2020 (see table 2.11). The unit costs of congestion (that is, total avoidable congestion costs for metropolitan Australia divided by total VKT) are also forecast to rise, by around 59 per cent over this period (see table 2.13), as average delays become longer and congestion more widespread, and as freight and service vehicle use continues to grow strongly.

In summary, allowing for the sensitivity ranges discussed in the previous section, the costs imposed on Australian society by urban traffic congestion are likely to fall in the range of 5 to 15 billion dollars for current levels—in terms of theoretically avoidable costs (i.e. if, disregarding any possible implementation or running costs, appropriate traffic management or pricing schemes were to be introduced, so as to reduce traffic conditions to the economically optimal levels)—with a median value of around $10 billion. This is likely to rise, under base case demand growth assumptions, to a level of between $10 and $30 billion by 2020, with a median projected value for the potentially avoidable social costs of congestion of around $20 billion.

While preparing this study, the Bureau encountered a number of deficiencies in the readily available information on traffic volumes, and on consequent congestion conditions, that limited the costing analyses to various extents. Though various jurisdictions' on-going Traffic Systems Performance Monitoring processes tend to collect a reasonable amount of useful congestion-related data (such as details on the distribution of traffic flows on the major road-links), there still appears to be a number of remaining data gaps—that could have a bearing on traffic and congestion management issues.

The BTRE's assessment of the main data/information shortcomings, related to congestion assessment, is that they include:

- The relative scarcity of data details on freight movements and service vehicle usage—for both urban freight and services distribution and for freight volumes passing through urban areas. Though there are currently a few on-going studies looking into the issue of urban freight vehicle use, there are not yet much data available, e.g. on average truck operating characteristics, average loads and commodities carried, origin-destination patterns, or trip scheduling. The lack of such information severely limits the suitable quantification of the impacts of congestion on freight costs.

- Limited data on the level and distribution of variability in average trip times. Though there are some data available on average network-wide variability magnitudes (mostly from limited floating-car measurements), there is little detailed information. That is, only scattered data seem to exist on how travel time variation is dependant on trip time of day and trip origin-destination; and its dependence on traffic volumes (especially as particular road-links approach full capacity). Trip time variability is particularly important to many businesses (especially those that need dependable service delivery times); and some travel surveys imply that many road users actually value travel time reliability considerably more highly than they value time lost to average delay levels.
- Typically only scattered data are available on the composition of the traffic mix and how it varies over the hours of the day. It would be useful if datasets were available that gave traffic volumes for significant portions of the networks in terms of vehicle type by time of day. Any further information that can be collected regarding the distribution of urban travel (e.g. by trip purposes or by journey origin-destinations) will also be useful for congestion modelling exercises.

As greater quantities of data continue to be collected in real-time, there would undoubtedly be social benefits in the greater provision of real-time traffic information systems, e.g internet sites showing current traffic performance statistics to aid travellers' trip planning, allowing trips to be rescheduled or re-routed (if notified of a particular incident or irregular delay on their usual route).

Enhanced data collection processes, along with greater data accessibility, will not only aid transport decision making and the direct evaluation of congestion management practices, but will also allow more robust modelling of congestion occurrence and its social impacts–which will, in turn, further assist the policy evaluation process. There are a variety of modelling approaches currently used for estimating congestion levels and their associated costs—some studies (including this current analysis) use aggregate methods, which are computationally straightforward but very approximate; others are based on detailed network models, which allow more precise traffic specifications but are much more data-intensive and difficult to adequately calibrate. The relative simplicity of aggregate methods means that, generally speaking, they are readily calibrated, and the current BTRE models have been calibrated against aggregate network performance data collected by the various State road authorities (including the annual statistics reported to the Austroads National Performance Indicators).

This allows *current aggregate* congestion cost levels (for the BTRE estimates) to be suitably benchmarked against actual on-road conditions, but it has to be acknowledged that such aggregate methods are rather blunt instruments for *projecting* congestion occurrence. Of course, aggregate methods are also not capable of describing the specific location or spatial distribution of the congestion over a particular city's network. Detailed traffic congestion forecasts are much more accurately performed using suitably calibrated network models, and the Bureau looks forward to each jurisdiction's efforts in developing network modelling tools that are continually more comprehensive, consistent, and informative.

For example, consider the Melbourne Integrated Transport Model (MITM), a detailed model of the Melbourne transport network used by the Victorian Department of Infrastructure (DOI). MITM has the advantage of allowing precise specifications of road link characteristics and the spatial assignment of the modelled traffic across those road links, and has been used to derive aggregate congestion cost estimates (e.g. see table 3.1 of VCEC 2006). However, MITM does not currently include any allowance for business traffic costs (VCEC 2006, pg. 63). The limitation of the modelled traffic to only passenger vehicles has a considerable bearing on comparability with some other studies, given that the current BTRE estimates typically have business costs as a greater proportion of the total congestion costs than private travel costs. The DOI continue to develop the MITM, and work is underway to redress this current shortcoming, with studies being undertaken aimed at adding an accurate representation of Melbourne's freight and service vehicle flows to the model framework. Most Australian researchers working in the field of traffic and congestion modelling will undoubtedly be interested in the results of this work.

Though various Australian studies have tended to derive significantly varying congestion cost estimates, much of the variation can usually be explained by definitional differences (e.g. exactly which congestion effects are included in the costings) or by different parameter inputs (such as the *value of time* or the assumed level of free-flow speeds). As mentioned previously, the most significant factor in correctly determining the level of congestion costs tends to be accurately assigning a dollar value of time—where there is a high level of uncertainty in how adequately standard values of time capture the worth that travellers actually attach to delays, and there are little data available on how the time values vary over different trip types and trip timings.

In closing, observe that irrespective of the questions over exact dollar valuations raised by the sensitivity tests or modelling result caveats, the principal finding of this study remains: that, in the absence of improved congestion management, rising traffic volumes in the Australian capitals are likely to lead to escalating congestion impacts, such that the net social costs of congestion over the next 15 years (under a business-as-usual scenario) are likely to at least double.

Given the scale of the congestion problem, it will be a challenge for future transport management measures to adequately address the increasing trends identified by this study. The most effective of any measures introduced to combat growing congestion levels will probably be those:

- that most successfully engage the community (and thus combat any reluctance to change existing travel behaviour), and
- that target particular city areas or particular times of travel where congestion is highest (e.g. freeway tolls or continuous electronic road pricing).

Ideally, the public would be clearly shown how the costs of any proposed congestion reduction policies are outweighed by the benefits (such as reduced trip delays and less air pollution), that any charges imposed would relate directly to the extent the road user contributes to overall congestion levels (such as through *optimal road pricing*), and that the revenue raised by any pricing mechanisms be distributed in a socially acceptable manner.

Appendix

Aggregate inputs and supplementary results

Table A.1 State and territory population projections

(thousand persons)

Year	*NSW*	*Vic*	*Qld*	*SA*	*WA*	*Tas*	*NT*	*ACT*	*Total*
1990	5 832	4 378	2 905	1 431	1 615	462	164	283	17 070
1991	5 896	4 415	2 967	1 444	1 637	466	166	289	17 280
1992	5 955	4 445	3 039	1 452	1 658	469	168	295	17 480
1993	6 005	4 464	3 123	1 459	1 679	471	171	299	17 670
1994	6 056	4 478	3 194	1 461	1 705	472	173	301	17 841
1995	6 120	4 507	3 270	1 464	1 735	472	178	304	18 050
1996	6 242	4 585	3 365	1 479	1 779	476	184	309	18 420
1997	6 280	4 612	3 409	1 479	1 803	472	188	307	18 550
1998	6 328	4 650	3 453	1 482	1 831	470	190	307	18 711
1999	6 399	4 703	3 505	1 490	1 857	469	193	310	18 926
2000	6 472	4 763	3 560	1 496	1 887	468	195	312	19 153
2001	6 555	4 827	3 624	1 506	1 919	468	199	315	19 413
2002	6 626	4 878	3 686	1 513	1 949	468	202	318	19 641
2003	6 687	4 917	3 797	1 527	1 952	477	198	323	19 879
2004	6 731	4 973	3 882	1 534	1 982	482	200	324	20 109
2005	6 845	5 019	3 892	1 538	2 047	469	213	328	20 350
2006	6 909	5 057	3 957	1 543	2 077	469	217	331	20 560
2007	6 973	5 095	4 022	1 549	2 108	468	220	333	20 768
2008	7 039	5 135	4 090	1 555	2 140	468	224	336	20 986
2009	7 103	5 173	4 156	1 560	2 171	468	228	339	21 196
2010	7 167	5 211	4 223	1 566	2 202	467	231	341	21 408
2011	7 229	5 246	4 288	1 570	2 233	467	235	344	21 612
2012	7 287	5 280	4 353	1 574	2 263	466	238	346	21 806
2013	7 343	5 310	4 415	1 577	2 292	464	242	348	21 991
2014	7 398	5 341	4 478	1 580	2 321	463	245	350	22 178
2015	7 455	5 372	4 542	1 584	2 351	462	249	353	22 367
2016	7 508	5 401	4 604	1 586	2 379	460	253	355	22 546
2017	7 561	5 430	4 667	1 589	2 408	459	256	357	22 726
2018	7 611	5 456	4 727	1 591	2 436	457	260	358	22 897
2019	7 661	5 482	4 788	1 593	2 464	455	263	360	23 068
2020	7 712	5 509	4 850	1 595	2 493	453	267	362	23 241

Sources: BTRE estimates based on ABS (mid-range series B) long-term projections.

Table A.2 Capital city population projections

(thousand persons)

Year	NSW	Vic	Qld	SA	WA	Tas	NT	ACT	Total
1990	3 632	3 127	1 331	1 047	1 174	189	75	283	10 857
1991	3 672	3 153	1 359	1 056	1 189	190	76	289	10 986
1992	3 712	3 180	1 390	1 063	1 207	192	77	295	11 115
1993	3 746	3 199	1 426	1 068	1 225	193	78	299	11 233
1994	3 782	3 214	1 456	1 070	1 246	194	78	301	11 341
1995	3 825	3 241	1 489	1 072	1 270	194	80	304	11 475
1996	3 904	3 302	1 530	1 084	1 305	196	82	309	11 714
1997	3 940	3 327	1 550	1 083	1 324	195	84	307	11 811
1998	3 978	3 364	1 573	1 086	1 342	194	86	307	11 929
1999	4 033	3 410	1 598	1 091	1 361	194	88	310	12 085
2000	4 093	3 462	1 624	1 097	1 385	193	90	312	12 256
2001	4 157	3 516	1 654	1 106	1 410	193	91	315	12 444
2002	4 212	3 561	1 684	1 113	1 433	193	93	318	12 607
2003	4 270	3 604	1 715	1 121	1 457	193	95	323	12 778
2004	4 325	3 643	1 747	1 128	1 481	194	97	324	12 938
2005	4 382	3 682	1 780	1 135	1 505	194	99	328	13 106
2006	4 433	3 717	1 811	1 140	1 528	194	101	331	13 254
2007	4 483	3 751	1 842	1 145	1 551	194	103	333	13 403
2008	4 536	3 787	1 873	1 151	1 574	194	105	336	13 557
2009	4 587	3 821	1 904	1 156	1 597	194	107	339	13 706
2010	4 639	3 855	1 936	1 161	1 620	194	109	341	13 857
2011	4 689	3 888	1 967	1 165	1 643	194	111	344	14 002
2012	4 738	3 919	1 997	1 169	1 665	194	114	346	14 142
2013	4 784	3 949	2 027	1 173	1 687	194	116	348	14 277
2014	4 831	3 978	2 057	1 177	1 709	194	118	350	14 412
2015	4 878	4 008	2 087	1 180	1 730	194	120	353	14 549
2016	4 924	4 035	2 116	1 183	1 752	193	122	355	14 680
2017	4 970	4 064	2 146	1 187	1 773	193	124	357	14 812
2018	5 014	4 090	2 175	1 189	1 794	192	126	358	14 938
2019	5 058	4 116	2 204	1 192	1 814	192	128	360	15 065
2020	5 103	4 143	2 233	1 195	1 835	192	130	362	15 193

Sources: BTRE estimates based on ABS (mid-range series B) long-term projections.

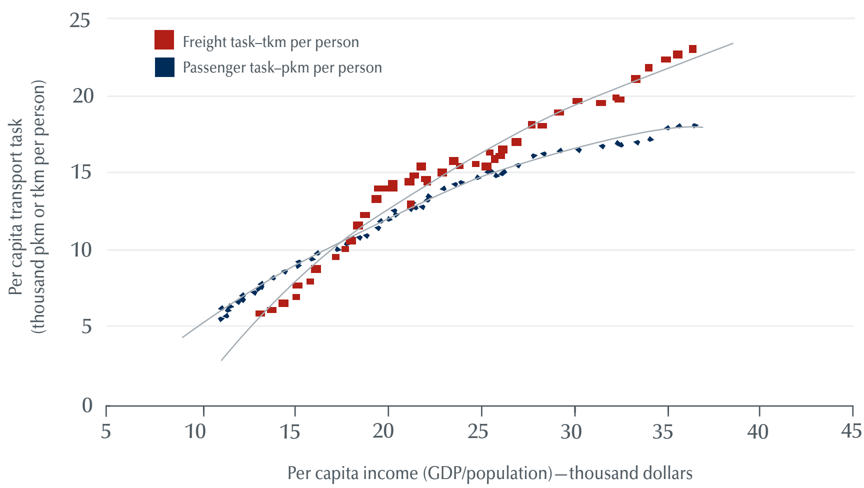
Table A.3 Base case GDP growth assumptions

(per cent *change* per annum)

Financial year	*Australian real GDP growth*
2003	3.21
2004	4.09
2005	3.00
2006	3.25
2007	3.50
2008	3.50
2009	3.10
2010	3.00
2011	2.85
2012	2.70
2013	2.55
2014	2.40
2015	2.30
2016	2.25
2017	2.20
2018	2.15
2019	2.10
2020	2.00

Source: AGO (pers. comm., based on Treasury estimates).

Figure A.1 Long-term trends in national per capita passenger and freight movement relative to per capita income levels



Sources: BTRE estimates.

Table A.4 Base case projected estimates of social costs of congestion for business vehicle travel, 1990–2020

($billion)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	1.023	0.908	0.266	0.150	0.202	0.011	0.005	0.022	2.586
1991	1.012	0.889	0.255	0.150	0.193	0.010	0.005	0.021	2.535
1992	1.029	0.907	0.268	0.152	0.202	0.010	0.005	0.023	2.596
1993	1.066	0.944	0.282	0.157	0.212	0.011	0.005	0.024	2.700
1994	1.104	0.979	0.296	0.162	0.223	0.011	0.006	0.025	2.806
1995	1.188	1.035	0.336	0.175	0.252	0.012	0.006	0.028	3.033
1996	1.242	1.060	0.363	0.180	0.272	0.013	0.007	0.030	3.167
1997	1.284	1.032	0.335	0.183	0.279	0.013	0.007	0.031	3.164
1998	1.300	1.116	0.373	0.196	0.291	0.013	0.007	0.031	3.327
1999	1.421	1.093	0.427	0.198	0.322	0.014	0.008	0.034	3.517
2000	1.434	1.118	0.475	0.208	0.329	0.015	0.008	0.034	3.621
2001	1.379	1.112	0.451	0.204	0.327	0.014	0.008	0.034	3.528
2002	1.485	1.260	0.454	0.216	0.345	0.015	0.009	0.036	3.819
2003	1.504	1.276	0.507	0.221	0.356	0.015	0.009	0.037	3.926
2004	1.707	1.478	0.571	0.243	0.397	0.016	0.010	0.042	4.463
2005	1.774	1.534	0.601	0.251	0.415	0.016	0.010	0.043	4.643
2006	1.865	1.593	0.637	0.260	0.438	0.016	0.011	0.044	4.865
2007	2.018	1.713	0.696	0.277	0.476	0.017	0.011	0.047	5.256
2008	2.179	1.842	0.757	0.295	0.515	0.018	0.012	0.050	5.668
2009	2.353	1.983	0.824	0.314	0.557	0.019	0.013	0.053	6.115
2010	2.518	2.113	0.890	0.332	0.598	0.019	0.013	0.056	6.540
2011	2.667	2.227	0.951	0.348	0.637	0.020	0.014	0.059	6.923
2012	2.816	2.340	1.014	0.363	0.676	0.020	0.015	0.061	7.305
2013	2.964	2.452	1.079	0.378	0.717	0.021	0.015	0.064	7.690
2014	3.120	2.567	1.149	0.394	0.760	0.021	0.016	0.066	8.093
2015	3.280	2.686	1.222	0.410	0.804	0.022	0.017	0.069	8.509
2016	3.442	2.803	1.297	0.426	0.851	0.022	0.017	0.071	8.929
2017	3.621	2.933	1.381	0.444	0.903	0.022	0.018	0.074	9.397
2018	3.804	3.061	1.467	0.461	0.955	0.023	0.019	0.077	9.868
2019	4.004	3.200	1.561	0.480	1.012	0.023	0.019	0.080	10.380
2020	4.239	3.366	1.669	0.503	1.078	0.024	0.020	0.084	10.982

Note: Time costs are based on deadweight losses for current congestion. That is, social costs refer here to the estimated aggregate costs of delay, trip variability, vehicle operating expenses and motor vehicle emissions—associated with traffic congestion—being above the economic optimum level for the relevant network.

Source: BTRE estimates.

Table A.5 Base case projected estimates of social costs of congestion for private vehicle travel, 1990–2020

($billion)

Year	*Syd*	*Mel*	*Bne*	*Adl*	*Per*	*Hob*	*Dar*	*Cbr*	*Total*
1990	1.023	0.889	0.279	0.199	0.231	0.021	0.004	0.039	2.686
1991	1.030	0.884	0.275	0.204	0.227	0.020	0.004	0.039	2.682
1992	1.045	0.901	0.288	0.208	0.237	0.021	0.004	0.042	2.746
1993	1.083	0.938	0.300	0.215	0.248	0.022	0.005	0.044	2.855
1994	1.118	0.970	0.313	0.221	0.259	0.023	0.005	0.045	2.954
1995	1.193	1.020	0.346	0.236	0.287	0.025	0.005	0.049	3.162
1996	1.247	1.043	0.368	0.243	0.306	0.027	0.005	0.052	3.293
1997	1.284	1.017	0.345	0.247	0.313	0.027	0.006	0.054	3.292
1998	1.299	1.097	0.377	0.267	0.323	0.027	0.006	0.054	3.450
1999	1.397	1.077	0.425	0.269	0.352	0.029	0.006	0.057	3.613
2000	1.427	1.111	0.469	0.286	0.365	0.031	0.006	0.059	3.754
2001	1.385	1.106	0.449	0.281	0.364	0.030	0.006	0.058	3.679
2002	1.476	1.235	0.453	0.296	0.381	0.031	0.007	0.062	3.943
2003	1.505	1.257	0.503	0.305	0.397	0.031	0.007	0.064	4.068
2004	1.699	1.441	0.564	0.337	0.442	0.034	0.008	0.070	4.594
2005	1.757	1.485	0.590	0.346	0.460	0.034	0.008	0.072	4.752
2006	1.828	1.532	0.618	0.356	0.481	0.034	0.008	0.073	4.931
2007	1.950	1.626	0.665	0.374	0.514	0.036	0.009	0.077	5.252
2008	2.081	1.729	0.715	0.395	0.550	0.037	0.009	0.081	5.596
2009	2.224	1.842	0.769	0.417	0.589	0.038	0.010	0.085	5.975
2010	2.353	1.941	0.820	0.435	0.625	0.039	0.010	0.089	6.312
2011	2.466	2.025	0.866	0.451	0.657	0.040	0.011	0.092	6.609
2012	2.576	2.106	0.912	0.466	0.690	0.041	0.011	0.095	6.897
2013	2.684	2.185	0.961	0.480	0.723	0.041	0.012	0.098	7.184
2014	2.795	2.265	1.011	0.495	0.758	0.042	0.012	0.100	7.478
2015	2.909	2.346	1.064	0.509	0.794	0.043	0.012	0.103	7.780
2016	3.021	2.424	1.117	0.523	0.829	0.043	0.013	0.106	8.076
2017	3.141	2.509	1.175	0.538	0.869	0.044	0.013	0.109	8.398
2018	3.264	2.591	1.235	0.553	0.909	0.044	0.014	0.112	8.721
2019	3.396	2.679	1.298	0.568	0.951	0.045	0.014	0.115	9.067
2020	3.516	2.757	1.358	0.581	0.990	0.045	0.015	0.117	9.380

Note: Time costs are based on deadweight losses for current congestion. That is, social costs refer here to the estimated aggregate costs of delay, trip variability, vehicle operating expenses and motor vehicle emissions—associated with traffic congestion—being above the economic optimum level for the relevant network.

Source: BTRE estimates.

Figure A.2 Summary flowchart–BTRE base case projections for traffic growth

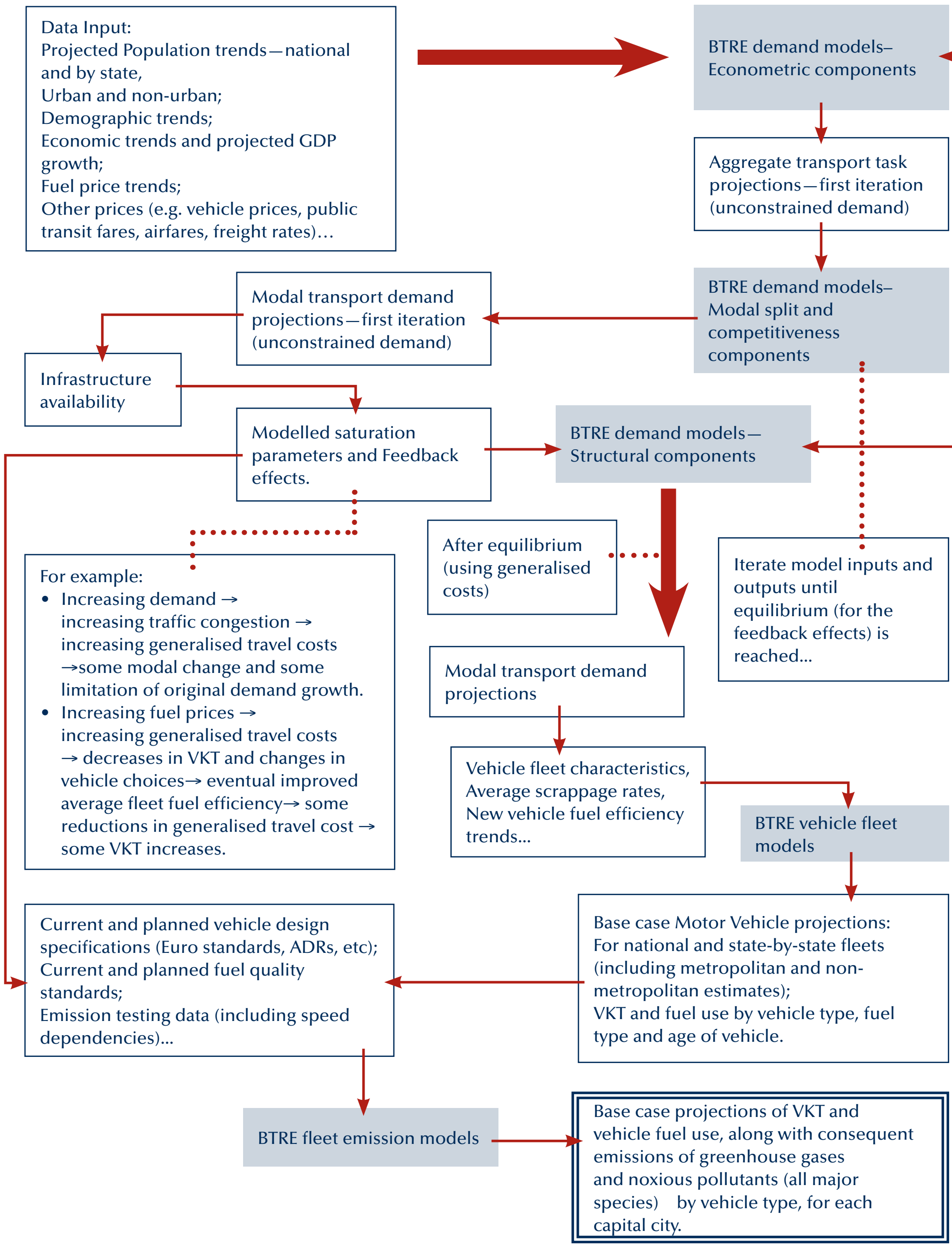


Figure A.3 Summary flowchart–BTRE method for congestion cost estimation

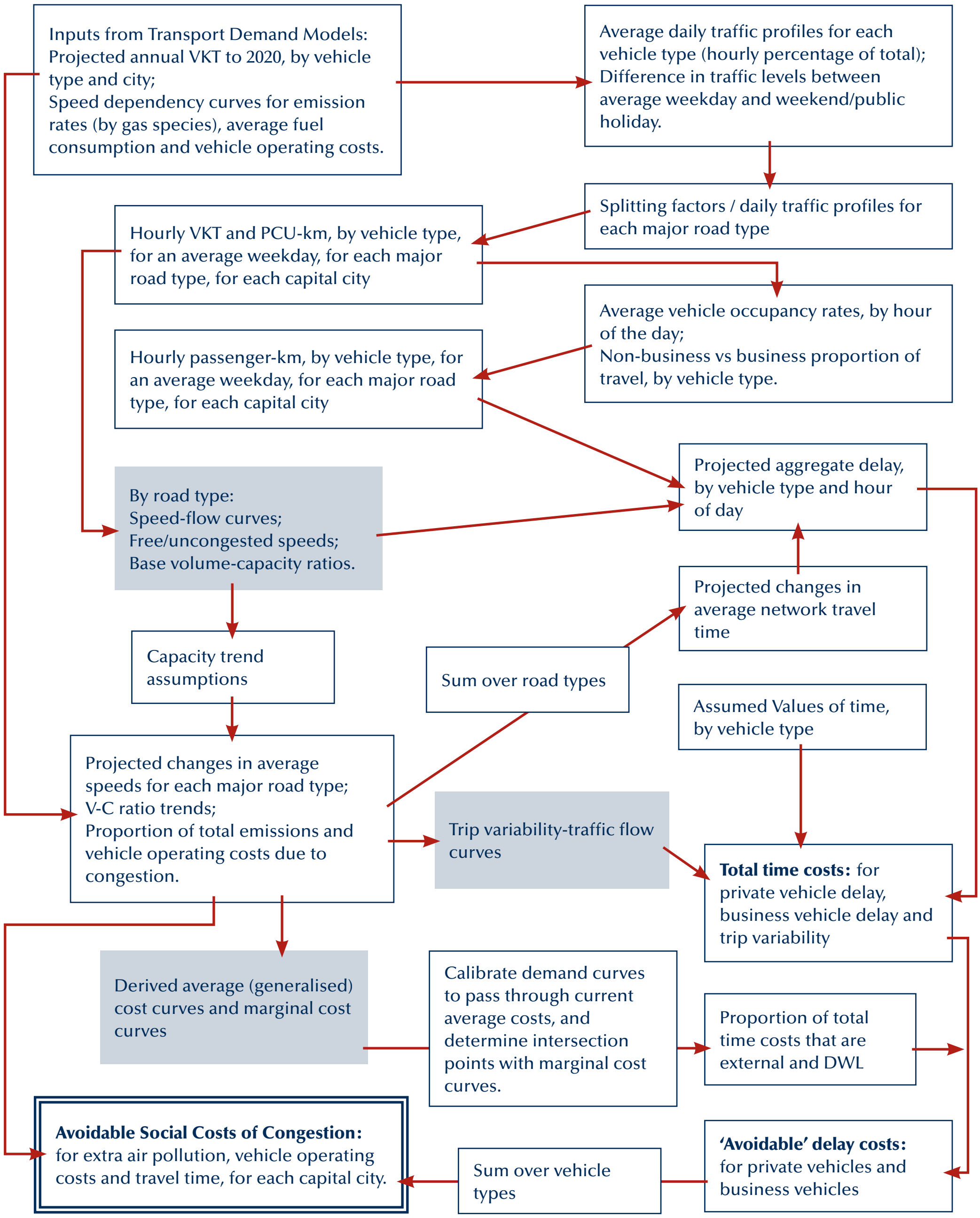


Figure A.4 Forecast fuel price trend for BTRE base case demand projections

Note: Crude oil prices are given here in 2004 US dollars (per barrel), based on US Energy Information Administration (EIA) results for their latest 'Reference' long-term projection scenario–adjusting the quoted $US RAC values (for calendar year forecasts) to WTI (2004 real) financial year values, averaging the given trends for all crudes (including light, low sulphur crudes), and smoothing across the latest EIA short-term forecasts

Sources: BTRE estimates based on US Energy Information Administration forecasts (Energy Information Administration 2006a).

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AGPS	Australian Government Publishing Service
ACG	Apelbaum Consulting Group
AGO	Australian Greenhouse Office
BTCE	Bureau of Transport and Communications Economics
BTE	Bureau of Transport Economics
BTRE	Bureau of Transport and Regional Economics
COAG	Council of Australian Governments
DISR	Department of Industry, Science and Resources
DITR	Department of Industry, Tourism and Resources
DOTARS	Department of Transport and Regional Services
DPIE	Department of Primary Industries and Energy
FORS	Federal Office of Road Safety
NGGIC	National Greenhouse Gas Inventory Committee
NCHRP	National Cooperative Highway Research Program
USEPA	United States Environmental Protection Agency
VCEC	Victorian Competition and Efficiency Commission
VTPI	Victoria Transport Policy Institute

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