

SUSTAINABLE TRANSPORT IN SUSTAINABLE CITIES

Land Use/Transport Working Group

Working Paper : “ROAD TRANSPORT – FUTURE DIRECTIONS” REVISITED

Dave Kilsby, June 2000

1. Introduction

The “Land Use/Transport” Working Group has agreed that the three main practical ways of reducing the unsustainability of cities are managing the demand for water, managing the demand for energy, and managing the production and disposal of waste. Transport systems have much greater impact on energy demand than on water or waste – although of course the wider urban system of which transport is an integral part impacts on all three.

The Working Group is therefore considering the practicality of assessing the energy balance implicit in alternative future land use/transport scenarios.

If we knew how to assess this, it would then be productive to generate some alternative options and compare their energy implications. The evaluation of these alternatives is more a community task in the political realm than a professional one, but the development of strategies to eliminate or circumvent obstacles to achieving desirable options is again a matter calling for professional expertise.

One difficulty in making assessments at such a scale is the lack of precedent. An initial scan of available information suggests a lot of attention at the micro scale (individual buildings, individual vehicles) but little at the macro.

The last known scenario testing exercise of substance for land use and transport in NSW was the “Road Transport – Future Directions” study of 1990-91. At the time I was responsible for managing the urban aspects of this statewide study and later, after the main report was issued, for collecting and editing all supporting documentation (fifty further reports in twelve volumes).

The study produced a comprehensive range of performance estimates but they did not directly include energy-related measures. I undertook to revisit the study to see whether any energy-related measures can be retrospectively derived and, if not, where the knowledge gaps are that prevent this being done.

2. Road Transport – Future Directions

The “Road Transport – Future Directions” Study was a major study undertaken for the NSW Roads and Traffic Authority in 1990-91. It was intended to provide advice to the RTA, at that time a relatively new organisation, on the optional directions open to it for developing a road network strategy for NSW.

The findings are a matter of public record and are still relevant ten years on.

The study worked by scenario testing. A number of different futures which could apply to a future NSW of 8.5 million people – expected to be reached in 20-30 years, ie about 2016 give or take – were devised. The study quantified scenarios with different balances of activity between Sydney and the rest of NSW, and different distributions within Sydney. These were assessed using an integrated framework which produced compatible performance measures for Sydney, for the provincial cities of Newcastle and Wollongong, and for regional NSW. This enabled statewide measures of economic, environmental and operational performance to be estimated and – where relevant – broken down by area type (Sydney etc).

For Sydney there were four land use scenarios. Oversimplifying, these were :

- “Current Trends” :continuation of current (1991) trends and practices in population and employment – 5.5 million people in Sydney, 3.0m elsewhere in NSW, extensive new development in the Cumberland Plain and its fringes at densities similar to those being achieved in 1991
- “Planned” : 5.0 million people in Sydney, 3.5 million elsewhere in NSW – stronger application of the Metropolitan Strategy of 1988 and a complementary range of limited decentralisation to centres outside Sydney
- “Intervention” : 4.5 million in Sydney, 4.0 million elsewhere. Less growth in Sydney, greater decentralisation and growth in Newcastle, Wollongong. Two variants within Sydney were produced – one with more government intervention and an emphasis on urban consolidation, and one with greater responsiveness to market forces and an emphasis on new integrated communities at the outer fringe (but also more intensive development of desirable inner areas).

The study also looked at two different approaches to network strategy in urban areas – crudely, demand satisfaction or demand management – and three different approaches to the pricing of the various transport modes – current pricing, road pricing (to manipulate demand) or real pricing (to reflect true economic costs).

In all, eight future scenarios were tested : the study did not have the resources to process all 24 possible combinations of land use, network and pricing futures.

The combinations processed for future years were as below. The number in brackets is a scenario identifier, used in the table which follows later. Additionally, 1991 settings for land use, networks and prices were used to produce directly comparable estimates from the same process.

- (11) “Current Trends” land use, network demand management, current pricing
- (17) “Current Trends” land use, network demand satisfaction, real pricing
- (12) “Planned” land use, network demand satisfaction, current pricing
- (16) “Planned” land use, network demand management, road pricing
- (18) “Planned” land use, network demand satisfaction, real pricing
- (13) “Intervention” land use, network demand management, current pricing
- (15) “Intervention” land use, network demand management, road pricing
- (14) “Private Sector Led” land use, network demand management, road pricing

Strategic conclusions were drawn from scenario comparisons and, after due consultation, many became incorporated in State Government transport planning not only for the NSW road system but also for the integrated planning of the metropolitan region.

There is much documentation in the public domain.

- *Road Transport – Future Directions : Report on Options* (1991) was the consultants' report to RTA.
- *Road Transport – Future Directions – Outline Report* (1992) was a much-abridged version of the Report on Options, prepared by RTA.
- 12 volumes of supporting reports were also prepared, of which the most relevant to the Land Use/Transport Working Group are :
 - Report C6 : *Population and Employment Distributions for the Sydney Region and the Remainder of NSW* (quantification of 1991 and four possible future scenarios).
 - Report L1 : *Sydney Metropolitan Model* (the development and application of a multi-modal sketch planning model for Metropolitan Sydney).

Aspects of the study are also described in :

- *A Strategic Planning Process Applied to Land Use and Transport Development in New South Wales*, Road and Transport Research, Vol 2 No 1 1993 – reviews the general process.
- *Is Sketch Modelling of Practical Value in Transport Development ?* 16th Australasian Transport Research Forum, Canberra, 1992 – reviews the modelling work.
- *Sydney - A Case Study in Ecologically Sustainable Development* Institution of Engineers (Australia) seminar, Perth, 1993 – reviews the environmental findings.

There are also some comments on my web site (www.kilsby.com.au) prompted by a recent feature in the *Sydney Morning Herald* (16 May 2000). This referred extensively to the 1991 results without quite grasping what was behind the figures quoted.

3. Reported results from study

Table 1 gives an overview of the four land use scenarios developed for Sydney. These were quantified using a 76-zone spatial system. It must be understood that these are just the Sydney components of NSW scenarios, all of which (except 1991) had a total population of 8.5 million people.

Table 1 Population and Employment Scenarios for NSW (thousands)

	1991	Current Trends	Planned	Intervention	Private Sector Led
Population	3,694	5,500	4,994	4,482	4,498
Employment	1,464	2,360	2,123	1,874	1,869
• "Centres" jobs – Sydney CBD	193	224	218	240	270
• Other "Centres" jobs	211	361	410	429	397
• Elsewhere or "dispersed, industrial or special use" employment in centres	1,060	1,775	1,495	1,205	1,202

Measure	Units	Measure	Units
		- trucks	cents/litre cents/vkm
NETWORK EFFICIENCY		ECONOMIC ANALYSIS (cont'd)	
Person hours	- road - train - bus - total	M hours/yr M hours/yr M hours/yr M hours/yr	Total disc trans resource cost \$B pres.value Ann. transport resource cost \$/head/yr per head
Vehicle hours	- road - train - bus - total	M hours/yr M hours/yr M hours/yr M hours/yr	REGIONAL (x13) MEASURES by origin of trip
Av peak speed	- road	km/hr	self containment per cent
Av peak trip time		minutes	auto share per cent
Slow travel	(SL=speed limit)	% of veh km <75% SL	transit share per cent
Slow roads		% of road km <75% SL	Av. auto time per trip minutes
Congestion	- time lost - time lost/passenger	person years minutes	Av. transit time per trip minutes Av. regional time per trip minutes
Delay as a % of trip time		per cent	Av. auto dist. per trip km Av. transit dist. per trip km Av. regional dist. per trip km Av. transit fare per trip \$ Av. auto cost excluding time \$ Av. transit cost excluding time \$ Av. auto cost including time \$ Av. transit cost including time \$
			by destination of trip (as above)

Table 3 lists some parameters used in the study in estimating performance measures.

Table 3 Performance Calculation Parameters

Parameter	Value	Parameter	Value
Percentage of trucks in traffic	6.5%	Fuel efficiency	
Peak car occupancy 1991	1.20	- cars 1991	13.36 l/100km
Peak car occupancy 2016	1.20 to 1.24	- trucks 1991	38.82 l/100km
		- buses 1991	32.89 l/100km
		- cars 2016	10.02 l/100km
		- trucks 2016	29.12 l/100km
		- buses 2016	24.67 l/100km

Table 4 gives the relevant estimates for indicators which may potentially shed some light on energy use. The identifying numbers for the scenarios are as described earlier.

Table 4 Selected Performance Measures for Sydney from “Road Transport - Future Directions” Analysis (1991)

Measure	1991	11	17	12	16	18	13	15	14
Population (M)	3.694	5.500	5.500	4.994	4.994	4.994	4.482	4.482	4.498
Employment (M)	1.464	2.360	2.360	2.123	2.123	2.123	1.874	1.874	1.869
Road Network (lane km)	11,283	11,756	13,153	12,722	11,790	12,834	11,639	11,639	11,639
Car Travel (M vkm/yr)	21,044	34,606	31,762	30,841	28,251	28,385	24,402	23,479	23,681
Truck Travel (M vkm/yr)	1,502	2,449	2,232	2,171	2,024	2,006	1,749	1,687	1,700
Train Services (M trn-km/yr)	26	34	33	33	32	31	31	31	32
Bus Services (M bus-km/yr)	97	219	169	147	207	144	146	147	144
Trips by car (M pers-trips/yr)	2,447	3,605	3,761	3,428	3,338	3,518	2,967	2,849	2,851
Trips by train (M pers-trips/yr)	236	422	424	360	398	365	323	386	398
Trips by bus (M pers-trips/yr)	294	1,086	707	428	765	592	511	648	668
Travel by car (M pers-km/yr)	27,118	46,055	42,250	39,705	37,629	37,771	32,503	31,279	31,546
Travel by train (M pers-km/yr)	3,103	6,449	5,644	5,254	5,116	5,263	4,229	4,934	5,308
Travel by bus (M pers-km/yr)	1,070	5,107	2,780	1,602	2,937	2,237	1,782	2,348	2,489
Person-km/head (000 km/yr)	8.47	10.47	9.21	9.32	9.15	9.07	8.59	8.60	8.75
Fuel consumption (Mlitres/yr)	3,426	4,235	3,874	3,759	3,471	3,464	2,990	2,880	2,903
Average trip length (km)	11.7	13.5	12.8	12.5	12.2	12.2	11.5	11.6	12.1
Average peak road speed (kph)	48.9	42.3	46.7	46.0	46.3	47.8	48.5	48.9	48.9
Average peak rail speed (kph) ¹	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5	42.5

¹ Calculated from reported results

4. Modelling and reproducibility

I have sometimes been asked whether “the model” used to produce these outputs is still usable.

The model had two main components – an inner transport network-based model of conventional structure, used to predict weekday morning peak travel behaviour, and an outer shell which derived the performance measures from the outputs of the inner model and a wide range of external inputs as well.

The inner part of the model is still available (Sinclair Knight Merz are the custodians) but whether you actually need it depends on what you are trying to do. Additionally, it was built with 1980's data and you would probably be better off building a new one from scratch (with flexibility to adjust the design) based on data available in 2000 rather than updating the old one (without design flexibility). To update it, you would need to add in at least major road and rail infrastructure added 1990-2000 (the central M4, the M5, the M2, the Gore Hill Freeway, the Anzac Bridge and the Harbour Tunnel ; the Cumberland Line and possibly the New Southern Railway), update the bus service descriptors, validate the model with recent count data, and when it didn't fit you'd have to decide whether to recalibrate with more recent behavioural data than 1981 or whether to tweak the network descriptions, the traditional and easier recourse. Not worth the effort when you can no longer be certain what was in the model in the first place.

The outer part of the model applied the degree of understanding of relationships that the team had developed at the time. To attempt to reapply the complex outer model without that understanding (now largely dissipated) would in my view be positively dangerous, even if were possible to update all the many parameters used. This part of the model should be treated as unavailable.

In my view “the model” does not have a life of its own and cannot now be separated from its time and purpose. The work necessary to give it continuing functionality was proposed at the conclusion of the Future Directions Study but never funded.

My advice is therefore that if you need this sort of sketch model, it will be more efficient and effective to design and build a new one to do what you want it to, than cannibalise a left-over. And if you don't know what such a model should do, then you don't need it.

5. Derivation of Energy Measures

What can we derive from the data in **Table 3** and **Table 4** ?

First, the population level varies considerably between scenarios and so any comparison must be based on rates rather than volumes.

For convenient summary the five “demand management” scenarios for 2016 have been combined, as have the three “demand satisfaction” scenarios.

The future scenarios included an allowance for improved engine technology. To remove technology from the picture, I have added in figures for a scenario called 1991T, which also assumes 2016 technology but otherwise is as per 1991.

The fuel consumption estimates do not include the fuel used to generate and distribute electricity to operate the electric train system. This is a major deficiency as it is impossible to produce energy measures for the whole public transport system.

It would not be appropriate to stretch the truck figures any further than the Study did already, and freight energy will not be considered further. It is of course important.

The Future Directions study looked at walking and cycling trips qualitatively rather than quantitatively. The large size of the model zones precluded any meaningful analysis (and even models with much finer zoning systems do not treat this travel sector credibly).

For motorised use of the road system, we can compare fuel efficiency (per vehicle kilometre) with fuel effectiveness (per person kilometre). This is shown in **Table 5**. Fuel effectiveness figures recognise vehicle occupancy for cars, and for public transport relate the fuel to operate all services over 24 hours to the number of passengers actually travelling. Measures that use peak loadings only are of course much more favourable to public transport.

Table 5 Fuel efficiency and fuel effectiveness

		1991	1991T	2016 demand mgt	2016 demand sat
L/100 vehicle km	car	13.4	10.0	10.0	10.0
	bus	32.9	24.7	24.7	24.7
L/100 passenger km	car	10.4	7.8	7.5	7.5-7.8
	bus	3.0	2.2	1.1-2.0	1.5-2.3

We can also look at the fuel consumption per capita. If we assume that the energy needed to operate the train system is proportional to train-kilometres, then we can show how the various scenarios relate relative to 1991 – or rather 1991T - for both road (diesel and petrol) and rail (electricity) as shown in **Table 6**. Further, the figures in **Table 3** and **Table 4** can be massaged to separate out car and bus estimates, as also shown in **Table 6**. It can be seen that the much greater per capita use of buses, and the greater fuel effectiveness of buses as seen in **Table 5**, have little effect on the performance of the road sector overall because of the dominance of private cars in all scenarios.

Table 6 Transport energy use indices per capita

		1991	1991T	2016 demand mgt	2016 demand sat
Road	car and bus	133	100	92-111	100-108
	car only	133	100	92-110	100-108
	bus only	133	100	122-158	110-117
Rail	train	n/a	100	88-101	85-94

Another measure of energy effectiveness could be a comparison of total movement quantity with payload movement quantity. The payload is of course people, who are encased in vehicles of various sizes. Some vehicles (in the case of public transport) may continue circulating around the city at times though nearly empty. If we assume that :

- the average person weighs 75kg
- the average car weighs 1,500kg empty
- the average bus weighs 14,000kg empty
- the average train weighs 400,000kg empty

then calculation based on **Table 4** yields the ratios shown in **Table 7**. The high “mass overhead” of trains is offset by their more energy-efficient operating environment – rolling on rails, using reticulated electricity, precise – though not necessarily accurate - scheduling, signalised control of all sections, gentle grades, large radii, few intersections, no mixed use and hence hardly any requirements for varying speed between stations.

I note that many of these advantages could also be given to non-rail and/or lower-mass systems. Rail rights of way would make perfect cycleways !

Table 7 System tonne-kilometres per payload-kilometre

	1991/1991T	2016 demand mgt	2016 demand sat
car	17	16	16-17
bus	18	9-16	12-18
train	46	29-40	32-34

Table 7 shows the energy benefits of more intensive use of public transport and trains, and the energy inelasticity of private transport (because more people bring more cars with them).

Embodied energy is harder to estimate. The employment scenarios did distinguish four employment types – centres, industrial, dispersed and special uses. Intuitively these should be associated with different building types and hence different rates of embodied energy in the built environment. The population scenarios would probably need to be augmented with density estimates if a similar “heroic” procedure were to be adopted for housing. **Table 4** does estimate the size of the main road network in lane kilometres (excluding local streets). This could be then turned into an area of bitumen, and ultimately into an embodied energy estimate. There could be no allowance for earthworks or structures at this scale of analysis.

The energy embodied in Sydney’s vehicle fleet should not be forgotten either, although it is probably far less than that of the static built environment. (This remains to be confirmed by someone).

Readers of this paper are invited to see what else they can come up with from the data given here.

6. Energy Auditing

The analysis above is an attempt to take some rather old work further than it was first intended to go. It should be regarded more as an exploration of methodology than a search for strategic insights. The Sydney scenarios were but one component of statewide scenarios, and the energy performance outside Sydney should be considered along with the performance within Sydney. A statewide perspective may produce different conclusions to those from a metropolitan perspective. This was certainly the

case with greenhouse gas emissions, another performance area where the analysis was extended well after the original study.

However what the process did illustrate is that with a sketch planning approach it is possible to achieve quite significant insights quite quickly. Hence energy analysis of the urban land use and transport system may not have to remain always in the Too Hard basket.

I am not aware of any established techniques for the sort of analysis of urban energy flows and capital we are wishing to do, at the scale we are wishing to do it. I see this as being fairly analogous to economic analysis, but with energy rather than monetary value as the central referend.

This seems to offer rich opportunities for the Working Group to pursue, subject to practical constraints (time and money). Some of the issues that could be discussed further are noted below.

- 1) We would need a universal metric (joules), and a Ready Reckoner of energy rates for both embodied and operational energy of buildings, infrastructure and transport vehicles.
- 2) We would need to broadly understand how the energy flows and where it is consumed, and the various structures for power supply and their efficiencies.
- 3) Because we are not concerned with the absolute sustainability of cities, but rather making them less unsustainable, our analysis would have to look at marginal change to the system over a given time period. This avoids having to estimate the energy embodied in the city we already have, which intuitively seems to me infeasible.
- 4) Hence, we would need to have a future base case against which to compare other options. It would be meaningless to look at a single scenario. Planning for the “most likely” scenario has been an endemic practice in transport in the past.
- 5) We may need a mechanism similar to economic discount rates, to make operational energy flows and energy capital comparable. The rates might need to be supplementary rather than discounted, for non-renewable sources.
- 6) We would need to understand the energy efficiencies of transport technologies, especially rail relative to road, and on-board power relative to reticulation.
- 7) Low-energy road transport vehicles should be on our mental radar. Anyone who has been on holiday to Bali will have been struck by the huge number of light motor-cycles in use. If they were significantly cleaner and quieter they could be the ideal vehicle for their tight urban environments (which cars clearly are not).
- 8) It would be useful to know how much energy is devoted to achieve outcomes (eg moving things) as against converting energy from one form to another, overcoming internal and external friction, overcoming topography, and being thrown away via emissions and other residue or through process inefficiencies.

- 9) Transport and land use are the mobile and static components of a human activity system, which interact with each other and with the energy, water and waste systems. Is this line of thinking too mechanistic ?
- 10) The basic metabolism of each of the above systems is similar. At the beginning of a time period you have a certain amount of capital, which is added to by natural or human processes or imports and depleted similarly. It also has a call for operational energy to function – even the energy system needs energy itself to extract, process and distribute fuel and/or power.
- 11) The Working Group has been talking about the energy trade-offs between different configurations of land use and transport systems. Logistics practices may offer an additional or alternative case study to reducing the planned densities of central areas, the topic which was first raised. It clearly makes financial sense for businesses to reduce warehousing space by relying more on just-in-time delivery methods, but does it make energy sense ? Is it, in fact, just treating road infrastructure as a surrogate warehouse because its use is under-priced ? Would energy efficiency point us towards a greater number of freight interchanges in urban areas – an idea which industry would probably hate ? I don't know the answer, but I think it is a fair question.
- 12) My comments are limited by unfamiliarity with urban energy issues. It would be helpful if others in the Working Group or the project generally could point us to any relevant literature or people.

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