Long-term emission trends for Australian transport

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1 Introduction

The decades since the end of World War II have seen significant changes to Australia's economy, population and social structure. The decades ahead will doubtless bring further changes – including the demands of dealing with major environmental challenges, such as global climate change or eventual oil depletion. Transport use, along with the efficiency or accessibility of the various passenger and freight modes, has always played a major part in economic and societal development. Along with population increases, total Australian passenger travel (in terms of passenger-kilometres performed) has grown almost ten-fold over the last 60 years, while the domestic freight task (in tonne-kilometres) has grown by over 16 times. As an aid in assessing possible future developments – specifically, the transport sector's likely role in helping to deliver a future with not only continuing prosperity, but also adequate levels of social amenity, public wellbeing and environmental sustainability – this paper presents estimates of the long-term historical trends in Australian transport activity, along with the energy use and pollutant emission levels arising from that activity.

Estimates of aggregate emission levels, for the period covering the 1945 to 2007 financial years, are provided for the primary greenhouse gases and noxious air pollutants released by Australian transport vehicle use. *Base Case* (or 'business-as-usual') projections of further growth in transport demand over the medium term (to the 2030 financial year) are also presented – where the current base case or 'reference' scenario includes a continuation of current trends in vehicle efficiency improvement, but does not include the possible effects of yet-to-be-introduced emission abatement measures (such as the proposed Australian Emissions Trading Scheme), and assumes that the real price of crude oil over the forecast period averages around that over the 2005 to 2007 financial years (at about $US60 per barrel, in 2006 dollars). The reference case projections thus contain quite conservative assumptions regarding future fuel costs, and if the price of oil does not come off the current historical highs, or continues to rise even further, then expected transport growth could be appreciably lowered, even with the relatively inelastic response of most travel to fuel prices. Notwithstanding the possibility of high future fuel costs, the sizeable increases in transport demand, that are quite likely over the coming years, serve as a challenging preface to any discussions concerning which are the best available options for abating transport emissions and mitigating the impacts of transport fuel use on the environment and our communities.

2 Per capita transport trends

There are a whole series of underlying causes or 'drivers' of growth in transport demand (and in consequent transport energy consumption and transport emission levels). The main drivers (or generators) behind the strong historical growth in total Australian passenger travel (as well as behind the significant growth in travel by private road vehicles) have tended to be increases in population and increases in per capita annual travel. The latter trend increase has principally been the result of rising (per capita) incomes, typically allowing greater choices in trip selection, and higher potential travel speeds, as road networks have developed over time. Rising national income levels have also been strongly associated with growth in the amount of general freight transported.

Demographic effects (including changes to land-use, urban form, or city density patterns) can also be important with respect to how much daily travel increases; especially with the tendency for Australian cities to have grown ever outwards (as the demand for increasing levels of residential living space has typically lead to more and more greenfield developments), often resulting in longer average trip lengths.

People's transport choices will furthermore depend on a whole range of factors – such as perceived safety, comfort or affordability. The desirability of any extra travel will depend on the overall costs of that travel – not only direct expenses like fuel prices, the cost of vehicles or public transit fares, but also in a more generalised sense, such as the travel time limits imposed by traffic congestion delays. Similarly, the choice of a mode for freight movement will not depend solely on direct costs, such as freight rates, but will also be affected by such factors as the timely delivery required by perishable commodities.

For many years, Australia has seen the complex interplay of all these underlying effects lead to steadily increasing levels of both personal mobility and the distribution of goods and services – particularly in parallel with the wider availability of motor vehicles. The resulting historical trends of increasing passenger and freight tasks, essentially ever since the end of World War II, along with the increasing mode shares of motor vehicles, has lead to steadily increasing transport energy use and to the growing incidence of urban traffic congestion. Transport systems that operate with such high private motorisation levels, and relatively low public transit patronage, will often lead to high social costs from congestion delays, and will also typically exhibit a range of detrimental environmental impacts. These can involve increased community health costs (for example, from respiratory conditions associated with noxious vehicle emissions) and higher than optimal greenhouse gas emission levels (especially if the car fleet continues to be largely petroleum-fuelled). This is particularly the case in the absence of any pricing mechanisms (such as carbon or congestion charges), to make motorists more aware of the social costs their travel imposes on other travellers and the wider community (as opposed to simply making their travel choice decisions based on their own private costs).

An important relationship underlying BITRE projections of the historical task trends concerns the connection between rising income levels and per capita travel. Figure 1 plots estimates for over five decades of Australian per capita passenger and freight movement (for total annual transport tasks), against a measure of average per capita income levels.

Figure 1 shows how markedly the growth rate in annual passenger-kilometres (pkm) per person, relative to average income – in terms of Gross Domestic Product (GDP) per person – has reduced in recent years (righter-most points on curve), especially compared with past very high growth in per capita travel (for values on the left-hand side on the curve – roughly corresponding to the 1950s to 1970s). Basically, as income levels (and motor vehicle affordability) have increased over time, average travel per person has increased. However, there tend to be limits on how far this 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 their limited time budgets on yet more travel, even if incomes do happen to rise further. The (per capita) pkm versus income curve has in fact been quite flat for over a decade if we restrict it to urban daily travel (see Figure 2) – where the slight upward trend towards the higher-income end of the Figure 1 (national) pkm curve is essentially due to continuing strong growth in air travel (with its inherent advantages in reducing travel time spent per kilometre).

Future increases in Australian passenger-kilometres travelled are therefore likely to be more dependent on the rate of population increase, and less dependent on increases in general prosperity levels. As shown in Figure 2, which gives the correlation plots for different components of the overall passenger task, the 'saturating' relationships identified between increases in annual passenger-kilometres per person and per capita income levels are even stronger if the effects of tourism are separated out. These relationships imply that annual growth in per capita daily travel in Australia is likely to be lower in the future than for the long-term historical trend.

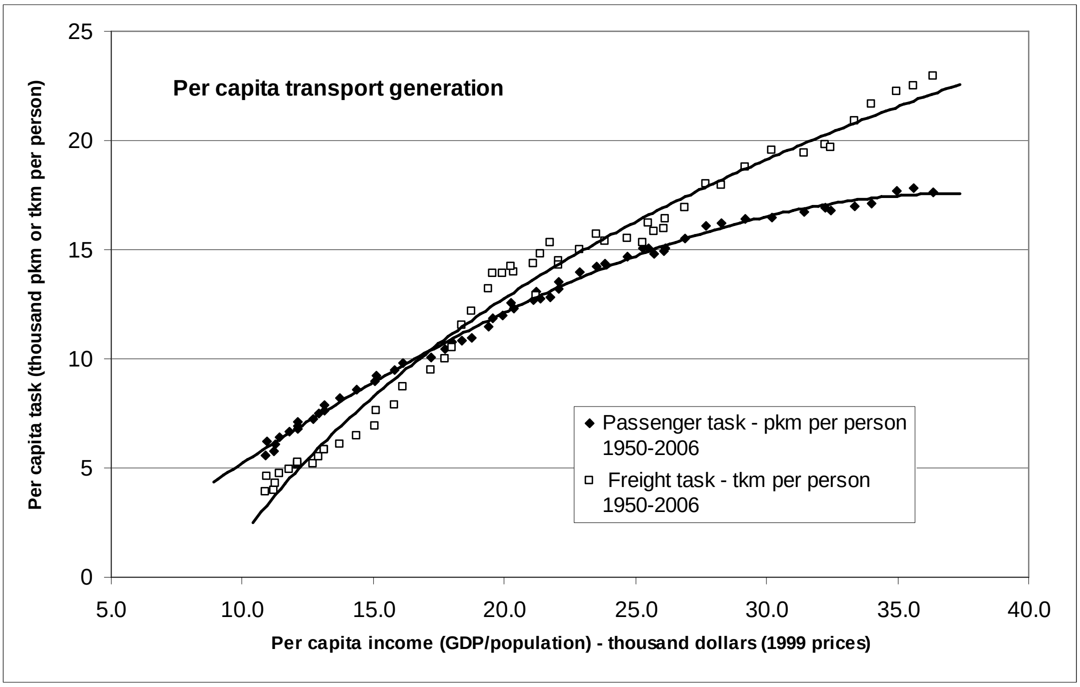

Figure 1 – Relationship of national per capita transport tasks to per capita income

Sources: Cosgrove and Gargett (2007), BTRE (2002a, 2006), BITRE estimates.

Also note (again referring to Figure 1), that this decoupling of income levels from personal travel trends is not yet apparent in the current freight movement trends. Tonne-kilometres (tkm) performed per capita are still growing quite strongly, with current tonne-kilometre growth reacting approximately proportionally to the overall growth rate of the economy – and even though the freight trend curve is slightly concave, there is no saturating tendency evident for the near future. Eventually this trend curve would be expected to shallow off too (over the longer term), but there is no sign of it occurring any time soon. Growth in freight and service vehicle traffic is therefore projected (over at least the next couple of decades) to be substantially stronger than for passenger vehicles.

It is worth noting that there appear to be clear signs of a decoupling of aggregate economic growth (in GDP terms) and freight transport demand already occurring in the United Kingdom. The UK Commission for Integrated Transport (2007) has presented results showing a gradual decline in average tonne-kilometres per unit of GDP, over recent years. This is likely due to changes in the structure of the UK economy, with shifts over time away from traditional primary industries, and towards service-based and Information Technology-related sectors (in which freight transportation tends to play a lesser role). Since the GDP compositions of many countries (including Australia) show similar trends (that is, of movements towards higher-value, less freight intensive production), this UK decoupling experience could be replicated more widely in the coming years.

Regressing the historical task trend estimates against real (per capita) Australian GDP gives an indication of the appropriate parameterisation for the eventual saturating behaviour (i.e. the shape of the structural curves required to project those trends out over the medium to longer term). The trend projections typically rely on the specification of appropriate functions relating per capita demand for the relevant transport activity to the (real) per capita income level under which that activity has been undertaken – where these functions differ from constant elasticity log-linear models (which are generally unconstrained over the long term), by exhibiting asymptotic behaviour towards an eventual 'saturation level'. If required, the amplitude of this fundamental or underlying curve (for demand versus income) can then be shifted up or down by appropriate amounts (typically using long-term price elasticities) to allow for any significant changes expected in future transport cost levels. For example, when analysing cost of fuel variations, most fitted values of *short-term* fuel price elasticities for Australian car usage tend to fall around -0.15 (with the range of likely values covering about -0.05 to -0.3); while the *long-term* elasticity will generally be higher – since it incorporates motorists responding to price increases by gradually changing to more fuel efficient vehicles – and estimates usually range between about -0.25 to -0.65 (with a central estimate of around -0.45).

Figure 2 and Figure 3 give more detailed per capita relationships (than Figure 1) for major elements of the aggregate Australian passenger and freight tasks. Due to the differing growth characteristics of various components of the overall transport tasks, the analysis here splits the sectors into several parts, with each having separate structural curves fitted – and where The figures also show the continuation of the relevant functional forms (modelled for each component of the total task) to higher than current income levels (for use in the base case projections). Figure 2 gives separate, saturating forms (typically fitted by either logistic or logarithmic functions of per capita income) for urban travel, total non-urban travel and non-urban travel by Australian residents (that is, separating out the faster growing component of aggregate long-distance trips, due to foreign tourists travelling on domestic networks) – along with the resulting aggregate curve for total domestic passenger movement. Figure 3 provides the assumed functional forms for bulk, non-bulk and total domestic freight tasks.

Since per capita daily travel in Australian urban areas started exhibiting slowing growth over a decade ago, the asymptotic behaviour identified (for the travel demand versus income curve, fit from the existing urban transport data – see Figure 2) is likely to remain valid for any projection scenario that does not entail large structural changes to our urban transport systems. Appropriate asymptotic curves for various other Australian transport sub-sectors (e.g. long-distance domestic travel, international visitors, or bulk freight movement) are harder to estimate – since their current growth patterns do not yet exhibit clear saturating trends. Some of these tasks have seen growth rates in recent years slow somewhat from earlier historical periods – enough to give some indication of the likely degree of eventual saturating behaviour – but, typically, such tendencies have not yet held for long enough to allow regression analyses or curve fitting to fix on a clear-cut saturation level. The long-term demand projections for these sectors are therefore subject to considerably higher uncertainties than for day-to-day passenger travel. That is, the asymptotic behaviour of the fitted curves for long-distance passenger travel and for domestic freight movement are likely to be less exact than that derived for short-distance passenger travel (since that sub-sector has already seen enough progress towards per capita saturation that its intrinsic asymptote is strongly determined by the historical data).

In summary, most of the primary BITRE projection methods rely on using historical trend data to determine functional or econometric relationships between growth in a particular transport task and relevant income level or price changes – either constant elasticity values (typically used for tasks not exhibiting constraints in their growth behaviour) or curve fitting (for saturating trends, such as the per capita passenger tasks plotted in Figure 2). The aggregate task estimates projected by these methods are then split into finer modal subdivisions, usually based on market share competitiveness models (again fit from the historical data, typically allowing for generalised cost parameters – which take into account factors such as average travel times for the various modes, as well as direct expenses such as fuel prices and fares). The long-term trends in modal splits for the various transport tasks are addressed in the following section.

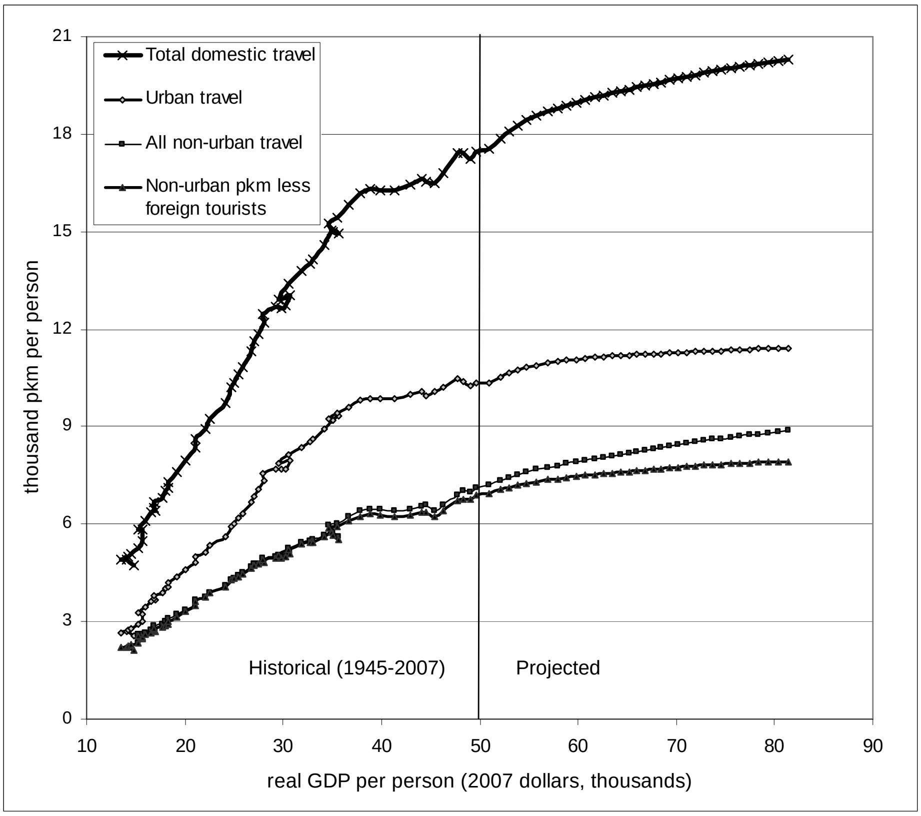

Figure 2 – Relationship of per capita passenger travel in Australia to per capita income

Sources: BTRE (2002a, 2006), Cosgrove (2003), BITRE (2008), BITRE estimates.

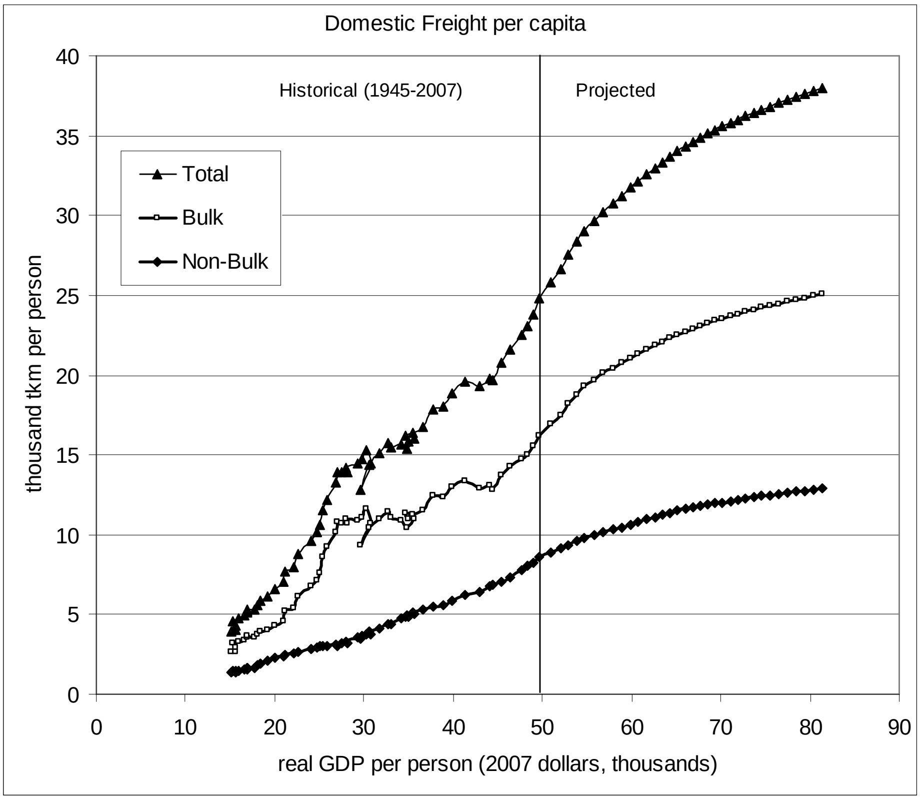

Figure 3 – Relationship of per capita Australian freight movement to per capita income

Sources: BTRE (2002a, 2006), BITRE (2008), BITRE estimates.

3 Modal share patterns

For urban transport, private road vehicles (‘car’ plus ‘other road’ in Figure 4) currently account for about 90 per cent of the motorised passenger task in Australian cities. Urban public transport (UPT), though generally a major component of peak travel into central business districts, currently represents only about 10 per cent of the total metropolitan passenger task. Moreover, UPT’s modal share has remained remarkably constant since the early 1980s, when the long downward trend in the market share of public transit, from a level of over 60 per cent just after World War II, finally halted and levelled off. Figure 4 demonstrates the current dominance of private motor vehicle travel (in aggregate mode share terms), with rail transport accounting for around half of total metropolitan passenger-kilometres up until the 1950s, but since falling to a national average mode share of only about 5 to 6 per cent. The modelled ‘Base Case’ projections for urban mode shares are also given in Figure 4, where even though the business-as-usual scenario assumptions have annual UPT patronage growing at substantially higher rates than car travel – essentially due to future levels of congestion and relatively high petrol prices discouraging some car use – the enormity of the task disparity, between private vehicle use and public transit, means that the projected modal share of cars only decreases slightly over the forecast period.

For domestic non-urban passenger transport, the long-term modal share patterns have certain similarities to the urban case – with the major transport mode directly following World War II once again rail (accounting for about half of total non-urban pkm), and once again rail losing most of that mode share to road vehicles over the next few decades (see Figure 5). However, the non-urban case differs with the fast growing contribution of air travel – such that, by the end of the 1970s, the modal share of non-urban car travel had started on a gradually declining trend. Domestic aviation is expected to remain the fastest growing component of long-distance travel throughout the forecast period.

Figure 6 and Figure 7 display the long-term mode shares (as a proportion of aggregate domestic tonne-kilometres performed) for Australian non-bulk and bulk freight movement. The domestic non-bulk freight task is dominated by road transport, while the current modal split for domestic bulk freight tkm is more evenly distributed between road, rail & coastal shipping.

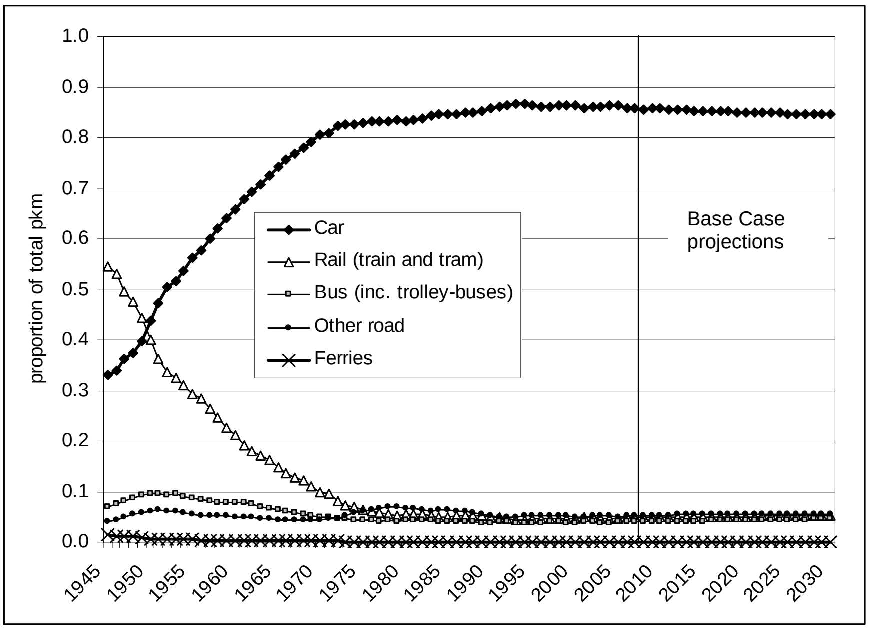

Figure 4 – Modal share, Australian urban passenger travel

Notes: 'Other road' primarily consists of non-business use of light commercial vehicles (LCVs), with minor contributions from motorcycles and heavy vehicles.

All dates (for all graphs) refer to financial years.

Sources: BTRE (2002a, 2006), BTCE (1996), Cosgrove (2003), BITRE (2008), BITRE estimates.

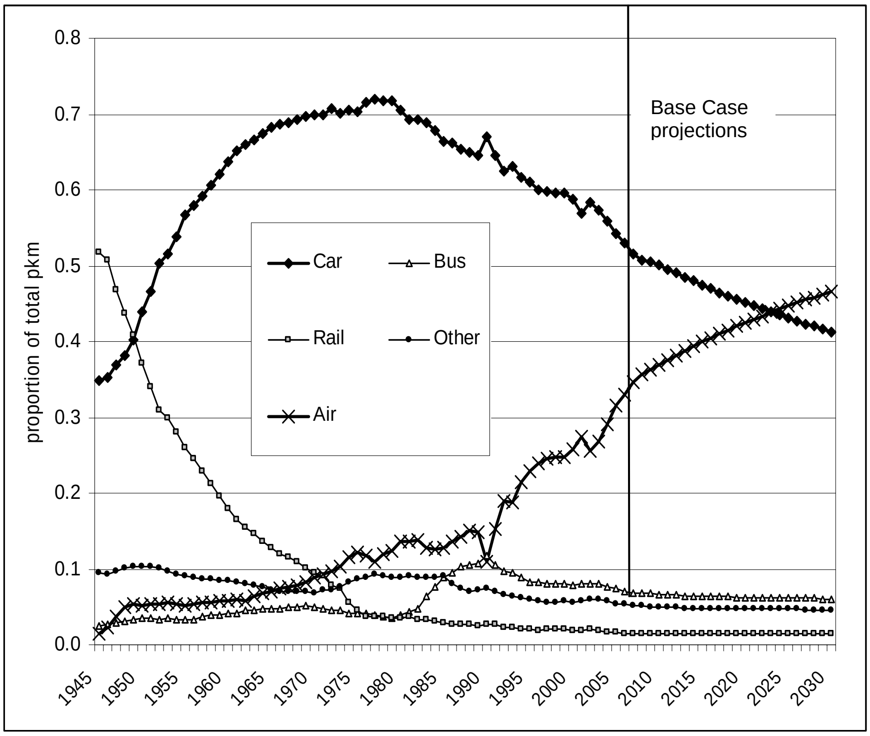

Figure 5 – Modal share, Australian non-urban passenger travel

Note: 'Other' primarily consists of non-business use of light commercial road vehicles, with contributions from motorcycles, heavy vehicles and domestic navigation (interstate ferries and cruise ships).

Sources: BTRE (2002a, 2006), BTCE (1996), Cosgrove (2003), BITRE (2008), BITRE estimates.

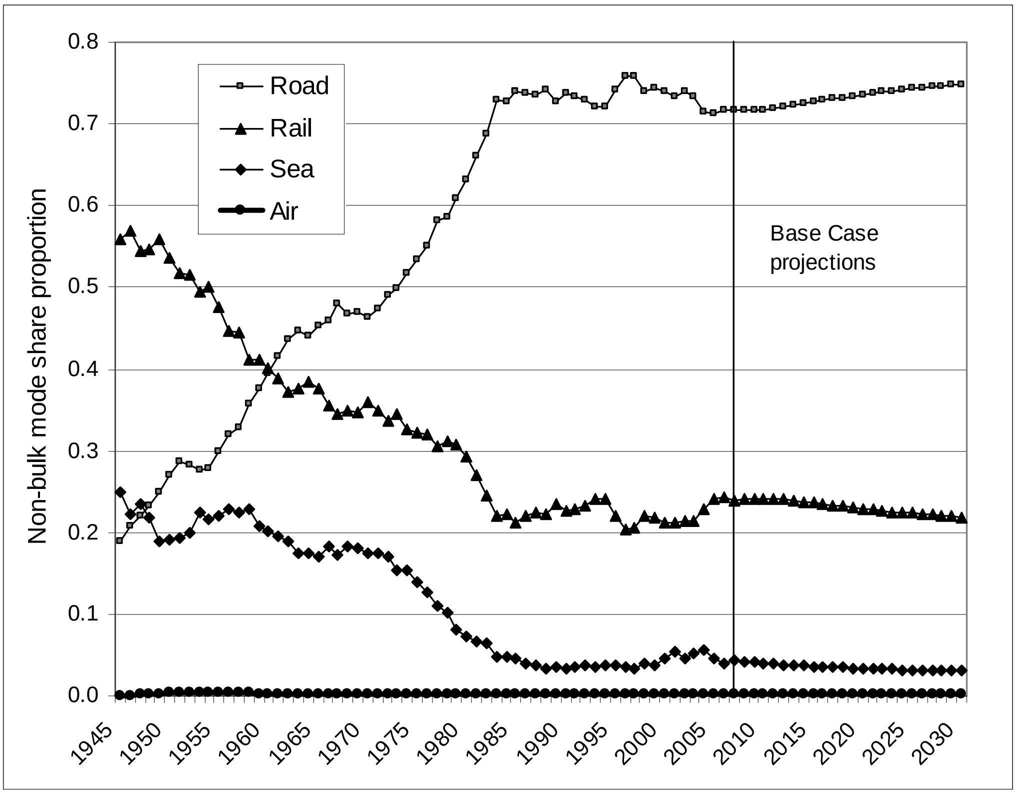

Figure 6 – Modal share, Australian non-bulk domestic freight

Sources: BTRE (2002a, 2006), BTCE (1996), BITRE (2008), BITRE estimates.

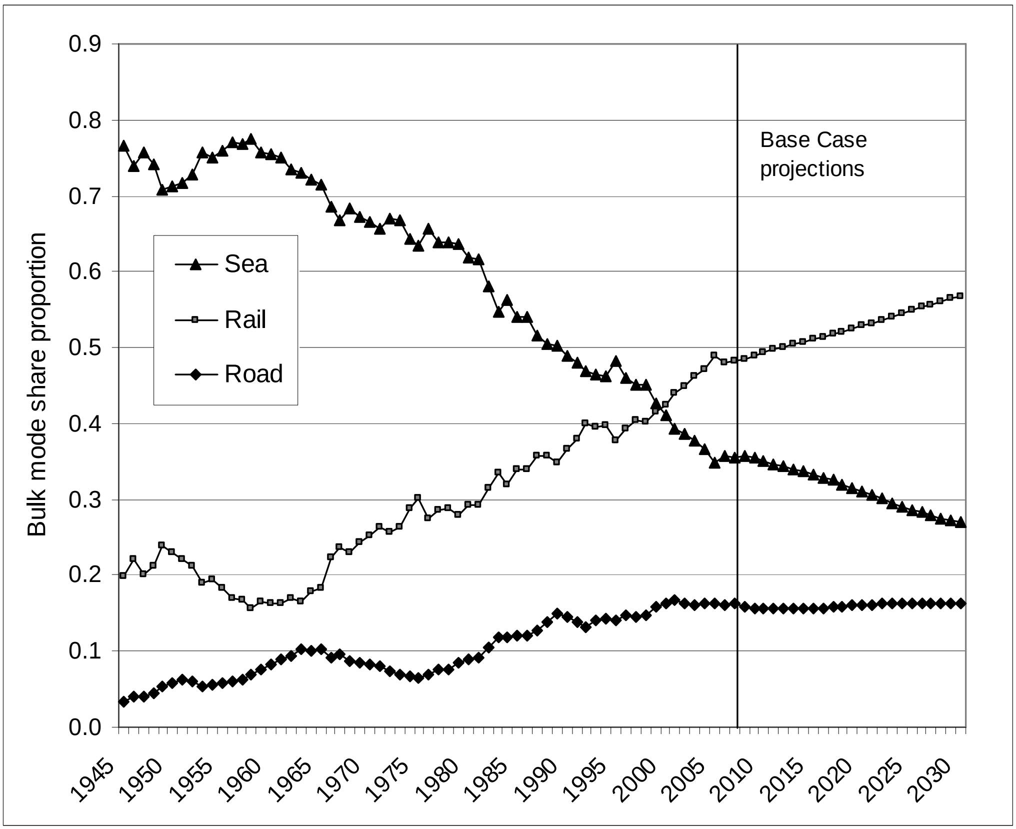

Figure 7 – Modal share, Australian bulk domestic freight

Sources: BTRE (2002a, 2006), BTCE (1996), BITRE (2008), BITRE estimates.

4 Aggregate task levels

The historical long-term trends for Australian aggregate transport tasks – domestic passenger travel (in billions of passenger-kilometres) and domestic freight movement (in billions of tonne-kilometres) – are displayed in Figure 8 and Figure 9, respectively. The base case forecasts for these task levels are also provided using the demand relationships (from Figure 2 and Figure 3), combined with the projected modal split proportions (Figures 4 to 7).

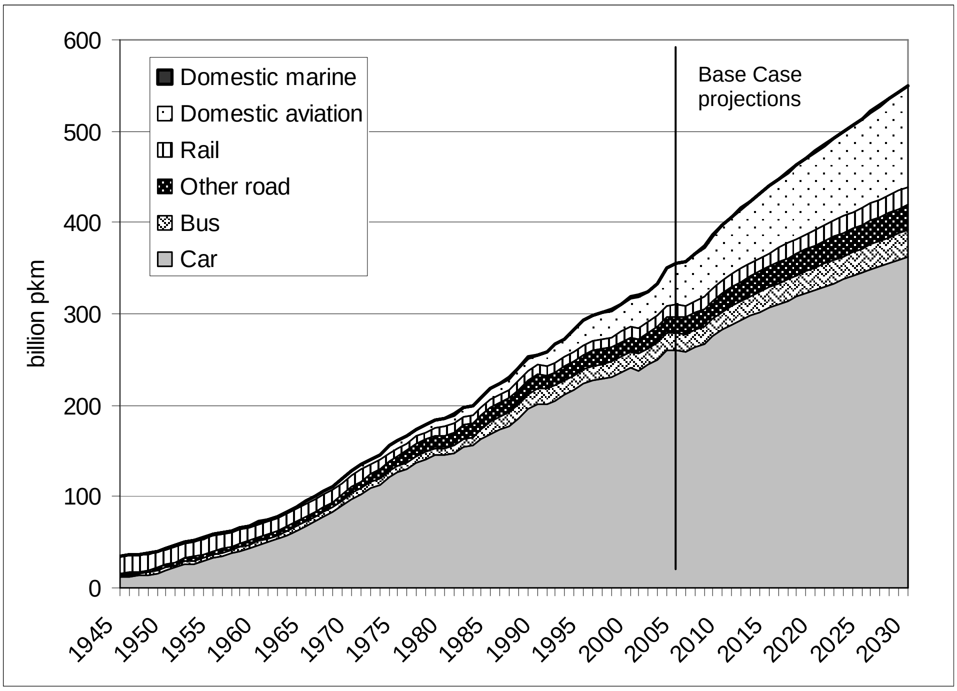

Figure 8 – Historical and projected Australian passenger movement, total domestic task

Note: 'Other road' primarily consists of non-business use of light commercial vehicles (LCVs), and of motorcycle use

Sources: BTRE (2002a, 2006), BTCE (1996), BITRE (2008), BITRE estimates.

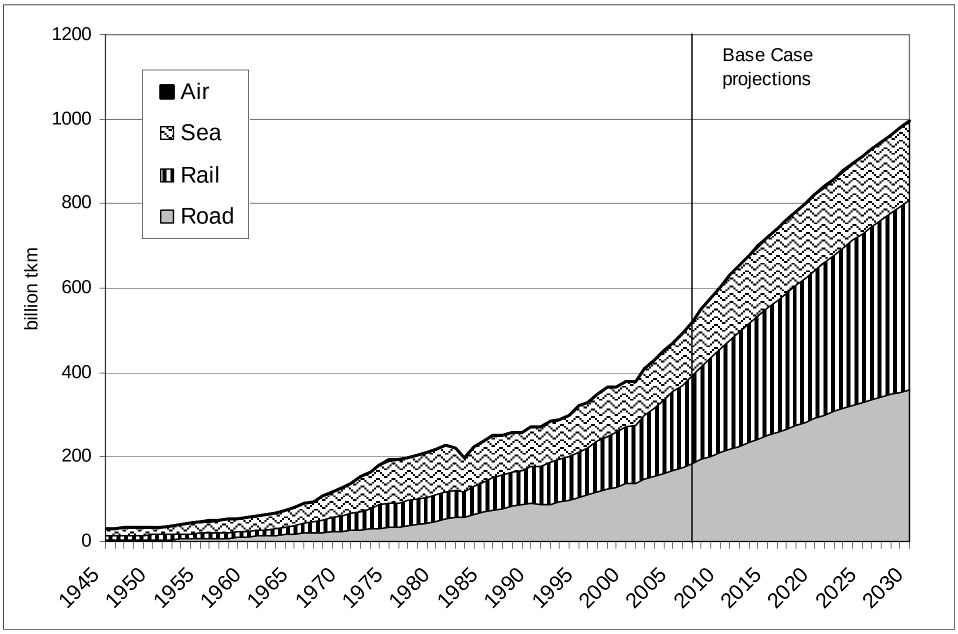

Figure 9 – Historical and projected Australian freight movement, total domestic task

Sources: BTRE (2002a, 2006), BTCE (1996), BITRE (2008), BITRE estimates.

5 Transport energy consumption

The growth in Australian transport tasks has been closely allied with the trend in national use of petroleum-based fuels (since approximately 90 per cent of domestic liquid fuel sales are consumed by the transport sector). Transport fuel combustion is the primary generator of emission output by the sector, and its magnitude has two main components – the level of transport demand and the fuel consumption rates with which those transport tasks are undertaken. The previous sections of the paper have addressed the scale of the Australian transport task levels, and Figure 10 goes on to examine an important component of aggregate fuel use – the average fuel intensity of the on-road car fleet.

Technological innovation has been gradually improving the *intrinsic* efficiency of motor vehicle engines for decades. However, on average, vehicles have also been getting larger and more powerful over time – as consumers have typically traded much of the potential gains in fuel efficiency (allowed by technical improvements to engine design) for higher vehicle performance. The result (referring to Figure 10) of buying generally heavier vehicles, including the increased popularity of 4-wheel drive passenger vehicles, has been periods where the average fuel consumption rate (litres per 100km) of Australian new car sales has failed to improve (such as the 1960s and 1970s) or only improved slightly (such as the 1990s). There appears to have been reasonable fuel intensity reductions (for the sales-weighted new car fleet) over the last few years, as relatively high fuel prices have suppressed the sales of larger sedans. Further gradual reductions are probable – see Figure 10 for projections of the likely trends, if fuel efficient petrol-electric hybrids continue to increase their sales penetration rates. However, large future reductions in vehicle fuel use and emissions output will probably be contingent on solving various technological bottlenecks – such as the current limited performance (and high cost) of batteries used in high-efficiency 'plug-in' hybrid vehicles (which can be charged directly from the electricity grid); and the need to further increase the conversion efficiency (and affordability) of renewable power generation, such as solar thermal or photovoltaic systems, serving to provide low-emission electricity for such vehicles.

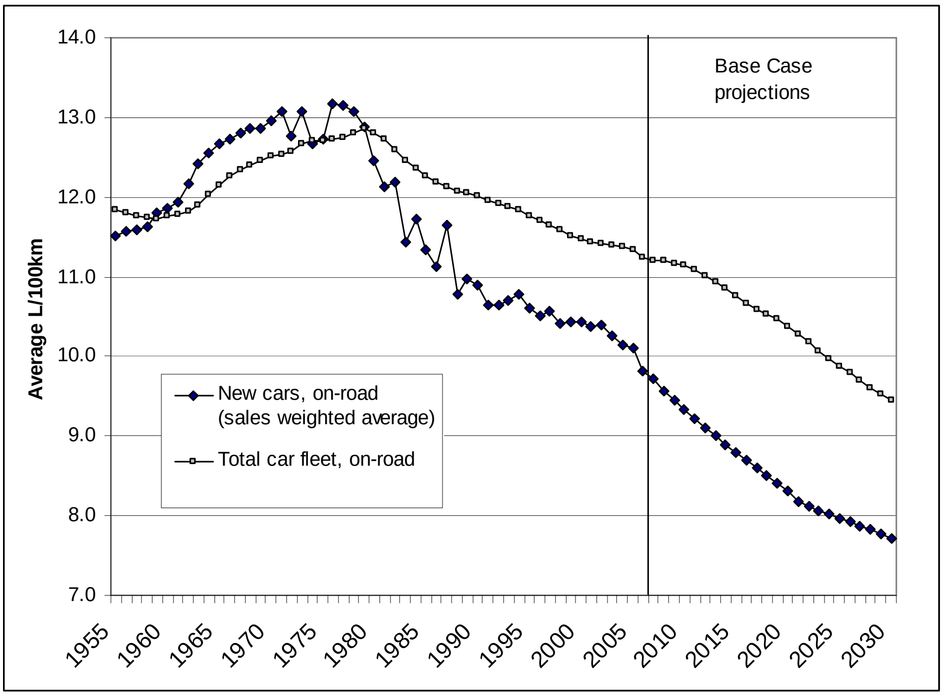

Figure 10 – Trend in on-road fuel consumption for Australian passenger vehicles

Sources: ABS (2007 and earlier), BTRE (2002a, 2000b, 2006), Cosgrove (2003), BITRE (2008), BITRE estimates.

The growth in total energy consumption by Australian transport vehicles, resulting from the historical task level increases and the trends in vehicle fuel efficiency, has averaged about 3.1 per cent per annum over the last 60 years; and, under the base case scenario assumptions, is expected to increase by around 1.5 per cent per annum over the projection period (see Figure 11). Coal use accounted for the largest fraction of total energy end-use by the domestic transport sector until the middle of last century, eventually giving way to the dominance of petroleum fuels – automotive gasoline (petrol) is currently the primary component, but with the use of automotive diesel oil and aviation turbine fuel (avtur) having faster growth rates. Medium-term growth rates for some alternative fuels, such as natural gas or ethanol, could be high – but from such a low base that their market shares by 2030 are likely to still be relatively small. Some market penetration of derived liquids – such as petroleum produced from non-conventional sources, or synthetic fuels from gas-to-liquids (GTL) or coal-to-liquids (CTL) processing – is likely within the projection period.

Over the longer term, global oil demand growth is likely to outstrip the market's capacity to supply that rate of petroleum production – with many energy sector forecasters expecting the steep projected growth in world future energy requirements to overtake the economically viable level of total petroleum supply before the middle of the century. Further development of some non-conventional sources of oil could also be affected by future climate change policies (e.g. the production of synthetic petroleum from bituminous sands tends to cause even higher CO_2 emissions, per unit of production, than for conventional crude oil). Such possible oil shortages will have significant implications for future transport task levels, probably before 2050, unless the projected gap between energy supply and demand can be bridged before then; either by increased energy efficiency, or by the large-scale introduction of more-sustainable alternative fuels. Until the form of future oil supply is more precisely known, energy use projections longer than about a 2030 timeframe should be considered as highly speculative – and where even the (conservative) oil price assumptions adopted here, for the years up till 2030, have a significant level of uncertainty attached to them.

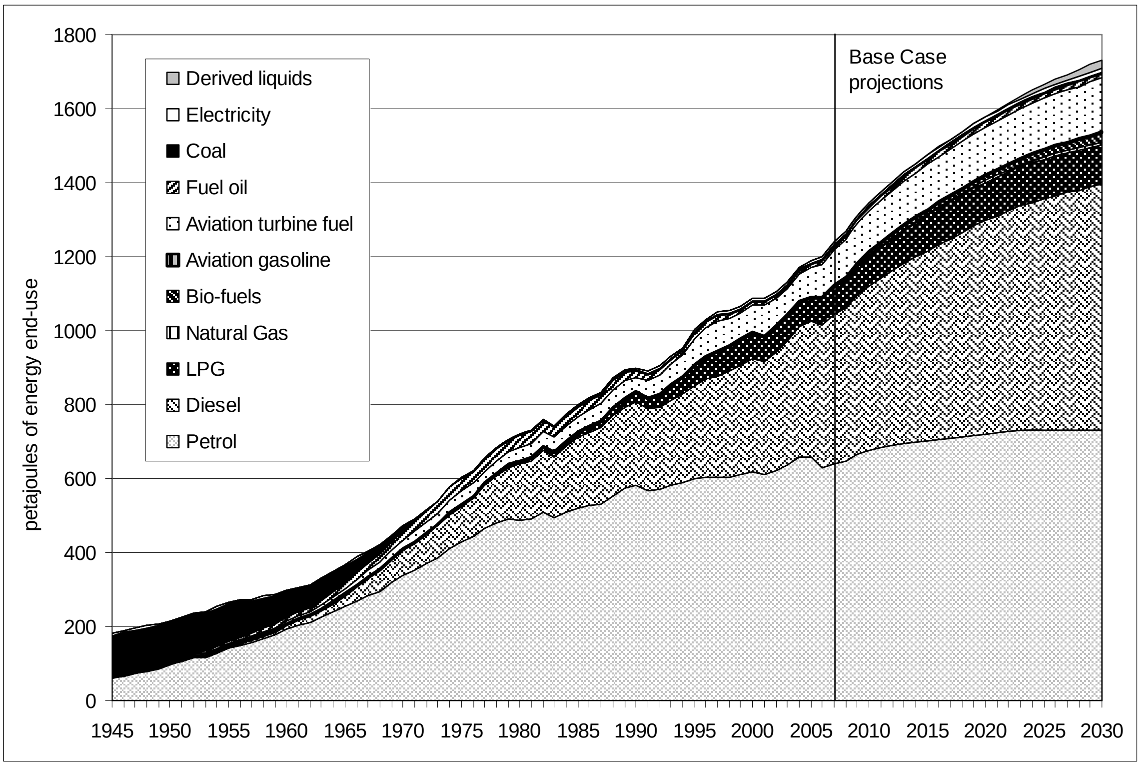

Figure 11 – Energy end-use by Australian domestic transport, long-term trends

Sources: RET (2008), ABS (2007), BTRE (2002a, 2006), Cosgrove (2003), BITRE (2008), BITRE estimates.

6 Greenhouse gas and noxious emissions

The high level of fossil fuel use by Australian transport (illustrated by Figure 11) has direct implications for the greenhouse gas emission intensity of the sector. As for most sectors relying heavily on fossil fuel combustion, carbon dioxide is the primary greenhouse gas for transport – yet non-CO_2 emissions probably also contribute significant amounts to the total radiative forcing levels. Rough estimates of the *total* warming potentials of transport emissions (BITRE 2008) – that is, considering both the *directly* radiative effects of gases like carbon dioxide, and the *indirect* effects of gases that influence direct gas concentrations, such as ozone-precursors like carbon monoxide – reveal that even though the CO_2 contribution is the dominant one, the non-CO_2 emissions account for roughly a quarter of the current sectoral total (and are even more significant for aviation, probably accounting for around 40 per cent of aggregate *CO_2 equivalent* emissions, due to high-altitude effects).

Specifically, for motor vehicles:

a.) the effects of the two direct greenhouse gases nitrous oxide (N_2O) and methane (CH_4) – though quite important for some sectors such as agriculture – tend to be relatively minor for transport, and account for about 2 per cent of the total estimated radiative contribution of road vehicle emissions;

b.) the indirect warming effects of noxious gases emitted from transport – particularly the ozone-precursors carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs), all of which are pollutants with adverse effects on human health as well as on climate change – are likely to be significant, probably averaging around 7 per cent of the annual total (radiative contribution) due to road vehicles;

c.) the direct warming effects of fugitive halocarbon releases (primarily hydrofluorocarbons, following the gradual phasing out of chlorofluorocarbons after the mid-1990s), escaping from Australian motor vehicle air-conditioning systems and refrigerated transport vehicles, probably account for something like a further 6 per cent of the radiative total for road transport; and

d.) the net effects of atmospheric aerosols (calculated from estimates of the black carbon portion of road vehicle particulate matter emissions, allowing for some cooling effects from sulphate formation due to vehicle emissions) possibly add a further 5-10 per cent to the total.

The levels of some noxious non-CO_2 emissions will be reduced by various developments in vehicle technologies (e.g. electric vehicles) and by the increased use of advanced emission-control technologies (such as on-board catalyst heaters to reduce the very high emission rates during vehicle 'cold starts', where the first couple of minutes of engine operation, until the full operating temperature of the catalytic converter is reached, can account for half or more of a car trip's noxious emission output; or particulate traps/filters to reduce fine exhaust particles, which not only contain carbon soot, implicated as one of the major sources of climate change, but also ultrafine constituents that are probably the main cause of transport-related health damages). If the widespread use of such emission technologies were to be pursued, many could be successfully retro-fitted onto existing vehicles, as well as requiring new vehicles to be suitably equipped.

In addition to technology options, one example of a possibly cost-effective emission abatement measure involves the use of roadside remote sensing devices – which could be used to select 'gross polluting' vehicles from traffic streams, to target for vehicle servicing or replacement/retirement schemes. Many studies into vehicle fleet emission profiles have demonstrated that ‘gross polluters’ (which typically comprise roughly 10 to 20 per cent of the overall vehicle fleet) account for an inordinate amount (generally between 50 to 90 per cent) of total pollutant emissions, as well as having higher than average fuel consumption rates.

Figure 12 displays the composition, by major emission type, of the estimated total CO_2 equivalent (direct plus indirect) greenhouse gas emissions due to Australian domestic transport. Figure 13 splits the long-term aggregate emission trend into modal components.

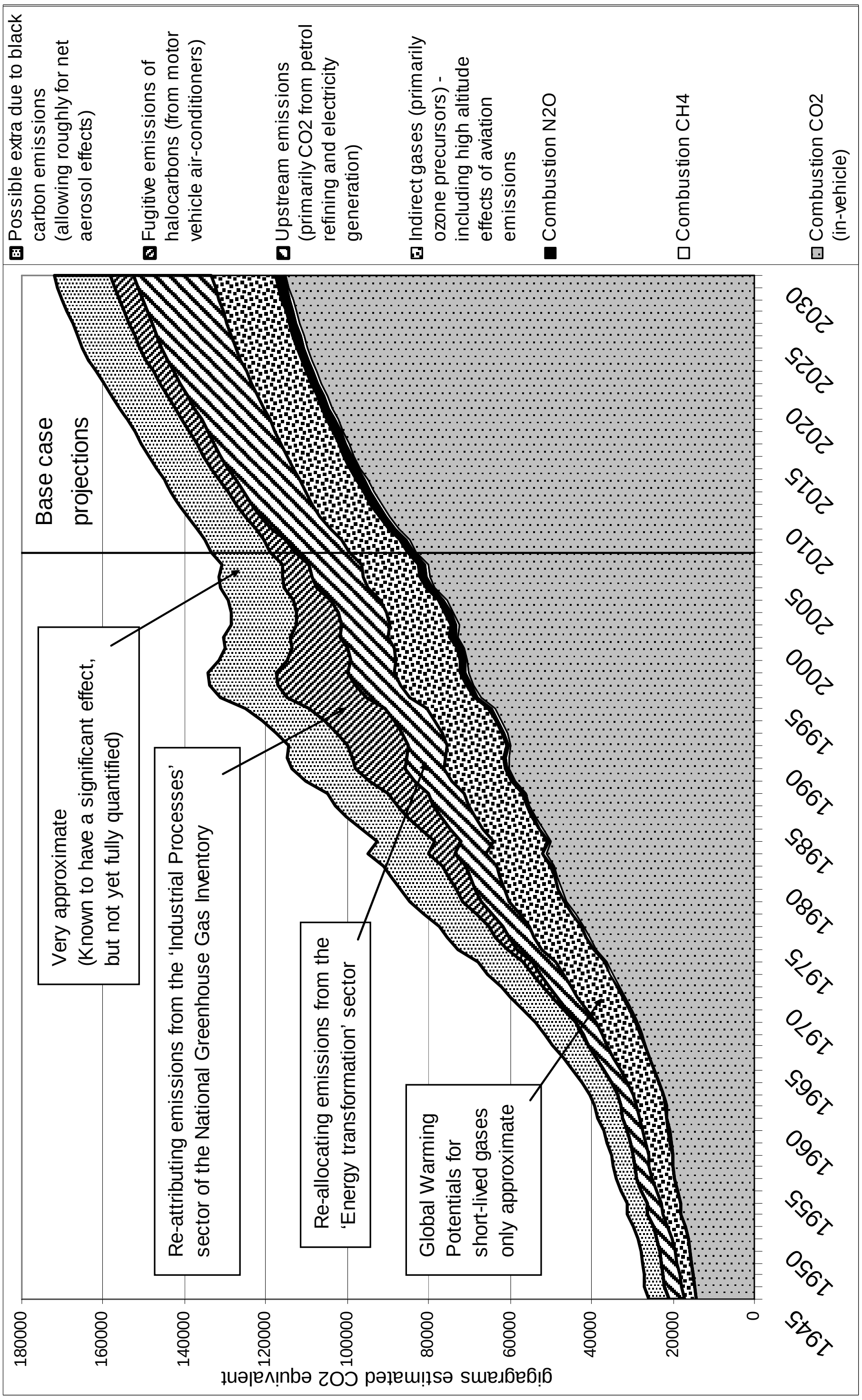

Figure 12 – Estimation of the full greenhouse contribution of Australian domestic transport

Sources: BITRE (2008), BITRE estimates.

Including international transport (using an indicative allocation of half the total fuel consumption by all aircraft and ships travelling to and from Australia) lifts the current estimate for aggregate domestic emissions (of around 134 million tonnes of CO_2 equivalent, all direct and indirect gases, for 2007) by around 28 per cent (to about 171 million tonnes).

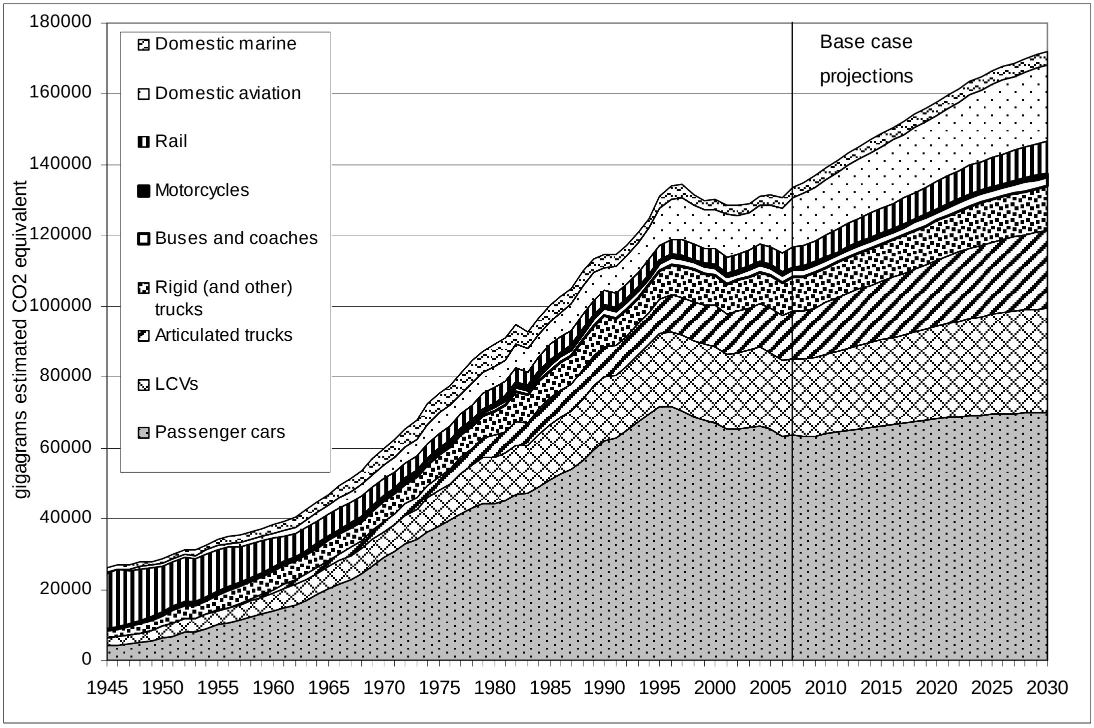

Figure 13 – Total greenhouse gas emissions, Australian domestic transport by mode

Sources: BITRE (2008), BITRE estimates.

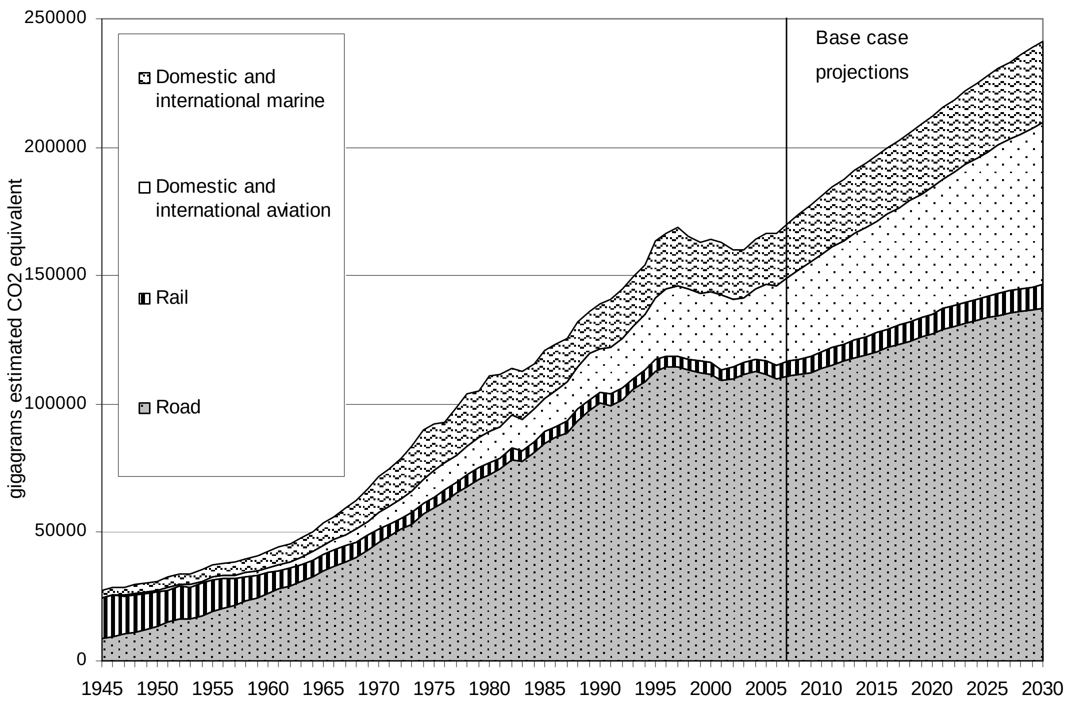

Figure 14 – Total greenhouse gas emissions, all Australian transport by mode

Sources: BITRE (2008), BITRE estimates.

Table 1 – Emissions due to fuel use by Australian domestic civil transport

Financial	*CO_2*	*CO*	*CH_4*	*N_2O*	*NO_x*	*NMVOCs*	*SO_x*	*PM_{10}*
year	*million tonnes*				*thousand tonnes*			
1960	25.1	2.0	14.60	0.54	324	426	69.3	22.0
1961	25.4	2.0	14.53	0.56	335	438	66.2	21.8
1962	25.9	2.1	14.75	0.57	341	451	64.4	21.8
1963	27.2	2.2	15.27	0.61	353	471	64.6	22.3
1964	28.5	2.3	15.85	0.64	369	494	65.5	22.9
1965	29.9	2.4	16.47	0.68	387	520	66.3	23.6
1966	31.2	2.5	17.02	0.71	410	538	66.3	24.3
1967	32.2	2.6	17.26	0.75	428	555	63.2	24.4
1968	33.4	2.7	17.79	0.79	445	574	65.1	24.9
1969	35.3	2.8	18.53	0.84	466	607	66.0	25.7
1970	37.1	3.0	19.16	0.90	480	638	65.8	26.1
1971	38.6	3.0	19.61	0.94	488	632	67.0	26.4
1972	40.4	3.2	20.35	1.00	502	648	70.9	27.3
1973	42.0	3.2	20.78	1.05	511	649	71.8	27.9
1974	45.0	3.4	21.77	1.13	529	670	77.9	29.4
1975	46.8	3.5	22.19	1.19	527	678	76.5	29.6
1976	48.2	3.5	22.47	1.24	525	680	73.2	29.5
1977	50.7	3.7	23.36	1.31	540	692	74.1	30.5
1978	53.1	3.7	24.03	1.38	550	695	77.9	31.4
1979	54.6	3.8	24.05	1.42	546	692	72.7	31.3
1980	55.8	3.7	23.99	1.47	550	676	76.3	31.9
1981	56.8	3.7	24.09	1.53	551	668	80.4	32.6
1982	59.0	3.9	24.77	1.62	548	679	75.3	32.6
1983	57.6	3.8	24.06	1.62	517	656	69.6	30.7
1984	60.0	3.9	24.80	1.71	524	666	71.0	31.4
1985	62.1	4.0	25.26	1.80	530	671	68.9	31.7
1986	63.7	4.0	25.53	1.87	531	668	72.0	31.9
1987	64.8	4.0	25.64	1.94	530	661	68.4	31.4
1988	67.9	4.1	26.28	2.06	545	672	71.2	32.4
1989	69.8	4.2	26.66	2.16	544	680	67.8	32.0
1990	70.1	4.3	26.97	2.24	545	675	63.3	31.4
1991	69.3	4.1	26.84	2.52	530	644	56.6	29.0
1992	70.5	4.1	27.41	2.80	539	639	54.8	28.5
1993	72.2	4.2	28.27	3.13	545	642	50.4	28.2
1994	74.0	4.2	29.05	3.47	554	634	46.4	27.9
1995	77.8	4.2	29.97	3.89	583	636	52.1	29.1
1996	80.0	4.2	30.29	4.23	595	623	52.0	29.2
1997	81.5	4.1	30.57	4.50	600	609	50.5	28.7
1998	81.8	4.0	30.66	4.71	590	591	45.4	27.4
1999	82.6	3.9	30.91	5.00	580	575	40.1	26.1
2000	84.4	3.7	31.04	5.29	581	559	39.5	25.5
2001	84.3	3.5	30.17	5.42	563	528	37.0	24.5
2002	85.8	3.4	30.35	5.71	561	516	35.1	24.2
2003	87.7	3.4	30.67	5.96	561	509	31.3	23.7
2004	91.0	3.3	31.30	6.25	565	508	30.0	23.4
2005	92.5	3.2	30.83	6.27	556	487	29.5	22.8
2006	93.2	3.0	29.35	6.22	545	460	28.6	22.0
2007	96.4	2.9	29.25	6.36	542	449	28.9	21.8

Note: Full fuel cycle emissions, from all modes and fuel types, for carbon dioxide (CO_2), carbon monoxide (CO), nitrous oxide (N_2O), methane (CH_4), nitrogen oxides (NO_x), non-methane volatile organic compounds (NMVOCs), sulphur oxides (SO_x) and exhaust particulate matter less than 10 microns (PM_{10}).

Sources: BTRE (2002a, 2006), Cosgrove (2003), BITRE (2008), BITRE estimates.

7 Conclusion

As shown in Figures 11 to 14, total energy consumption and consequent greenhouse gas emission levels for Australian transport have grown, on average, by around 3 per cent per annum over the last half a century or so – and using 'reference' case scenario assumptions (i.e. with no further rises to current real fuel prices) yields projections for expected further increases of approximately 1.5 per cent per annum over the next couple of decades.

Current aggregate emissions from Australian transport are dominated by the road sector (with cars, light commercial vehicles and trucks accounting for almost 83 per cent of domestic transport's CO_2 equivalent emissions in 2007 – see Figure 13). Recently there has actually been stronger task growth in several other transport sectors, partly due to relatively high oil prices discouraging some vehicle use. For example, annual UPT patronage for several major cities (including Melbourne, Brisbane and Perth) has apparently been growing at higher rates than car travel over the last few years – probably partially due to UPT infrastructure or service improvements, and partially due to disincentives to vehicle travel such as traffic congestion and high petrol prices. The result of recent national UPT passenger growth (between the 2004 and 2007 financial years) averaging almost 3 per cent per annum (as opposed to average growth over the preceding 30 years of only around 1 per cent per annum) has been a slight increase in UPT mode share (with the 2004 national average of around 9 per cent, of aggregate urban pkm, growing to almost 10 per cent by 2007 – see Figure 4). The future will probably see further growth in UPT mode share – but if oil prices remain fairly stable up till 2030, then the relative dominance of motor vehicles is likely to only decrease slightly over the forecast period (given the enormity of the current task disparity between private vehicle use and public transit – again see Figure 4).

Growth in future mode share is possible for several sectors that offer emissions benefits over road vehicles (such as urban passenger rail, cycle commuting, and non-bulk freight rail transport) – but the general pattern of such movements will probably be fairly dependent on fuel price trends. If oil prices do not rise significantly before 2030, then any move away from road vehicle use, over the *base case* projection period, is likely to be relatively muted (Figure 8 and Figure 9). Yet rapidly escalating petrol prices remain a possibility within the projections' 2030 timeframe (and will become even more likely over the longer term, with the prospect of economically viable supplies of oil eventually becoming scarce). Even with the relatively inelastic response of most transport tasks to fuel prices, large enough price increases will, of course, promote a wide range of behavioural changes. High petrol prices would encourage sales of fuel-efficient vehicles (such as hybrid cars), modal share increases for the more energy efficient of modes (such as rail transport), and (over the longer term) development of alternative fuel supplies; while discouraging some discretionary travel. Certain of such adaptations (including the production and distribution of many alternative fuels, and some large-scale modal shifts) would likely require significant infrastructure development.

As shown in Figure 12, carbon dioxide is clearly the major greenhouse gas for transport – yet the figure demonstrates that non-CO_2 emissions also make substantial contributions to the total radiative forcing levels due to transport activity. The results given in Section 6 highlight that any examination of transport emission levels (including the appraisal of greenhouse emission abatement measures) should ideally be based on the total likely impacts of all relevant emission types and sources. That is, as far as is practicable, analyses of transport emissions should consider both direct and indirect greenhouse gases – from fuel combustion, fugitive releases and any upstream processing activities (such as from transport fuel supply or distribution).

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