Chapter 1

ASSESSING IMPACTS OF GREENHOUSE GAS ABATEMENT MEASURES ON URBAN FREIGHT

Leorey Marquez and Nariida Smith, CSIRO Australia
David Kilsby, Kilsby Australia
Mike Taylor and Rocco Zito, Transport Systems Centre, University of South Australia

ABSTRACT

A study to investigate the sensitivity of urban freight patterns to various greenhouse abatement policy measures is underway with Metropolitan Sydney being used as the case study area due to the availability of detailed freight and passenger network level data and models at the New South Wales Transport Data Centre (TDC). The study is designed to build on methodologies under development by TDC to derive freight traffic due to total requirements for freight and relative requirements for categories of goods from actual or forecasted commodity flows and associated information. This paper describes the selection of candidate policy measures for investigation and presents the methodology and processes used in modelling their impacts on urban freight patterns. The discussion will focus on six scenarios which provide policy instruments for application to a 1996 base case. Some results of the modelling of these scenarios will then be presented and issues arising from the study discussed. Special attention will be given to the relative changes in travel characteristics and emissions brought about by these instruments.

INTRODUCTION

The relative proportion of freight to passenger traffic in Australian cities is increasing. Although passenger demand is expected to plateau, there is no sign of that happening for freight. Thus the environmental impacts of freight traffic such as greenhouse gas (GHG) emissions are of increasing concern. In view of this, the Australian Greenhouse Office (AGO) has commissioned a study to investigate the sensitivity of urban freight patterns to various greenhouse gas abatement policy measures.

The Sydney urban area is being used as the focus of the case study due to the availability of detailed freight and passenger network level data and models at the New South Wales Transport Data Centre (TDC). However the estimated impacts of changing freight vehicle operations across the urban area, via vehicle technologies, infrastructure improvements, logistic and land use changes are expected to be generally applicable to all Australian cities and potentially applicable to cities elsewhere.

The study is designed to build on methodologies under development by TDC to derive freight traffic due to total requirements for freight and relative requirements for categories of goods from actual or forecasted commodity flows and associated information. These are to be used in conjunction with a model of passenger travel, which estimates the passenger traffic on the urban road network. Passenger traffic information is needed since the performance of freight traffic is dependent on the volume of passenger traffic on the network.

However while the TDC passenger travel model is behaviourally based, the freight estimation, in common with numbers of other freight models, is being based on commodity movements. In essence, the model links the demand for different commodities to be moved from A to B with *the usual ways and means of getting the freight there*. Thus the TDC model will predict changes in traffic on the network due to changes in the need for different types of freight but not changes in *the usual means of getting there*. This study defines a process for investigating the impacts of policy intervention on ways and means of moving freight. This is particularly important as policies for GHG abatement seek better emissions outcomes without hindering supply of goods.

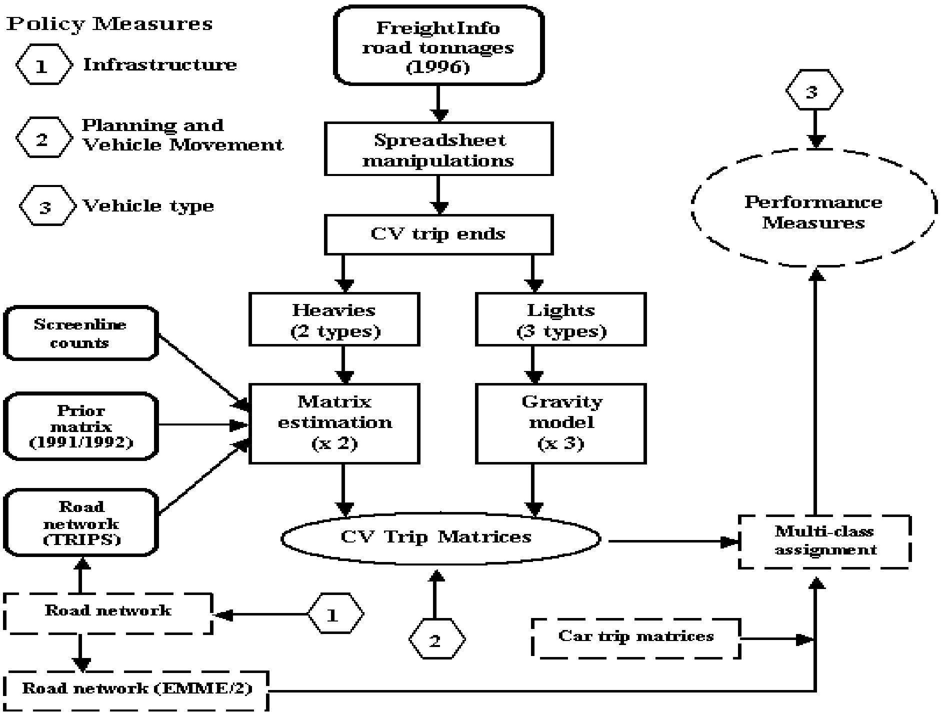

Figure 1. Process for applying policy measures

Figure 1 shows a diagram of the modelling process by which the Transport Data Centre (TDC) synthesises a trip matrix of commercial vehicle movements for Sydney.

The process is designed to convert a base year snapshot of commodity flows into an estimate of commercial vehicle movement. The base year is currently 1996, and the flows are based on the FreightInfo database of FDF Pty Ltd, a Melbourne company specialising in freight flow estimation. This database will be updated, but will remain retrospective, when later data is released by FDF. There are some exclusions from the FDF database, of which the most notable is waste disposal. Therefore the eventual trip matrix will not include any estimate of garbage truck movements.

The volumes of different vehicle and fuel types on a link-by-link basis are determined as part of the outputs of Sydney's Strategic Traffic Model (STM) / CTS (Commercial Transport Study) for each policy alternative to be tested. These outputs essentially define the transport task by vehicle type. The four types of vehicles used in the model are passenger vehicles (PV), light commercial vehicles (LCV), and rigid trucks (RT) together with articulated trucks (AT). One of the limitations of this method of classification of outputs is that none of the vehicle categories are further disaggregated by fuel type. The fuel used by a vehicle obviously makes a significant contribution to the characteristics and quantities of emissions.

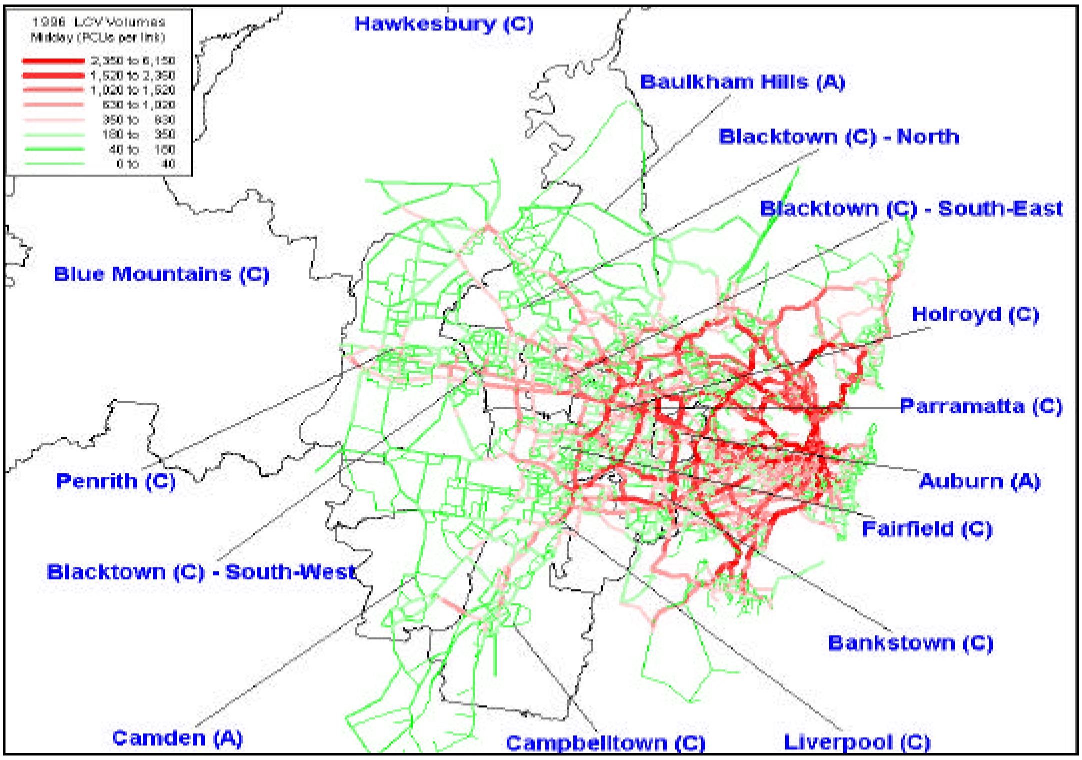

Figure 2. Thematic map of LCV link volumes in 1996 base case

Intervention in the TDC modelling process will predict the effect on 1996 commercial vehicle movements if the various policy measures to be tested had been implemented in 1996. This is referred to as the Base Case. Thus, for the road system, the base network used is a subset of the Sydney road network that existed in 1996 consisting of around 15,000 one-way links and excluding local roads. Network additions, which have been opened since 1996, including the M2 and the Eastern Distributor tunnel, were also not included. Figure 2 shows a thematic map of this limited network.

The strong interactions between road freight and other road users and the impacts of policies on these are modelled explicitly by combining commercial trip tables with car trip tables, and assigning both to the same road network. Multi-class assignment techniques allow reporting on each vehicle type separately despite the interaction between them.

The traffic on the network is derived from trip tables for travel between origin and destination traffic zones. Link volumes are calculated for three categories of commercial vehicles: light commercial vehicles (LCVs), rigid trucks (RTs) and articulated trucks (ATs). VKT (vehicle kilometres travelled) and speeds are estimated for both the 1996 base case year and change scenarios. Base passenger car traffic emissions are then added to the freight scenario emissions resulting in sets of emissions within time of day periods.

POLICY INSTRUMENTS AND ASSESSMENT

The first stage of this study, conducted in April to July 2002, used a literature search and expert advice to develop a qualitative understanding of the urban freight task, and investigate a range of potential policy measures. A modelling framework was designed to test the measures. The study concluded with a workshop for the project steering committee and other stakeholders. This led to an agreed set of measures to be tested (shown in Table 1) by the methods proposed.

Table 1. Proposed Policy Instruments

Category	Instrument
Infrastructure Measures	▪ General reduction in congestion ▪ Improved traffic management ▪ An orbital road project
Vehicle Movement Measures	▪ Higher (and lower) load factors ▪ Real time traffic information
Planning and Land Use Measures	▪ Industry relocation as a result of an orbital road
Vehicle Measures	▪ ‘Best Practice’ truck fleet fuel efficiency

Note that the selected policy instruments actually refer to a desired state perhaps achieved from a set of unspecified initiatives. Thus, ‘general reduction in congestion’ may be brought about by a combination of various traffic initiatives, taxation policies, and infrastructure projects. The focus of the study is not on the individual initiatives that can help bring about a ‘general reduction in congestion’, but rather on the impact that this instrument, once it has been achieved, will have on urban freight. This approach keeps the study from being bogged down with the complexities of assessing each of a myriad of individual initiatives available.

Various performance measures are calculated in order to obtain a qualitative assessment of the magnitude of the potential effects of the policy instruments. The assessments are based on the propensity to:

- Reduce the number of vehicles required to service the freight task;
- Reduce the required number of trips;
- Reduce the trip length;
- Reduce VKT for the given freight task;
- Reduce fuel consumption, and
- Reduce the rate of non-GHG emissions per litre of fuel consumed.

For each measure, the possible performance is rated against the following criteria:

- Relative size of the GHG effect;
- Market size affected;
- Overall GHG emissions; and
- Overall Non-GHG emissions.

BASE CASE SCENARIO

All the chosen policies represent deviations from the 1996 business-as-usual settings. Therefore the first requirement was to model the 1996 base case to obtain the benchmark against which all policy variations are compared.

As noted above, the purpose of modelling is to obtain strategic level estimates of policy impacts and compare options rather than produce absolute values for forecasting purposes. Thus modelled estimates of commercial vehicle and car trip-making patterns for 1996 should be regarded as the best available with current data and models. Their accuracy was not an issue for this study and therefore no validation was undertaken. The question was rather, given that these matrices described a complex movement patterns in detail, what effect on those patterns (and hence emissions) would the selected policies have?

Table 2 shows the four weekday time periods used in the route assignment, the length of each period and the factor used to convert to a representative 2-hour period. The conversion was necessary because the descriptions of link capacities in the network relate to 2-hour capacity. Hence it was necessary to convert trips in each of the four time periods to their two-hour equivalents for assignment, and then to reverse the conversion to obtain the results for the full time period.

Table 2. Durations of weekday time periods and conversions to 2-hour period

Time period	Duration	Conversion Factor
AM Peak (7am-9am)	2 hours	1
Business Hours (9am-3pm)	6 hours	0.33
PM Peak (3pm – 6pm)	3 hours	0.67
Evenings (6pm – 7am)	13 hours	0.25

It was also necessary to convert the larger commercial vehicles to “passenger car unit” equivalents (pcu’s) before assignment, because the network capacity and behaviour (via the volume-delay curves used in assignments) are based on pcu’s rather than vehicles generically. As with the time periods, the reverse conversion is required after assignment to turn the results back into commercial vehicle units. Following common modelling practice, the pcu equivalents used for the three types of commercial vehicles are:

- Light commercial vehicles = 1 pcu
- Rigid trucks = 2 pcu’s
- Articulated trucks = 3 pcu’s

Table 3 shows the number of weekday trips made by vehicle type and (expanded) time period, for the 1996 base case. The table also shows the proportion of vehicles in each class travelling at each time of day. For cars, these were obtained by a complex system of factoring based on data collected for the ongoing Household Travel Survey. Thus, passenger vehicles or cars account for more than 92% of all daily trips with 36% of all trips made during business hours. For commercial vehicles, the corresponding splits were obtained from the Commercial Vehicle Survey of 1992.

Table 3. Percentage of weekday trips (000) in Sydney by vehicle type and time of day

Vehicle type	AM Peak	Business Hours	PM Peak	Evenings	24 hours
Cars	1,146 *(16%)*	2,455 *(35%)*	1,778 *(25%)*	1,734 *(24%)*	7,113 *(100%)*
Light CVs	74 *(17%)*	215 *(48%)*	87 *(20%)*	65 *(15%)*	443 *(100%)*
Rigid trucks	26 *(19%)*	73 *(53%)*	19 *(14%)*	20 *(14%)*	138 *(100%)*
Articulated trucks	5 *(19%)*	13 *(49%)*	3 *(10%)*	5 *(22%)*	25 *(100%)*
All vehicles	1,251 *(16%)*	2,755 *(36%)*	1,888 *(24%)*	1,825 *(24%)*	7,720 *(100%)*

POLICY SCENARIOS

The seven policy scenarios and the base case are evaluated in line with the procedure shown in Figure 1. As indicated, the TDC process is designed to convert a base year snapshot of commodity flows into an estimate of commercial vehicle movement. Our estimation is currently based on 1996 tables and addresses combined freight and passenger traffic in four time of day periods - morning peak, midday, afternoon peak and evening/night.

With this methodology, it is possible to model the effects of "infrastructure measures" by adding the commercial vehicle trip pattern estimates to those of the car driver trip patterns produced by the passenger travel model.

Changes in congestion are modelled via appropriate reduction of passenger traffic. The loading factors are addressed by reduction of trips due to increased loads and via use of larger vehicles producing changes in relative numbers of trips by the vehicle classes of light commercial vehicles, rigid truck and articulated trucks. In both cases the proportion of changed trips is estimated from the opportunities for higher loads in commodity classes and for use of larger vehicles. Unfortunately, the converse situation of more frequent trips at lower loads due to increases in “just in time” deliveries was not tested due to time constraints.

Changes brought about by planning measures are effected through a redistribution of the population of workers of industries deemed most likely to be susceptible to the measures. This results in a revised trip distribution matrix using new locations for the selected industries.

Fuel efficiency changes are tested in the emission estimation procedure which follows the network traffic information. The detailed network speed estimates by time of day allow congestion sensitive estimates of the variation in impacts of better fuel efficiency across the urban area.

The implementation of each of the policy scenarios in the transport model is briefly summarised as follows.

Scenario 1: Improved Fuel Efficiency

For the purposes of modelling, we assumed that improved fuel efficiencies in the commercial vehicle fleet would only effect the emission outcomes, not the amount of travel. The emissions are calculated from 1996 base case travel patterns but using the lower fuel consumption coefficients. The elasticity figures from stage 1 justify the assumption that better fuel efficiencies and hence lower fuel costs are not likely to induce significant amounts of extra freight travel. Thus, this scenario did not utilise the transport model.

Scenario 2: Lower Congestion

This scenario assumes that there are numbers of ways to reduce congestion ranging from encouragement of public transport to enforcing parking restrictions to improve free flow. The outcome of such policies is then modelled by assuming a 15% reduction in congestion, due to passenger vehicles, in the AM and PM peaks. Information from stage 1 of the study suggests that a 15% reduction in congestion would be reasonable.

Scenario 3: Better Traffic Management

Again this scenario encompasses a number of strategies to better manage traffic flow on the network, from removing bottlenecks to sophisticated intelligent transport systems for traffic management. The performance of roads in the network under traffic is governed by a relationship known as the Volume-Delay Function derived from the capacity of the road and the numbers of vehicles using it.

This scenario adjusts this function so that at saturation point each arterial road would be operating at 3kph faster than previously, and 10% would be added to the traffic capacity of the road. Arterial roads potentially benefit most from improved traffic flow management. Freeways/motorways are more likely to have systems already in place and sub-arterial/local roads usually do not reach their capacity.

Scenario 4: Higher Load Factors

In this scenario, load factors are increased for commercial vehicles. This can be achieved by higher loads per vehicle, or the use of a larger vehicle either in the same class or a larger class. All result in fewer vehicle trips to move a given quantity of goods around the city.

The scope for this sort of change varies from industry to industry. The 1996 commercial vehicle trip matrices were factored to take into account feasible changes in such practices, given the location of industries and the types of vehicles involved. The industry mix in each area is weighted by an estimated likely percentage trip change in each industry to estimate potential changes in each travel zone.

Scenario 5: Real-time Traffic Information

Provision of real-time traffic information to improve network performance was modelled using the same Volume Delay Function as used for traffic management with the information provision restricted to the principal arterial routes to the Sydney and Parramatta CBD (Central Business District) and the main ring routes.

Scenario 6: Infrastructure Improvement

This policy test assessed what difference the Sydney Orbital Route, expected to be completed in 2006, would make if it had been present in 1996 and if the origins and destinations for commercial and private vehicles trips remained as they were without the Orbital. Figure 3 provides a sketch map of the western route in relation to other links in the Sydney orbital network.

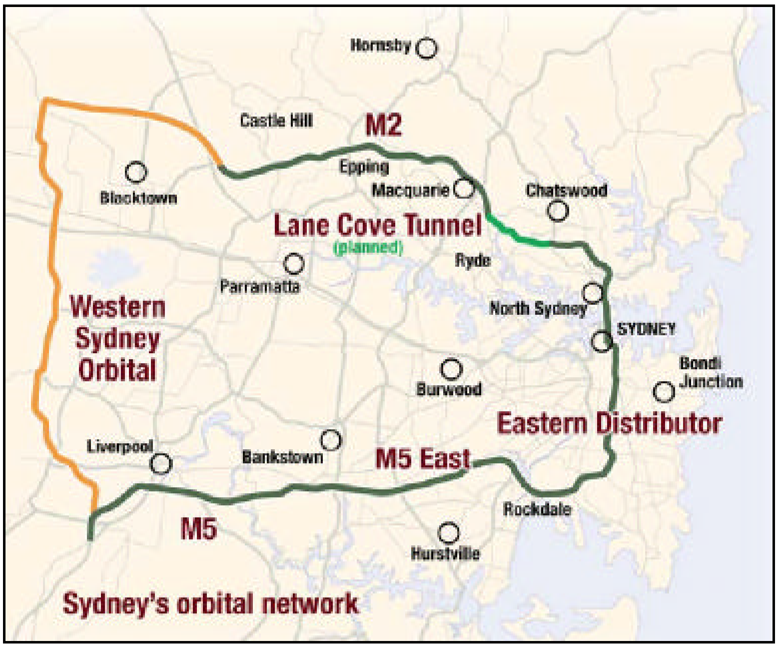

Figure 3. The proposed Western Sydney Orbital Route

Scenario 7: Infrastructure Improvements with Land Use Change

The Sydney Orbital Route improves access from Western Sydney. This scenario evaluates the impact if, in addition to the new orbital infrastructure in the previous scenario, businesses in Inner Sydney moved west closer to the orbital route. 10% of manufacturing jobs were moved to travel zones near the route and the impact of the estimated loss and gain of 2.2 freight trips per day due to each of those jobs was estimated.

Table 4 summarises the implementation approach to the selected policies adopted by the transport modelling component of the study.

TRANSPORT MODELLING RESULTS

Seven runs were performed to produce the link volumes for a 24-hour period representing the travel patterns under the given scenarios. The runs and their corresponding scenarios were performed as follows:

- Run 1: 1996 base case (Also used for Improved Fuel Consumption)
- Run 2: General reduction in congestion
- Run 3: Improved traffic management
- Run 4: Higher load factors
- Run 5: Real time traffic information

- Run 6: Infrastructure improvement - the Sydney Orbital
- Run 7: The Sydney Orbital with industrial relocation

Table 4. Transport modelling approach to selected policies

Policy (Scenario)	Transport modelling approach
Improved fuel consumption (Scen 1)	Travel patterns from 1996 base case. Calculate emissions directly from lower fuel consumption figures.
Lower congestion (Scen 2)	15% reduction in car use in AM and PM peaks
Better traffic management (Scen 3)	Volume-delay functions on arterial roads modified to increase speed at saturation by 3 kph and to add 5% to capacity.
Higher load factors (Scen 4)	Commercial vehicle trip matrices modified to give same quantity of goods being moved between same places but with higher load factors and some transfer of goods to larger vehicles.
Real-time traffic information (Scen 5)	Volume-delay functions on major approaches to CBD and Parramatta and on major orbital routes modified as per “better traffic management”.
Infrastructure improvement (Scen 6)	Sydney Orbital route at freeway standard added to 1996 road network for Sydney.
Infrastructure improvement with land use and distributional feedbacks (Scen 7)	Sydney orbital route at freeway standard added to 1996 road network for Sydney; westward shift of employment assumed; modified CV patterns as a result

Again, base case (Run 1) results were used as reference for assessing the relative impact of the six policy measures. Figure 2, shown earlier, provides a thematic map of the volumes of LCVs on the road network for the midday period of the base case. The graduations in this map have been split up into eight classes with different colors and line widths to illustrate the spatial distribution of the volumes. These thematic maps can be produced, if required, for any emission, vehicle and fuel type combination used in the emissions model.

As validation, the base case results have been compared to results using simplified emissions factors as given by the Australian Greenhouse Office (AGO, 1998) and Environment Australia (2001). All the results showed strong correlation, and hence provide a firm basis for the analysis of the other policy options.

The results of applying each of the policy scenarios in the transport model are briefly presented as follows.

Lower congestion

Lowering peak congestion reduces both peak VKT and VHT. The percentage reduction in VHT exceeds that of VKT and average travel speeds increase. This only occurs in peak periods and the 24-hour performance is therefore watered down. The majority of commercial vehicle movement takes place outside the peaks.

Better traffic management

Improvement of the performance of arterial roads improves traffic flow thus reducing VHT and increasing average speed. But the overall effect is small, because the better-performing roads tend to attract more traffic, which slows them down again.

Higher load factors

A move to higher load factors and load consolidation produces a large net decline in VKT by commercial vehicles and hence is likely to reduce emissions. The use of larger trucks would reduce the number of trips but there is very little change in operating speed, since VHT declines in roughly the same proportion as VKT.

Real-time traffic information

This increases the performance of the principal arterial and orbital routes. It has practically no effect on commercial vehicle VKT but VHT decreases slightly and hence higher operating speeds are achieved (for light CV's and rigid trucks).

Effects of infrastructure improvement

If trip patterns did not change, the addition of the Sydney Orbital to Sydney's road infrastructure in 1996 would have encouraged longer but faster trips by both cars and commercial vehicles, with the result that VKT would go up, VHT would go down and average travel speed would increase.

Effects of infrastructure improvement with land use change

Relocation of some freight-generating employment from inner areas to Western Sydney actually increased commercial vehicle activity because some of the displaced movement would still have the docks and central industrial areas as its destination pattern. Some increase may be a result of modelling assumptions but it is also likely that larger scale land use changes such as new terminals are needed for freight travel.

EMISSIONS MODEL

On completion of the transport model runs, data was passed on to the Transport Systems Centre (TSC) which developed the model for calculating total emissions for each link in the network. The emission model covers 12 different types of greenhouse gas and air quality emissions as well as the four vehicle types (passenger vehicles, light commercial vehicles, rigid trucks and articulated truck) used in the study. The emissions species considered include CO, CO_2, VOC, NOx, N_2O , SO_2, CH_4, PM_{10}, Benzene and 1,3Butadiene.

Each vehicle type has been further disaggregated into three different fuel types: petrol, diesel and liquefied petroleum gas (LPG). The outputs from the transport models however do not provide information on the numbers of the different vehicles by fuel type. These vehicle-fuel numbers were obtained by multiplying the appropriate vehicle number by the proportion of the fleet that makes up the particular fuel type. The proportions of vehicles by corresponding fuel types were obtained from the 1997-1998 ABS Small Area Motor Vehicle Data (ABS, 1999).

In all, 132 combinations were investigated for use in this study. Emission estimates were not derived for LPG-fuelled articulated vehicles since ABS (1999) showed that there were only three of this type of vehicle-fuel combination in the Sydney metropolitan area and hence would have no significant effect on total emissions produced.

The emission model used parameters from four information sources. The first source of information was the European emissions inventory guidebook (European Environment Agency, 2002). The guidebook contains emission and fuel consumption functions for the four vehicle types listed. Most of these functions are sensitive to varying link average speeds and differing vehicle loads. This is an important requirement since many of the policy scenarios that are being tested require this degree of sensitivity. However since the study is concerned with the Australian vehicle fleet, a method of scaling these functions was developed to allow these European models to reflect the emissions characteristics of the Australian vehicle fleet. Scaling factors were derived from the second and third information sources namely the Australian Greenhouse Office (AGO, 1998) and Environment Australia (2000).

The fourth information source was the Apelbaum Consulting Group Transport Facts publication (Apelbaum Consulting Group, 2001), which was used to derive fuel consumption values for the 1996 vehicle fleet. The information sources used were considered to be the best sources data for use in this study.

DISCUSSION OF PARTIAL RESULTS

The result of the runs will be presented in detail in the project final report. This section presents representative results for two of the emissions: carbon dioxide (CO_2) and particulates (PM_{10}).

CO_2 Emissions

Figure 4 displays a comparison of the daily CO_2 emissions from each type of commercial vehicle for the seven runs. The chart shows that the emissions from Run 4 (Higher Load Factors) present significant reductions from those of the base case (Run1) especially for LCV's and rigid trucks. Run 2 (General reduction in congestion) also showed improved results. On the other hand, the results of Run 7 show increased emissions from the base case, with emission levels doubling for articulated trucks. However, these results should be viewed in the context of overall vehicle emissions.

Total daily CO_2 emissions from passenger vehicles are about ten times those of freight vehicles, as shown in Figure 5. This means that policy measures that impact passenger vehicles will produce greater reductions than those targeting freight vehicles. Thus, Run 2 results provide more significant reductions than Run 4. In fact, even Run 7 results, when viewed from overall perspective, offer long-term attraction in terms of reducing car emissions inspite of potential increases in freight emissions.

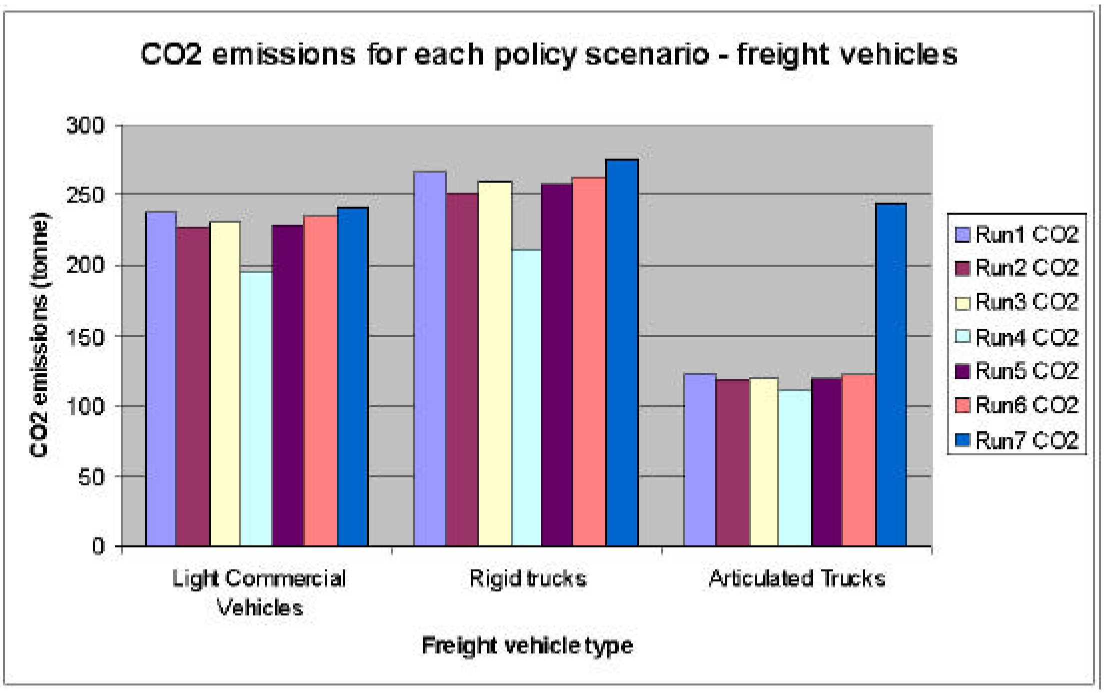

Figure 4. 24-hour CO_2 emissions from freight vehicles only

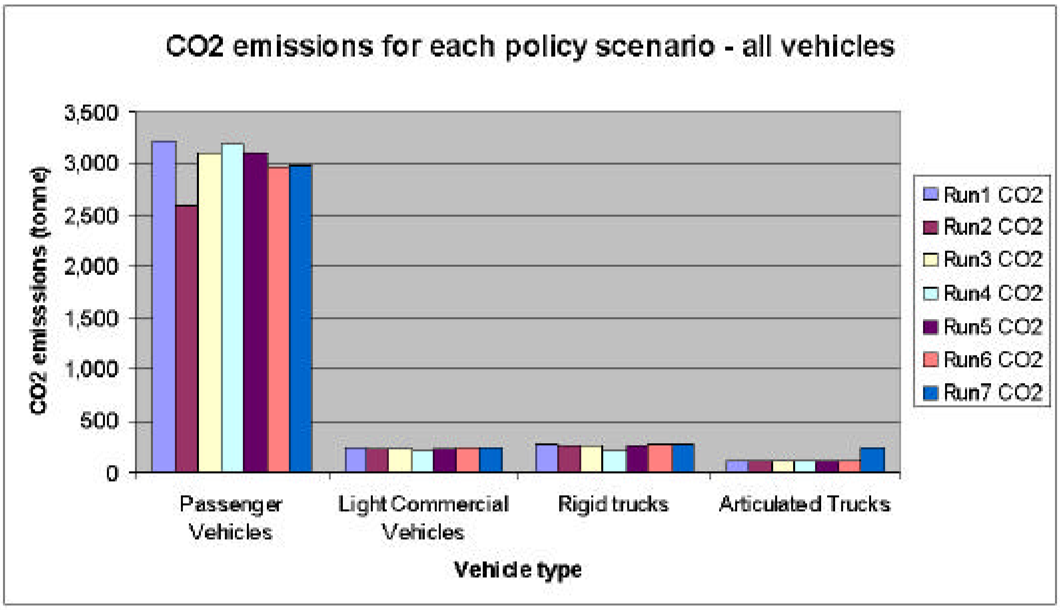

Figure 5. 24-hour CO_2 emissions from all vehicles

Table 5 further illustrates the implications of this imbalance. As pointed earlier, Scenario 4 can significantly reduce CO_2 emissions from freight vehicles, up to 17.3%. On the other hand, the application of Scenario 7 may increase freight emissions by 21.4%. However, since freight vehicles only account for 16.3% of all vehicle CO_2 emissions, and all scenarios reduce emissions from passenger vehicles, all scenarios offer emissions reduction benefits overall. Scenarios 3, 4, 5 and 7 appear to offer the same 3% level of reductions over all traffic while

Scenario 6 offers a reduction rate of 6.6%. Scenario 2 appears to have the most significant reduction potential at 17%.

Table 5. CO_2 emission deviations from base case by scenario

Policy Instrument (Scenario)	ALL Traffic	Freight Traffic Only
Lower congestion (Scen 2)	-17.1 %	-4.8 %
Better traffic management (Scen 3)	-3.3 %	-2.8 %
Higher load factors (Scen 4)	-3.4 %	-17.3 %
Real-time traffic information (Scen 5)	-3.2 %	-3.2 %
Infrastructure improvement (Scen 6)	-6.6 %	-1.0 %
Infrastructure improvement with land use and distributional feedbacks (Scen 7)	-2.6 %	+21.4 %
Base Case: Freight vehicles contribute 16.3% of total CO_2		

PM_{10} Emissions

In contrast with carbon dioxide emissions, particulate emissions have more variable sources. Figure 6 shows that rigid trucks contribute almost as much emissions as passenger cars with articulated trucks and LCV's following close behind. This results in freight vehicles accounting for 51.5% of all PM_{10} vehicle emissions.

According to Table 6, Scenario 4 again provides the best potential for reducing PM_{10} emissions from freight at about 17.7%. Scenario 2 comes second at 6.6%. Scenario 7 again creates the opposite effect with increases in freight emissions of up to 20.1%. Since the proportion of passenger vehicles is considerably smaller, the overall effect of Scenario 7 continues to point to increases of 6.8%. Scenarios 2 and 4 again provide the best options for overall reduction, at 12.9% and 9.5% respectively.

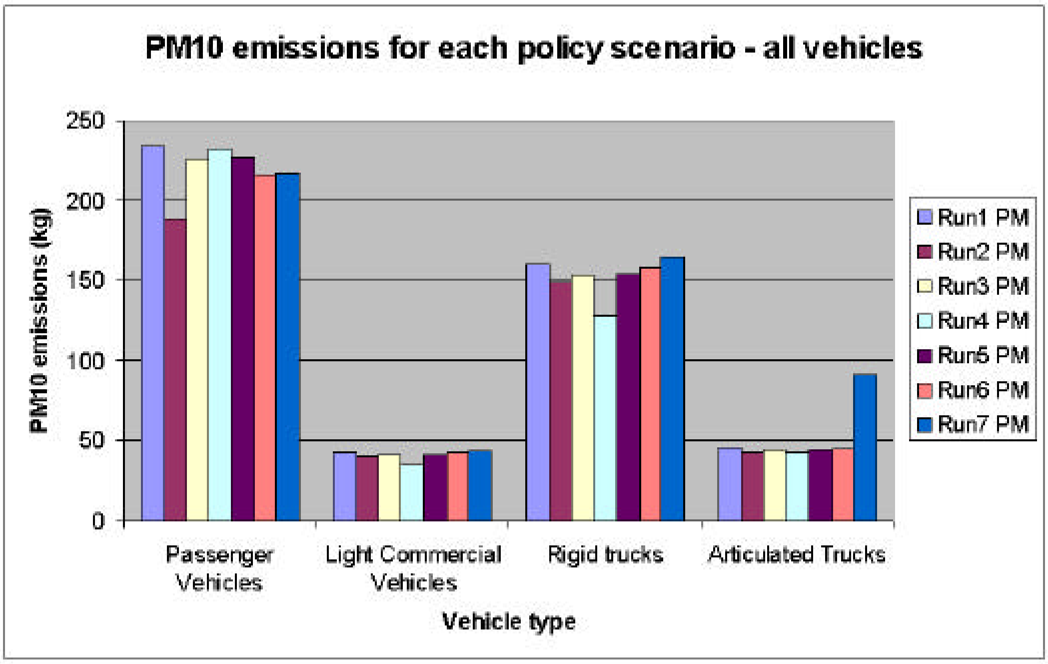

Figure 6. 24-hour PM_{10} emissions from all vehicles

Table 6. PM_{10} emission deviations from base case by scenario

Policy Instrument (Scenario)	ALL Traffic	Freight Traffic Only
Lower congestion (Scen 2)	-12.9 %	-6.6 %
Better traffic management (Scen 3)	-3.8 %	-4.1 %
Higher load factors (Scen 4)	-9.5 %	-17.7 %
Real-time traffic information (Scen 5)	-3.7 %	-4.0 %
Infrastructure improvement (Scen 6)	-4.6 %	-1.6 %
Infrastructure improvement with land use and distributional feedbacks (Scen 7)	+6.8 %	+20.1 %
Base Case: Freight vehicles contribute 51.5% of total PM_{10}		

CONCLUSION

Table 7 below summarises the effect of the policy instruments on the performance measures chosen for assessment. All instruments have the potential to reduce VHT, trip length as well as emissions. The use of ‘higher load factors’ has positive implications across the board, including reductions in the number of vehicles, reductions in the number of trips, and significant reductions in freight emissions. However, this scenario is contrary to industry trends towards lower load factors and “just in time” deliveries, which are likely to increase emissions.

In contrast, the positive effects of ‘infrastructure improvement with land use changes and feedbacks’ were limited. The principal effect assumed as a result of allowing land use to respond to the introduction of the Sydney Orbital was a relocation of some freight-generating employment from inner areas to western Sydney. When this was input to the model, the prediction was that this would actually increase commercial vehicle activity if the same destinations were to be served. This is because some of the displaced movement would still have the docks and central industrial areas as its destination pattern. The impact was most noticeable for articulated trucks, whose VKT was predicted to increase by 27% per day.

Table 8 presents an assessment of the size of the impacts of the policy instruments based on four criteria. It is clear that all instruments present significant effects relative to the freight task with ‘General reduced congestion’ and ‘Higher load factors’ having strong positive effects while ‘Orbital with land use change’ pose strong negative effects. Overall, the transport and emission modelling results suggest that ‘General reduced congestion’ presents the widest coverage and strongest effects in terms of market size, GHG emissions and non-GHG emissions.

Table 7. Performance measures of policy instrument effects

	Type of Effect					
Policy Instrument	**Reduce No. of Vehicles**	**Reduce No. of Trips**	**Reduce Trip Length**	**Reduce VKTs**	**Reduce Fuel Use**	**Reduce Emissions per Litre**
General reduced congestion			YES	YES	YES	YES
Better traffic management			YES		YES	YES
Higher load factors	YES	YES	YES	YES	YES	YES
Real-time traffic information	YES		YES		YES	YES
Sydney orbital road	YES		YES	YES	YES	YES
Orbital with land use change			YES			YES

Table 8. Impact assessment of policy instruments

	Size of Effect			
Policy Instrument	**Relative Size of GHG Effect**	**Market Size Affected**	**Overall GHG Emissions**	**Overall Non-GHG Emissions**
General reduced congestion	✓✓✓✓	✓✓✓✓	✓✓✓	✓✓✓
Improved traffic management	✓✓	✓✓✓✓	✓	✓
Higher load factors	✓✓✓✓	✓✓	✓	✓
Real-time traffic information	✓✓	✓✓✓✓	✓	✓
Sydney orbital road	✓✓	✓	✓✓	✓✓
Orbital with land use change	✓✓✓✓	✓✓	✓	✓✓

REFERENCES

ABS (1999). *TranStats Small Area Motor Vehicle Data 1997-98*, Report No. 9312.0.30.001, Australian Bureau of Statistics, Commonwealth of Australia.

AGO (1998). *Energy Workbook for Transport (Mobile Sources) 3.1*, Australian Greenhouse Office, Commonwealth of Australia.

Apelbaum Consulting Group (2001). *Australian Transport Facts 1998,* Report No. 0642721726, The Centre for Transport Energy and the Environment.

Environment Australia (2000). *National Pollutant Inventory Emission Estimation Manual for Combustion Engines Version 2.1*, Commonwealth of Australia.

Environment Australia (2001). *National Pollutant Inventory Summary Report of Second Year Data 1999 - 2000*, Report No. 0 642 54694 0, Commonwealth of Australia.

European Environment Agency (2002). *Emissions Inventory Guidebook*, Report No. 3, European Environment Agency.