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Transport and Greenhouse: What Won't Work and What Might Work

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Abstract:

Proposals for meeting the Toronto target for reducing carbon dioxide emissions from the Australian domestic transport sector under a 'no-regrets' policy have been examined. The biggest emitters by far are private road vehicles. Without government intervention emissions from them will increase greatly. Government cannot depend on the usual 'solutions', technological change and modal shift. Rather it will have to intervene to change social choice — to limit the growth of cities, to reduce the size of cars and reduce the demand for travel.

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Introduction

The combustion of fossil fuels releases carbon dioxide at rates believed by atmospheric modellers to be high enough to cause serious disruptions to the world's climate. Despite disagreements on detail the growing consensus among the modellers has caused the world's leaders to take the threat seriously, and to consider what might best be done. Possible responses are:

- to leave the burning of fossil fuels to market forces, as at present, and cope with any future problems which might turn up if and when they do turn up - the so-called 'business-as-usual' option,
- to intervene to ensure that all possible actions which will reduce the emission of greenhouse gases without net cost are taken now - the so-called 'no-regrets' option,
- to intervene strongly enough to stabilize the levels of greenhouse gases at something equal to or less than present levels, even if this were to result in a downturn in world economic activity.

World attention has been focussed on a target set by a World Conference on Atmospheric Change held in Toronto in 1988 to reduce the emission of carbon dioxide to 80% of the 1988 levels by the year 2005 (Pearman et al 1989). The response of the Australian government is that we will aim for this target, but only insofar as there will be no net cost to the nation, ie we will pursue the no-regrets option. Clearly the advisers to the policymakers in Australia as elsewhere should be busy working out the most effective ways of reducing greenhouse emissions and the costs of the various options for all the energy-consuming sectors of the Australian economy. Discussion of costs is beyond the scope of this paper, but what we can do is to identify policy options which would be worth evaluating.

To simplify our examination let us assume that the government sets the Toronto target as a target for each separate sector of the Australian economy, including the transport sector, one of the biggest emitters of carbon dioxide (according to the Australian Bureau of Agricultural and Resource Economics (ABARE) (1991) the direct use of energy in the transport sector in 1987-88 accounted for 26% of the primary energy consumption in Australia. If the energy provided overseas for use in international air and sea transport to and from Australia were to be added this percentage would increase to 32% (Apelbaum 1991)).

If our Department of Transport and Communications were to decide that the best way to tackle the development of appropriate policy was to call for submissions from interested parties on what it should do it would not be short of suggestions. All the single-interest enthusiasts would wheel out their ideas, from car-pooling and solar cars to fast trains and B-doubles. Some of these proposals would be trivial or just plain useless, some might be unable to reduce emissions although useful on quite other grounds, others would have the ability to make a worthwhile contribution to the reduction of greenhouse emissions. These latter are the ones that "might work"; but even they won't work unless the government introduces measures to make them work, otherwise what would happen in the future would be determined largely by the present balance of market forces and government intervention, ie business as usual.

Thus the aim of this paper is to establish which proposals could make an appreciable contribution to meeting the Toronto target for the Australian transport sector under a no-regrets policy, and the measures which would be required to implement them. Particular attention will be given to the question of whether technological developments will be able to get us well on the road to the Toronto target, or whether these will have to be augmented by actions to change people's behaviour.

The following method is used to achieve this aim. First, the present transport task is documented by sub-sector and mode, together with the corresponding energy requirements and carbon dioxide emissions. This will give us a guide as to the future pattern we may expect without government intervention. Next, proposals which have been suggested in the literature for making changes to the present pattern are listed. Then criteria are identified which will permit us to exclude useless proposals from consideration, "what won't work". The proposals which remain can then be evaluated to tell us "what might work". Finally, suitable measures for implementing these potentially useful proposals are examined.

Identification of feasible proposals

Present pattern of energy use and emissions in the transport sector

The starting point for our enquiries must be a clear picture of the present pattern of transport energy use and consequent emissions. Several comprehensive surveys of the transport task and the energy consumed in fulfilling this task are available. Because of differences in methodology and assumptions these surveys differ in the detail of the results, but a clear enough picture emerges for us to proceed with our examination. The first set of data was prepared for the National Energy, Research, Development and Demonstration Program by Nelson English Loxton & Andrews (NELA) (1988). This is for the year 1984-85, but includes a comparative set for the year 1975-76 prepared using the same assumptions. The period spanned is in the post-oil-crisis (high-oil-price) period, which should provide a basis for predicting the growth in energy use for the next ten or so years if the present array of government energy intervention measures were to be left in place. It will be used in this paper for that purpose. This set has been updated by Apelbaum (1991) to include a second set, for the year 1987-88. The third set was prepared by the Bureau of Transport and Communication Economics (BTCE) (1991a) for the years 1984-85 and 1987-88. This set has the advantage that the energy figures in it have been translated into carbon dioxide emissions. The BTCE data will be used here for examining carbon dioxide emissions.

The passenger task: Table 1 shows data for the passenger task for the various transport modes in 1987-88. It is dominated by domestic travel, with only 17% of it coming from international travel. The domestic task is in turn dominated by road travel, which itself is dominated by the motor car. Non-urban bus travel has been increasing rapidly over the last few years, but it still comprises only a few per cent of the total. This table also shows the average rate of growth for each mode over the period 1976 to 1985 as calculated from the NELA data. The task grew by an average of 4.0% per year over that period.

Table 2 breaks down the domestic passenger task into specific functions (NELA 1988). Two thirds of the task is private travel, nearly all of it by private road vehicles, and only one third business plus the journey to work.

Table 1 Australian passenger task in 1987-88, billions of passenger.km

	urban	non-urban	total	% of total	annual % growth 1976-1985 (b)
domestic (a)					
road	144	74	218	75	4.0
cars	131	56	187	65	
LCVs	7	5	12	4	
buses	5	12	17	6	
rail	7	2	9	3	7.6
air	-	13	13	5	3.5
domestic total	151	90	241	83	4.1
international (c)					
air	-	50	50	17	4.0
sea	-	negl	negl	negl	
grand total	151	140	291	100	4.0

LCVs are light commercial vehicles. Sources: (a) BTCE (1991a); (b) NELA (1988); (c) Apelbaum (1991)

Table 2 Breakdown of Australian domestic passenger task in 1984-85, percentage of total passenger.km

	road		rail	air	total
	bus	other			
journey to work	1	16	3	negl	20
business	negl	12	negl	2	14
private	1	59	3	2	66
total	3	87	6	4	100

Source: NELA (1988:32)

The freight task: Table 3 shows the freight task for 1987-88. The task carried out by international shipping is shown for completeness, even though some workers do not consider it (for example it was not considered in the Final Report by the Ecologically

Sustainable Development Working Group on Transport (Commonwealth of Australia 1991)). The carbon dioxide emitted from these ships adds to the world's carbon dioxide burden, and presumably the exporting and importing nations have to take joint responsibility for it. The task is in fact dominated by international sea freight. However an earlier draft of this paper revealed that it was almost entirely beyond the ability of the Australian government to influence, and this paper will therefore be confined to the domestic transport task. Domestic freight, which takes up only a few percent of the total, is distributed fairly evenly over road, rail and coastal shipping.

Like the passenger task, the freight task grew at an average rate of 4.0% per year over the period 1976 to 1985, with domestic road freight showing much stronger growth.

Table 3 Australian freight task 1987-88, billions of tonne.km

	urban	non-urban	total	% of domestic task	annual % growth 1976-1985 (b)
domestic (a)					
road	31	55	86	33	8.2
LCVs	3	2	5	2	
rigid trucks	13	8	21	8	
articulated trucks	15	45	60	23	
rail		81	81	31	2.6
government		50	50	19	
non-government		31	31	12	
air		negl	negl	negl	
sea (coastal)		94	94	36	-3.4
international (c)					
air		2	2		11.8
sea		3550	3550		4.1
total task				% of total task	
domestic total	31	230	261	7	1.9
international total		3550	3550	93	4.1
grand total	31	3780	3810	100	4.0

Sources: (a) BTCE (1991a); (b) NELA (1988); (c) Apelbaum (1991)

Carbon dioxide emissions: Table 4 shows the BTCE figures for carbon dioxide emissions resulting from the execution of the domestic passenger and freight transport tasks in 1987-88. Road transport accounted for 86% of the total, of which 57% came from cars and that part of the LCVs used for passenger transport. Put on a per capita basis, the average

Australian emitted more carbon dioxide from his or her motor car than the average Chinese person did for the whole Chinese economy.

According to NELA (1988) domestic transport energy consumption continued to grow at an average rate of 3.0% per year over the decade 1976-85, and we may assume that the carbon dioxide emissions grew at the same rate. This was smaller than the 4.1% growth of the domestic transport task of the same period, indicating that the task was being performed progressively more efficiently, with a corresponding reduction in the carbon dioxide emission. However the rate of growth in transport energy use in Australia over the period 1976 to 85 was one of the highest in the world; for example over the same period growth in transport energy consumption for the OECD group of countries averaged only 1.6% per year.

Table 4 Carbon dioxide emissions from the domestic transport sector in Australia in 1987-88, (Gt/year)

	passenger (a)		freight (a)		total (a)		% annual growth rate
	Gt	% of total	Gt	% of total	Gt	% of total	1976-85 (b)
cars & LCVs		57		7		64	2.8
urban	29.1	42	3.1	4	32.2	46	
non-urban	10.2	15	2.3	3	12.5	18	
buses		2				2	4.6
urban	0.5	1	-	-	0.5	1	
non-urban	0.7	1	-	-	0.7	1	
trucks				18		18	3.5
rigid, urban	-	-	3.8	5	3.8	5	
rigid, non-urban	-	-	2.0	3	2.0	3	
artic'td, urban	-	-	1.8	3	1.8	3	
artic'td, non-urban	-	-	4.6	7	4.6	7	
rail		2		3		5	1.5
urban	1.0	1	-	-	1.0	1	
non-urban	0.3	<1	2.2	3	2.5	4	
air	3.5	5	0.6	1	4.1	6	0.8
sea	-	<1	1.5	2	1.5	2	-0.4
total	47.6	68	22.0	32	69.6	100	3.0

Source: (a) BTCE (1991a). In calculating these figures BTCE has included carbon dioxide emitted in the whole of the fuel cycle, from primary energy such as crude oil at the well and coal at the mine to energy such as petrol and electricity available at the point of use. This includes emissions from oil refineries and power stations. (b) NELA (1988. It is assumed here that the growth rates in transport energy use calculated from the NELA data translate into corresponding growth rates in carbon dioxide emissions.

Proposals suggested for reducing emissions

If the rate of emission of carbon dioxide were to continue to grow at 3.0% per year, as recorded for the period 1976 to 1985, the emissions in the year 2005 would be 65% higher than in 1988, rather than 20% lower, as envisaged by the Toronto call. However there will be some reduction in growth even without government intervention, for two reasons: there will be improvements in efficiency induced by market forces over the period, and there will be a movement towards saturation of demand (for example there will be a limit towards the number of hours per day that an individual will keep driving a car for enjoyment). The ESD Transport Working Group Final Report (Commonwealth of Australia 1991:14-19), using the ABARE projections (1991), estimated that the energy consumption of the transport sector would increase by only 39% over the years 1988 to 2005 for business as usual, ie no additional government intervention. That is, the year 2005 business-as-usual emissions would have to be reduced by 42% to reach the Toronto target ((139% - 80%)/139% = 42%).

Proposals for contributions to this reduction in emissions suggested by various workers fall into three groups:

- substitution of oil by other forms of energy, eg alcohol, natural gas, liquefied petroleum gas (LPG), compressed natural gas (CNG), hydrogen, electricity,
- performing the same task with less energy by increases in efficiency, eg more efficient engines, smaller cars, increased occupancy of passenger vehicles, and switching to other transport modes which are more efficient at performing the task and emit less carbon dioxide,
- reducing the task, eg by reducing discretionary travel, and by improving the design of cities.

Some of these would be politically difficult to implement, some have long lead times, and some, despite their popularity in folklore, would be unlikely to result in appreciable reductions even if they were implemented.

Eliminating infeasible proposals

Before we examine individual proposals in detail we will need some tests to dispose of proposals which are not worth further examination on the grounds that they can't possibly help us to achieve our aim of making an appreciable contribution to meeting the Toronto target for the transport sector under a no-regrets policy.

The first step is to exclude proposals which operate in any sub-sector or part of it which emits only a very small proportion of the total carbon dioxide from transport. Implementing such proposals might reduce emissions slightly, but we presume that a government with limited funds and personnel at its disposal should concentrate its attention on areas where real gains could be made.

Next, we should exclude proposals which will generate more carbon dioxide than the present practice that it is has been suggested they replace. Proposals for alternative fuels or alternative modes of transport should be put to this test.

Then we have to reject proposals which would cost more than the present practice that it is suggested they replace, even if they have passed the first two tests. This rather tough test arises from the adoption of the no-regrets option, which, as discussed earlier, is as far as the Australian government (or the world) is likely to go at present.

Finally we should exclude proposals which can't work in the time frame required to meet the Toronto target. Many of such proposals would be worth pursuing at the research and pilot development level, but as they can't, by definition, help us to meet the target, they should have a lower priority for the use of resources at the implementation level than those which do have that potential.

Examination of feasible proposals

Substitution

The oil crises of the 1970s resulted in many proposals being put forward for developing other forms of energy to substitute for oil used in transport. Over the last fifteen or twenty years an enormous effort has been put into research and development of these proposals, in Australia as elsewhere. Had the pattern of oil use in the world experienced up to 1973 continued half the world's oil would have been used up by the year 2000, but the reaction to the same oil shocks that provoked the flurry of substitution proposals also changed the pattern of oil use massively and irrevocably, and it now seems that the oil will not be half gone until around the year 2030, quite a difference! (Evans and Atkins 1992). Thus the development of oil substitutes is no longer a matter of urgency.

Unfortunately many substitution proposals are still being put forward, driven by this earlier momentum, and are still being supported, in some cases despite deleterious greenhouse effects. Oil from coal or oil shale and methanol from coal all produce far more carbon dioxide per unit of usable energy than conventional petroleum products. Hydrogen from coal and electric traction via batteries charged from coal-fired power stations also produce more carbon dioxide than conventional oil, and the performance of the vehicles using them is as yet inferior because of the added mass of the on-board energy-storage devices.

Substitution proposals which emit less carbon dioxide than oil have also been put forward, but most of them are either far more expensive than oil, present worse environmental problems of other kinds, or could not be developed before the year 2005. Hydrogen from nuclear power stations and ethanol from biomass both present very great environmental problems. Despite the solar car rallies held in Australia over the last few years these 2 kilowatt vehicles can never be more than a gimmick, and cars powered by hydrogen or electricity from solar power stations are many decades off.

The only oil substitution proposals for motor vehicles that are environmentally sound and technologically feasible at the moment, and which could therefore make a contribution by the year 2005, are the use of LPG, compressed natural gas (CNG), and perhaps methanol made from natural gas, with CNG as yet feasible only for short trips on standard routes. Supplies of LPG in Australia are limited, and could provide less than 10% of the total road transport requirement. In any case according to Oppenheimer and Zingarelli (1991) carbon dioxide emissions from LPG and from the two natural-gas based proposals are only marginally lower per km travelled than from conventional petrol.

One could sum all these proposals up by categorizing them as supply-side proposals. Greenhouse pressures seem likely to push us rather towards demand-side solutions - performing the same task with less by increasing efficiency, or reducing the task by demand management. I will now examine these in turn.

Energy efficiency

As consumption of transport energy and emission of carbon dioxide go hand in hand, increased efficiency means reduced emissions. Table 5 shows the energy efficiency of the various transport modes prevailing in Australia in 1987-88, calculated from BTCE data (1991a). The efficiency measures used are person.kilometres per megajoule (MJ) of transport energy for the passenger task, and tonne.kilometres per MJ for the freight task. The corresponding carbon dioxide emission figures are also shown. As efficiencies increase emissions decrease.

Table 5 Energy efficiencies and carbon dioxide emissions for various transport modes in Australia in 1987-88

	passenger efficiency (p.km/MJ)		CO_2 emissions (kg/p.km)	
	urban	non-urban	urban	non-urban
passengers				
cars	0.34	0.38	0.21	0.18
LCVs	0.26	0.28	0.27	0.25
trains	0.63	0.63	0.15	0.12
buses	0.62	1.25	0.12	0.06
air	-	0.26	-	0.26
	freight efficiency (t.km/MJ)		**CO_2 emissions (kg/t.km)**	
	urban	non-urban	urban	non-urban
non-bulk freight				
LCVs	0.06	0.05	1.2	1.4
rigid trucks	0.25	0.30	0.29	0.24
articulated trucks	0.63	0.71	0.12	0.10
rail	-	1.3	-	0.06
sea	-	1.4	-	0.05
air	-	0.02	-	3.1
bulk freight				
government rail	-	2.5	-	0.029
non-government rail	-	10	-	0.010
sea	-	5	-	0.013

Source: BTCE (1991a)

In most cases efficiencies are only around ten per cent higher for non-urban transport than for urban transport. Evidently the efficiency gains resulting from the relative absence of congestion and stop-start driving conditions are partly counterbalanced by the loss of efficiency due to air friction at the higher speeds. The exception is non-urban buses which are twice as efficient at moving people as urban buses, presumably because of the high occupancy rates achieved (see below). As expected, bulk freight is carried far more efficiently than non-bulk freight, especially in the dedicated railway systems used for carrying coal and iron ore from the mines to the coast for export. Although railways are more efficient than road transport for carrying non-bulk freight, they are less than twice as efficient when the comparison is limited to articulated trucks, which, as seen from Table 3, carry most of the non-urban road freight.

Proposals for improving efficiencies fall into four classes: switching to more efficient modes of transport; increasing occupancy rates of vehicles; technological improvements which increase the efficiency of the engines or reduce energy losses due to friction; and the use of lighter weight or less powerful vehicles. We will examine each of these in turn, concentrating our attention on the two big emitters, the private motor car together with light commercial vehicles used for passenger transport (57% of all emissions - see Table 4) and trucks (18%).

Modal switch: A popular catchcry is for a switch from the car to public transport. However, despite popular belief, Table 5 shows that trains and buses are not dramatically more efficient than the private car for moving people in urban areas, the reason being that occupancy rates averaged over the whole day are quite low (see below). Also emissions of carbon dioxide per MJ would be higher for trains than for cars, because they are based on electricity from coal rather than petrol.

Only a very small part of the urban passenger transport task is performed by these modes, 2% by bus and 3% by rail (Table 1). The switch from the car to rail would not be easy, as most of the switchable part is in peak periods on the journey to work and to school, at which times rail is now saturated; further switches to it would therefore require large investment in infrastructure. Because of the large infrastructure cost the switch from cars to rail is unlikely for the no-regrets option. If passenger transport by bus could be doubled by the year 2005 and transport by car reduced correspondingly emissions would be reduced by only about 0.6% because we would be gaining only a modest advantage in efficiency with the change, and the change would itself be for only 2% of the total task.

As seen from Table 5 moving freight by rail is more efficient than moving it by road. Despite this, domestic road freight was the fastest growing part of the domestic freight sub-sector in the period 1976 to 1985, because of the speed and flexibility it offers. As a result many proposals have been put forward for combining the efficiency of rail for long hauls with the flexibility of road, for example by transferring container loads from articulated trucks to rail for interstate hauls, then back again to trucks for final delivery. If the non-urban freight task moved by articulated trucks could be halved by the year 2005 and the task by rail correspondingly increased domestic emissions would be decreased by 1.3%. However because of the large investment in infrastructure required this switch is unlikely for the no-regrets option.

To summarize, despite strong suggestions to the contrary, even enormous effort and investment in schemes for shifting to more efficient transport modes could result in only one or two per cent reduction in emissions. These proposals are unlikely to be implemented under a no-regrets policy.

Occupancy rates: Occupancy rates in interurban buses and aircraft are already quite high. Occupancy rates for non-urban use of cars are less than 50%, and for urban public transport and urban use of cars they are 30% or less (NELA 1988). However at peak periods on the

journey to work there is a striking difference between these two: occupancy rates for public transport are close to 100% (or 50% if we consider that the vehicles have to do the return journey virtually empty), whereas for cars they are only around 25% (NELA 1988). This has led to proposals for encouraging car pooling on the journey to work, such as the use of dedicated traffic lanes on main routes to the city centre. Whatever advantages this would have in terms of traffic congestion it is unlikely to affect greenhouse emissions much, because the journey to work comprises only 16% of the private road passenger task (Table 2), and urban cars cause only 42% of the total domestic transport emissions. Therefore the journey to work by car plus LCV results in 16% of 42%, or 6.7%, of the total transport energy. Increasing the occupancy rates by 50% (an extraordinarily difficult task!) would reduce these emissions by one third, ie a decrease of 2.2%.

Technological improvements: Table 6 shows the fuel consumption recorded in 1985 for various classes of cars in Australia built in the years 1974-76 and 1985, together with a weighted average consumption over the whole fleet for these two years (NELA 1988). These figures show a reduction in petrol consumption of about 9% over the decade for individual classes, presumably due to better engine design and improved aerodynamics, although some of the effect must be due to the more recent cars being newer, and hence in better condition. These improvements are largely a response to regulations in the US which required car manufacturers to progressively reduce the petrol consumption of their average new car fleets by certain target dates.

Table 6 Average fuel consumption in 1985 of cars built in Australia in 1974-76 and 1985

car mass	1974-76 litres/100km	1985 litres/100km
under 1000 kg	9.9	9.1
1000-1100 kg	11.1	10.2
1100-1300 kg	12.6	12.1
1300-1500 kg	14.4	13.3
more than 1500 kg	16.2	13.0
mean	12.5	11.4

Source: NELA (1988:77)

Further improvements can be expected to be progressively introduced. According to Wylie of General Motors Holden's (1991) the Australian car manufacturing industry is so small that these improvements will be driven almost entirely by what happens overseas. He states that we could expect a further reduction of petrol consumption for new vehicles over the years 1989 to 2005 of 15% (my calculations from his figures). This improvement includes the effects of a presumed 10% reduction in car weight, apparently through the use of lighter materials without reducing the size of the car. Note that this is what Wylie considers is feasible, but not all of it is likely to occur without some prodding by government. It takes time for such improvements to work their way through the whole car fleet. As the average life of vehicles in Australia is now more than ten years, and not all of the various changes will be introduced immediately, the reduction in fuel consumption expected would be somewhat less than 15% by the year 2005, say 10%. This would result in a reduction of fuel consumption and emissions of 6.4% (10% of 64%, the present share of emissions by the private car plus LCVs). We might assume that half of this reduction (3.2%) will happen because of overseas developments and the normal operation of the market, but the other 3.2% will not happen without government intervention.

Data given in NELA (1988) shows that most freight modes improved their performances over the same period 1976 to 1985; for example trucks improved from 0.36 tonne.km/MJ to O.45 tonne.km/MJ. Some of this improvement can be attributed to improvements in vehicle efficiency, and some to better operating systems, although it is not clear how much is due to each. Further improvements in the efficiencies of the various freight modes can be expected, but the only sub-sector which emits enough carbon dioxide to make it worth looking at is road trucks. Since these emit 18% of the total carbon dioxide, a 10% reduction in emissions from the fleet average truck by the year 2005, as assumed for cars, would reduce the transport energy used (and therefore the greenhouse emissions) by 1.8%. This is likely to occur without government intervention - the only intervention required will be to relax any restrictions on the use of larger vehicles such as B-doubles.

Downsizing: All the items of work that a vehicle does, with the exception of overcoming air resistance, are proportional to its mass. As two people in a car increase its mass by only about 10%, the performance of the vehicle at modest speeds where air resistance is negligible is determined by the mass of the vehicle itself. Thus it is not surprising that if the real-life fuel consumptions in Table 6 are plotted against car mass we get a straight line passing through the origin. It is apparent that great gains can be made by downsizing; eg small cars of less than three quarters of a tonne could be expected to have only half the fuel consumption per km of standard 6-cylinder cars.

However there was little real movement to smaller vehicles over the period 1976 to 1985. Much of the gain made by the trend towards smaller cars in the 1970s was lost in the 1980s as real petrol prices dropped and the mix of car sizes moved back to that prevailing in 1973. Despite this a 20% reduction in the mass of the fleet average would be quite feasible by the year 2005. (Bear in mind the low occupancy rates of the 5-seat cars which make up most of the present fleet. Moreover, as Wrigley (1991) has pointed out, "at least fifty percent of new Australian cars [are] bought by companies and governments - mostly for use by individuals as part of a remuneration package rather than as a genuine commercial working tool". And very few of these are small cars; BTCE (1991b) cites the Paxus figures for 1990 which show that whereas 46% of private car registrations were small cars, only 19% of government and business registrations were small cars). A 20% reduction in the mass of the fleet average car (including those LCVs used for passenger transport) would reduce the transport energy consumption by 11.4% (20% of 57%). Using less powerful engines without reducing the size of the car would also reduce emissions. However it is clear that people would need quite a bit of persuasion to use smaller or less powerful cars even though in most cases they would suffer little more than the loss of prestige offered by the larger, more powerful car .

We cannot expect any appreciable gain by downsizing freight vehicles, as in their case

the mass is dominated by the mass of the load. (This is not true for those LCVs used as passenger vehicles, but they have been included above with the cars.) For trucks, in fact, the opposite holds - upsizing increases efficiency by reducing the proportion of the total mass of vehicle plus load made up by the vehicle. This is one of the reasons why articulated trucks are more efficient than rigid trucks (see Table 5), and why there is a push now for even bigger trucks such as B-doubles. This move to larger sizes is one of the reasons for the increase in the efficiency of carrying freight by trucks over the years 1976 to 1985 mentioned earlier (NELA 1988). Allowance has already been made above for further increases in efficiency, and hence further reductions in emissions.

Demand reduction

The demand by individuals for private travel has been increasing steadily for many years. For example the NELA (1988) figures show that the average Australian travelled 12.6 thousand km by private road vehicle in 1976 and 17.7 thousand km in 1985.

There are many reasons why people travel. They have to go to work or school. They have to purchase goods for daily living. They wish to visit friends and relatives. They travel to holiday destinations or to sporting grounds or concert halls. They travel because they like to enjoy the passing scenery or even just like driving around. To reduce demand requires that some of these reasons become less impelling or less attractive. Therefore there are two main groups of policies for reducing demand for passenger transport: bringing points of origin and destinations closer together, and persuading people that there are other more attractive ways of spending their time and money.

The first of these has received a good deal of attention lately, spurred on by the study of Newman and Kenworthy (1989) on 32 large world cities, which showed a strong hyperbolic relationship between petrol used per capita and population density. Transformation of this relationship yields the result that petrol consumed per capita is proportional to the area of the city, irrespective of population density.

Thus densification of cities is likely to substantially reduce petrol consumption. However because of the enormous investment in housing stock and physical infrastructure and the existing pattern of land values it is not easy to achieve such densification. As an example Melbourne has had as-of-right dual occupancy rules for several years now, and as a result there has been a significant investment in second houses on existing house lots. However this has not resulted in increased population density; rather it has merely slowed down the existing trend towards decreasing density, and very low density development on the urban fringe continues. This is not to say that it is not worth trying, as part of the increase in urban road energy over the period 1976 to 1985 has undoubtedly been due to increases in area and decreases in population density of the cities. Even if we could slow down these trends it would help.

Global correlations such as the Newman/Kenworthy one can give us an order-of-magnitude feel for these effects. Over the period 1976 to 1985 the energy consumption for private road transport grew by 3.1% per year, 1.5% per year of this being due to population growth. Let us suppose that half of the remainder came from increased per capita use due to the falling cost of motoring relative to income, and the other half, 0.8% per year, was due to the growth in size of cities. Now let us imagine that all state governments managed to stabilize the areas of their capital cities (this would require a high degree of government intervention). Future population growth would be accommodated by densification of existing cities or by increase of population in regional towns. Over the 17 years from 1988 to 2005 the energy saving of 0.8% per year would reduce emissions by 13%. However as this is a reduction in only 42% of the total emissions (Table 4), the reduction would be only 13% of 42%, or 5.5%. The pressure to expand our cities could, of course, be eased by curbing our population growth by reducing immigration rates, as advocated by various lobby groups in Australia, but that is an argument which should be considered in other forums.

The other demand management strategy for passenger transport is to persuade people that their interests are best served by spending less of their leisure time and money on travel and more on less energy intensive activities. Table 2 showed that two thirds of the passenger transport by cars (plus LCVs) is by private motoring, the so-called discretionary travel. Contrary to popular belief only a small part is used by the journey to work, the part that public transport might be substituted for. Part of this private car travel is due to the spread-out nature of our cities, as discussed above, but undoubtedly a very large part is due to our use of travel, both urban and non-urban, for enjoyment. We travel because we want to, and can afford it. As an example Figure 1 shows the very strong correlation between income and the number of journeys over 100 km taken. As travel becomes cheaper relative to disposable income more people will be able to afford to travel for enjoyment.

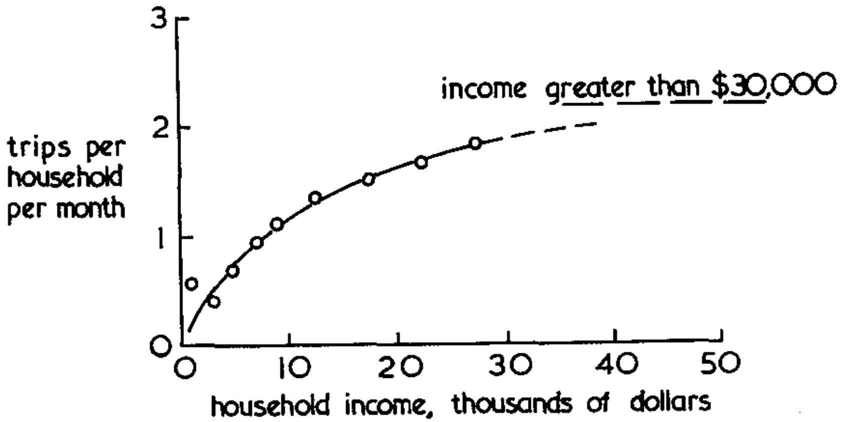

Figure 1 Relationship between income and the number of trips greater than 100km taken per month (Source: Australian Bureau of Transport Economics 1981)

Any proposal for reducing emissions that fails to acknowledge that travel is not just a means of going from place to place, but is a also a means of enjoyment, is failing to deal with more than half the kilometres travelled by road. How much could this be reduced by raising the price of petrol? Hensher and Young (1991) have reviewed the available methods for estimating the fuel-price elasticity of demand and the data obtained by various workers. The short-run elasticity for private road transport is only around -0.1, ie if the price of petrol were raised by 100% the demand would drop by only 10%. However long-run elasticities are much higher, at -0.66, of which 0.09 is due to increased fuel efficiency, 0.31 to reduced

vehicle ownership, and 0.26 to reduced kilometres travelled per vehicle. Thus an increase in the real price of petrol of 50% could be expected to reduce the consumption by private owners of cars by 33%, or by 28.5% if we exclude the efficiency gain, which we have allowed for elsewhere. Since private cars account for 57% of the total emissions, the reduction in emissions would be 28.5% of 57%, or 16%. But any such change would obviously be fraught with difficulty - there might be no regrets for the nation as a whole, but a government which raised the price suddenly might very much regret losing office! The price would have to be raised gradually, and not all the effects would be felt by the year 2005. Let us assume a reduction of only two thirds of this, or 11%. (Note that the ABARE (1991) data on which the business-as-usual scenario was developed has already allowed for a 40% increase in the price of petrol over the period, due to expected increases in the world oil price. Therefore four fifths of this reduction, or 9%, should be allocated to the business-as-usual reductions in emissions.

Summary of reductions in emissions possible under a no-regrets policy

The above discussion is summarized in Table 7. I do not wish to suggest that all these reductions are likely to be achieved. Clearly there would be great social and political resistance to implementing some of them. They constitute my guess at an upper limit to what might be achievable within the no-regrets policy option.

Table 7 Summary of possible reductions in emissions from the implementation of 'no-regrets' proposals (Reductions are expressed as percentages of the emissions expected in year 2005 if the present pattern of growth were to continue. n.a. = not applicable)

proposal	reductions for 'business as usual'		additional reductions for 'no regrets'	
	passenger	freight	passenger	freight
increased efficiency				
modal switch - car to bus	0	n.a.	1	n.a.
car pooling	0	n.a.	2	n.a.
technological improvement				
cars	3	n.a.	3	n.a.
trucks	n.a.	2	n.a.	0
downsizing	0	n.a.	11	n.a.
demand reduction				
cars				
city densification	0	n.a.	6	n.a.
increase in petrol price	9	n.a.	2	n.a.

As noted earlier, if emissions continued to grow at the 1976 to 1985 rate of 3.0% per year they would reach 165% of the 1988 emissions by the year 2005, whereas the ABARE (1991) estimate for business as usual is 139% of the 1988 figures. The difference is due to the reductions shown in the left-hand columns of Table 7, together with an allowance for growing saturation in private motoring. What would the additional reductions be if all the no-regrets reductions in Table 7 were achieved? As reductions in the passenger and freight task are independent of each other, they can be simply added. Similarly, reductions in different modes within the task can be added, unless they involve a movement between modes. But reductions within modes cannot be added if they represent processes in series. The proper way to compound reductions in series is to convert them to 'efficiencies' first. Thus cars: reductions of 1%, 2%, 3%, 11%, 6%, 2% give 99% of 98% of 97% of 89% of 94% of 98% = 77%, or an overall reduction of 23% rather than 25%. Thus a further reduction of 23% brought about by government intervention represents 23% of 139%, or 32%. In other words we could get down to 107% of the 1988 figure. This is still not much more than half way to the target of 80% of the 1988 emissions, and we have to remember that the government intervention required was very strong, even though it kept within the no-regrets option for Australia.

Comparison with the reductions given in the ESD Greenhouse Report

The three Working Group Chairs of the various ESD Working Groups pooled their results on greenhouse reductions and produced a separate Greenhouse Report (Commonwealth of Australia 1992). The results for the transport sector differ substantially from those worked out here. The main differences and the reasons for them are outlined below.

First, the criteria for determining what constituted possible reductions in emissions used in the ESD Transport Working Group Report (Commonwealth of Australia 1991) (from which the results in the Greenhouse Report were derived) were different from the one I used. I have tied back my reductions quite rigorously to what was feasible by the year 2005 under the no-regrets policy. As I remarked earlier, this is a very tough criterion, but using it does stop us from putting things from a fuzzy 'wish list' up as possible reductions. Omitting these means that I have excluded some reductions from expensive technological changes to vehicles and from modal switches requiring large infrastructure investments which have been included in the ESD Greenhouse Report (Commonwealth of Australia 1992:91). In my view the Working Group Chairs, in preparing their Greenhouse Report, which is firmly based on the Toronto target, should have excluded these reductions, as which had been worked out for ESD objectives other than reduction of emissions.

Second, although the ESD Transport Working Group Report did include demand management reductions due to changes to urban structure, it did not calculate how much demand for travel might be reduced by the price mechanism or how much the efficiency of carrying out the passenger travel task might be increased by downsizing (also driven largely by the price mechanism), which Table 7 shows to be two of the biggest potential reductions. Both of these would benefit the Australian economy rather than cost it, therefore no regrets. Of course both would appear to impinge on personal freedoms, and are therefore politically difficult, but in my view this is not a good reason for not even considering them. It is a question of balancing the social costs of the perceived limitation on personal freedom with the social gains arising from greenhouse amelioration. This is not a new problem, of course; governments are making this type of decision on our collective behalf all the time.

Measures for implementing proposals

What measures would be suitable for achieving the reductions identified in this paper? As seen from Table 7 all the feasible proposals which require government intervention to make them occur are to do with the use of the private car. The interventions required vary according to the particular strategy. Mostly they will involve taxes and regulations which many people would object to strenuously, and for this reason they will be difficult to implement. The use of taxes for reducing greenhouse emissions from transport has been examined in some detail by BTCE (1991b). Amongst other things, this study delineated the tax options which appeared to be socially most desirable. It has not been possible in the brief review below to deal with the finer points of the BTCE study.

Car pooling: The measures to be used are incentives and education: special express lanes on main traffic routes and special parking privileges, together with encouragement of workplace information exchanges.

Technological improvement: Part of this will occur anyway, because of overseas developments. Regulations requiring vehicle manufacturers and distributors to reach nominated fleet average efficiencies would help to ensure that *all* of these developments reached Australia.

Downsizing: Regulations requiring companies to reach nominated fleet average efficiencies would be required. These should be accompanied by price increases for petrol, together with education campaigns to demonstrate how these could be counteracted by buying smaller vehicles. Wrigley (1991) has pointed out that petrol is cheaper in Australia than in all of the other advanced economy countries except the USA, and that the average petrol consumption of new cars is higher in Australia than in any of these other countries. Sales tax should be increased on large new vehicles and reduced on small new vehicles. Tax laws should be revised to encourage those companies and government departments which include cars or vans as part of remuneration packages to provide smaller cars.

City densification: A very hard one! Regulations to contain cities within prescribed limits could be promulgated, but would meet resistance. Developers should be required to meet all the costs of new infrastructure in greenfields developments, including social infrastructure such as schools, hospitals, police stations and sporting facilities, as well as roads, rail, electricity, gas, water, sewerage and telephones. These costs would then be passed on to the buyer. Provision of affordable housing for poorer people should be tackled as a problem in its own right, and not be dealt with as at present by permitting poorly serviced city fringe development.

Demand pricing: The hardest one of all. No government likes to be voted out of office for putting up the price of 'essential services', and most people regard cheap motoring as an essential service. They would object strongly to a substantial increase in the fuel price. To overcome this would require education so that people could see that they can compensate for higher petrol prices by driving smaller cars; lowering of sales tax on smaller cars would help. Special compensatory packages for disadvantaged parts of the community such as pensioners and the disabled would be needed. Perhaps diesel fuel should be priced lower than petrol to help to reduce the cost of fuel for agricultural machinery. Above all it would require that the various political parties agree on the necessity for a non-partisan approach to fuel pricing, which we certainly don't have at present.

Conclusions

The Toronto Conference of 1988 called on the developed nations to reduce their emissions of carbon dioxide in year 2005 down to 80% of their emissions in 1988. Australia has accepted that challenge up to the point where there would be no net cost to the Australian community. Under a business-as-usual policy emissions from Australian domestic transport are expected to increase by 139% of the 1988 emissions, rather than decrease to 80%.

The two biggest domestic transport emitters are private vehicles for road passenger transport (57%) and road freight trucks (18%). Not surprisingly, schemes for reducing emissions from other parts of the transport sector can have very little effect, and this paper has therefore concentrated on these two sub-sectors.

Reductions beyond those expected under a business-as-usual policy will require government intervention. In the transport sector we are used to proposals which encourage technological developments, but the present work indicates that such proposals would have relatively small effects, and would in general be so costly that they would not be implemented under a no-regrets policy option.

The policies which could achieve appreciable reductions under a no-regrets policy are those which will require changes in attitudes and behaviour amongst the Australian public, which in turn will require research of the kind that asks why people think and act as they do, and how that thinking and acting might be changed.

These reductions would have no net disbenefits to Australia as a whole. There would, however, be problems of social equity which would have to be tackled at the same time that the measures required to bring about these changes were introduced. And a very strong education campaign would be required to show people that they could maintain their present levels of enjoyment despite some restrictions on their choice of vehicles and living places.

The analysis done here suggests that even with fairly strong attempts to change people's attitudes and behaviour the emissions could not be brought down to the 1988 figures, let alone 20% below them. To do this would require that the average size of car be reduced by more than 20%, and the price of petrol increased by more than 50%.

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Valuation of the Loss of Life Quality due to Non-Fatal Traffic Injuries

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Abstract:

The valuation of the loss of life quality resulting from non-fatal traffic injuries, although an important factor in the benefit cost analysis of transport safety projects, is a complex issue and research in this area has produced only limited results. The Association for the Advancement of Automotive Medicine has recently developed an Injury Impairment Scale (IIS) which indicates the most likely level of long term impairment resulting from an injury. This paper uses IIS and determines a probable range for the expected loss of life quality for hospitalised traffic injuries in New Zealand.

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