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MODELLING RESPONSES OF URBAN FREIGHT PATTERNS TO GREENHOUSE GAS ABATEMENT SCENARIOS

Modelling Responses of Urban Freight Patterns to Greenhouse Gas Abatement Scenarios

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Preface

This paper presents the results of applying a policy model to simulate the effects on Greenhouse Gas emissions from trucking in Sydney of various abatement scenarios. These include vehicle efficiency scenarios, traffic efficiency scenarios and alternative infrastructure and land use scenarios.

The model developed is quite comprehensive. It includes the effects of the interaction of trucks with car traffic in the city. And it extends the results, not only to the recognised Greenhouse gases, but also to the effect of the scenarios on pollutant emissions from road transport and thus on pollution in the Sydney airshed.

The research reported on here shows that, using the model developed, answers can be given as to detailed effects of transport policy measures on emissions in Sydney. Just as importantly, it points to methods that can be used to build such a model in other cities.

The series of five technical papers describing the construction and make-up of the model and its capabilities is available on the CSIRO website.(http://www.energytransformed.csiro.au). CSIRO was the co-ordinator of the research, with Parsons Brinckerhoff and the Transport Systems Centre of the University of South Australia contributing components. CSIRO prepared this report. The Transport and Population Data Centre of the NSW Department of Infrastructure, Planning and Natural Resources provided the datasets of traffic and now owns the model framework. All of the research was made possible by a grant from the Australian Greenhouse Office.

BTRE would like to thank all those involved in what was a complex cooperative task: Nariida Smith(especially) and Leorey Marquez of the CSIRO, Glen D'Este of Parsons Brinckerhoff, David Kilsby of Kilsby Australia, Paul van den Bos of Computing in Transportation, Mike Taylor and Rocco Zito of the Transport Systems Centre, John Peachman of the Transport and Population Data Centre, Martin Nichols of the NSW Roads and Traffic Authority, and Jo Evans, Kay Loong and Simon Wear of the Australian Greenhouse Office. Dr. David Gargett managed the project for the BTRE.

Phil Potterton
Executive Director
Bureau of Transport and Regional Economics

October 2004

At A Glance

- This study, undertaken on behalf of BTRE and the Australian Greenhouse Office by a consortium led by CSIRO, examines the responses of urban freight patterns to greenhouse gas abatement scenarios. Using Sydney as the city for analysis, seven scenarios are examined. These include:
    - improved fuel consumption (freight vehicles only);
    - less congestion;
    - better traffic management;
    - higher load factors (freight vehicles only);
    - real-time traffic information;
    - infrastructure improvement;
    - infrastructure improvement plus corresponding land use charges; and
- These scenarios represent outcomes of potential policy and/or industry action. However, the issue of whether governments should undertake any specific policy measure, that a scenario may imply, lies beyond the scope of this study.
- The model of Sydney developed for the analysis included cars as part of the vehicle fleet. As such, the final assessments of greenhouse gas effects of the scenarios, were of the overall effects on Sydney's total road transport system.
- Two scenarios showed the highest assessed decreases in greenhouse gas emissions from freight vehicles. *Higher load factors for truck trips* was assessed to have the highest effect in reducing emissions from freight vehicles. *Adoption of best fuel technology for trucks* showed the next highest effect. The rest of the scenarios had little effect in reducing emissions in trucks, although assumed decreases in congestion did have a noticeable effect on car emissions (and hence the largest impact on the total vehicle fleet).
- The modelling also allowed the calculation of the effect of the scenarios on individual pollutants by detailed location around Sydney. Whereas cars are the source of over 80 per cent of greenhouse gas emissions from motor vehicles in Sydney, trucks and light commercial vehicles contribute over 50 per cent of fine particulate matter and 35 per cent of nitrogen oxides. Adoption of best fuel technology for trucks and higher truck load factors produced the greatest reductions in emissions of these pollutants for the entire vehicle fleet.
- Finally, the modelling was linked to an airshed model of Sydney, allowing detailed assessment of the effect of transport sector behaviour on local pollution concentrations at all points around the city. Thus the effect of the policy outcome scenarios on pre-existing "pollution hotspots" could be estimated.

Executive Summary

This is the final report of a study undertaken by CSIRO to investigate the sensitivity of urban freight patterns to a range of potential policy measures aimed at reducing GHG emissions. BTRE commissioned the study on behalf of the Australian Greenhouse Office (AGO). The full study, including five technical Working Papers, is available on the CSIRO website (http://www.energytransformed.csiro.au).

Greater Sydney was used as a case study area because of the availability of detailed data on freight trips and passenger travel held by the Transport and Population Data Centre (TPDC) of Transport NSW. The TPDC Commercial Transport Study (CTS) has developed methodologies to derive freight traffic patterns that result from actual or forecasted commodity flows and associated information. In contrast, this study considers scenarios that introduce alternative ways and means of moving freight, rather than change in the overall amount of freight being moved.

Stage 1 of the study, via a literature search and market study, investigated potential outcome scenarios and developed a qualitative assessment framework for comparing their likely impacts. This informed a stakeholders workshop to select outcomes to be modelled. By focusing on identifying the operational outcomes of policy instruments (or combinations of policies), and modelling their effects on emissions, a broad range of policies with different approaches to achieving the same outcome could be implicitly included. For example, improved fuel efficiency and reduced emissions from each litre of fuel consumed, might be achieved by a range of vehicle, engine and fuel technologies. The table below shows the set of generic policy and/or industry outcomes tested.

Category	Outcome
VEHICLE	1. 'Best Practice' Truck Fleet Fuel Efficiency
TRAFFIC	2. Reductions in General Congestion 3. Improved Traffic Management
VEHICLE MOVEMENT	4. Logistics changes /Higher Load Factors 5. Real-Time Traffic Information
INFRASTRUCTURE AND LAND USE	6. Significant Additional Road Capacity 7. Changes to Land-Use following New Infrastructure

Scenarios to represent these outcomes were developed and compared to the base case of traffic on the urban road network in four time periods, morning and afternoon peaks, daytime and evenings. The process for each scenario involved:

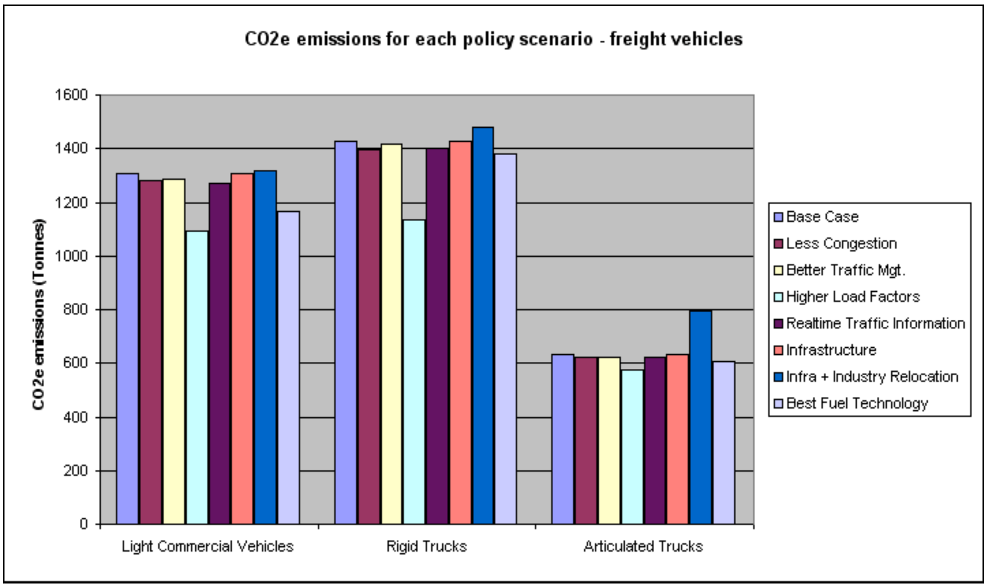
Transport Modelling to revise the matrices of trips between origins and destination in the Sydney region for light commercial vehicles (LCV), rigid trucks (RT) and articulated trucks (AT). The resulting pattern of freight vehicle trips was then combined with the traffic from passenger vehicles (PV) to produce a complete picture of travel distance and time for each type of vehicle, within time of day periods to allow for differences in traffic volumes.

Emissions Modelling: Fuel use, and resulting GHG and other emissions, for each link in the road network were estimated taking into account the mix of traffic, an estimated distribution of fuel types, the speed of traffic and the loadings of vehicles. The volumes of direct GHG gases: Carbon Dioxide, Carbon Dioxide Equivalents, Methane and Nitrous Oxide were estimated for each scenario. To check the impacts of the policy scenarios on air pollution, emissions of harmful pollutants (Carbon Monoxide, Volatile Organic Compounds, Oxides of Nitrogen, Particulate Matter, Benzene, Butadiene and Sulphur Dioxide), were also estimated.

Air Pollution Modelling Finally, the spatial distribution of air pollutants for each scenario was input to an airshed model of Sydney to estimate air pollution impacts across the city and the exposure of the population to air pollution in different parts of the city over an example day.

The results of scenarios compared to the base are summarised while noting that the strength of the network modelling approach lies in estimating location specific variations and variations by time of day which cannot be seen from summary figures. Technical papers supporting this report and a scenario viewer to zoom into individual road links provide detailed results.

Six of seven scenarios produced improvements with particular advantage from higher load factors and better fuel technology. (Industry relocation, moving jobs west, increased travel to ports and airports). When all traffic was considered reduced congestion reduction had the largest impact. However, the impact on greenhouse emissions from freight vehicles was only minor, as freight traffic to some extent avoids travel during urban peak periods.



Total modelled CO_2e emissions (in tonnes per day) for each freight vehicle type under the different policy scenarios

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1. Introduction

1.1 Study Background & Objectives

Road freight activity in Australian cities is growing more rapidly than passenger traffic, and although passenger traffic per person is expected to plateau at some point in the future, there is no sign of that happening for urban freight activity. As a result, the environmental impacts of urban freight traffic, especially in terms of greenhouse gas (GHG) and other air pollution, are of increasing concern to the community. In view of this, the Bureau of Transport and Regional Economics (BTRE), on behalf of the Australian Greenhouse Office (AGO), commissioned a study to investigate the sensitivity of urban freight patterns to a range of transport outcome scenarios aimed at reducing GHG emissions.

While the study aimed to provide results generally applicable to all Australian urban areas, Greater Sydney was used as a case study to build on the data and models held by the Transport and Population Data Centre (TPDC) of Transport NSW. The TPDC Commercial Transport Study (CTS) has developed methodologies 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 provides one of the most detailed estimations of the impacts of urban freight flows on the road network available anywhere in the world. 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. Such models are potentially powerful in predicting expected traffic on the network due to changes in the needs for different types of freight.

GHG emissions due to urban freight depend upon the fuel use by freight vehicles. This in turn depends upon vehicle technologies, and fuel, plus travel speed and flow, hence prevailing traffic. It also depends on the numbers of trips required, the loading of vehicles and the location of the industry and business dispatching or receiving freight together with the transport infrastructure, predominantly roads, linking freight origins and destinations. Potential scenarios or policy outcomes expected to produce positive GHG outcomes may thus be conveniently divided into the categories shown in Table 1.1.

A wide range of potential measures in these categories was identified, a modelling framework was developed and a set of scenarios for modelling was selected. The relative impacts of scenarios on vehicle emissions were then modelled. The models took into account the basic factors affecting the pattern of urban freight traffic activity, the rate of emissions under different traffic conditions, and the resulting impacts in terms of patterns of emissions in different parts of cities.

Table 1.1 Influences on urban freight GHG emissions

Category	Influences
VEHICLE	The type of fuel, efficiency of motors, and influences such as vehicle weight, aerodynamic properties and driving style all influence emissions.
TRAFFIC	Emissions vary with speed and differ between free flow and congested conditions, thus are affected by prevailing traffic conditions.
VEHICLE MOVEMENT	Emissions depend on numbers of trips, total trip distances, loading of vehicles and size of the vehicle used for the task.
INFRASTRUCTURE AND LAND USE	Land use governing the location of industries and business and their distances from suppliers and customers influence trip lengths, hence fuel use and emissions as does new infrastructure to provide better connectivity.

1.2 Content & Structure of this Report

This Final Study Report provides an overview of the study objectives, methodology, modelling results and their interpretation. Each section reports one aspect of the study with more detailed information available in the set of five technical papers, which support the study.

Section 2 Reponses to Scenarios: Describes the first phase of the study where a literature search and advice from experts were used to develop a qualitative understanding of the urban freight task, and identify the range of potential scenarios to be investigated. These candidate scenarios were then reviewed at a Knowledge Workshop. The section concludes with the final set of scenarios to be modelled as established at the workshop (see Table 1.1). More details are available in Technical Paper 1 (Smith & D'Este, 2003) and a database containing the details of the information found in this phase of the project is also available.

Section 3 Transport Modelling: Presents the approach taken to model each of the scenarios and the base case to which their impacts are compared. It begins by setting the study within the context of the existing TPDC models. We present summary results after the estimated patterns of freight vehicles trips by Articulated Trucks, Rigid Trucks and Light Commercial Vehicles under different scenarios are combined with the traffic from passenger vehicles. This produces a complete picture of travel distance and time for each type of vehicle, within time of day periods to allow for differences in traffic volumes. More details are available in Technical Paper 2 (Smith & Kilsby, 2003)

Section 4 Emissions Modelling: Explains the process employed to estimate first fuel use, then resulting GHG and other emissions (as shown in Table 1.2) for each link in the road network. This needed to take into account the mix of traffic, an estimated distribution of fuel types, the speed of traffic and the loadings of vehicles. These latter processes required recalibration of European data such as speed and load curves to suit the Australian context.

Some emission results are reported as an introduction to both the air pollution modelling in the next section and a discussion of the impacts of policy measures on GHG in Section 6. More details of emissions modelling and results are available in Technical Paper 3 (Zito & Taylor, 2003).

The section concludes with a very brief description of the Scenario Viewer included in the package to allow examination of the study results at road network link level. Further information about the uses and features of the Scenario Viewer can be found in Technical Paper 4 (Marquez, 2003).

Table 1.2 Emissions Modelled

Direct GHG		Air Pollutants	
CO_2	Carbon Dioxide	CO	Carbon Monoxide
$CO2_e$	Carbon Dioxide Equivalents	VOC	Volatile Organic Compounds
CH_4	Methane	NO_x	Oxides of Nitrogen
N_2O	Nitrous Oxide	PM	Particulate Matter
		C_6H_6	Benzene
		C_4H_6	Butadiene
		SO_2	Sulphur Dioxide

Section 5 Air Pollution and Exposure: Describes the extension to the study where the link level emission results for each air pollutant were input into an air shed model of Sydney to estimate their spatial dispersion across the urban area throughout the day. The process used to estimate population whereabouts by time of day using data on household activity from the TPDC Household Survey is presented. Relative impacts of the alternative GHG scenarios for urban freight on air quality are reported in terms of exposure of the population to air pollution in different parts of the city over a representative day. In view of the extensive output when the impacts of 7 scenarios on exposure to 4 pollutants in different areas of the city are considered, only example results are presented here. Full detail of the results for each pollutant and each scenario can be found in Technical Paper 5 (Marquez & Smith, 2003).

Section 6 Conclusions and Policy Implications: Summarises the key study outcomes, and discusses the application of these results for urban Australia. It also emphasises the value of modelling generic policy outcomes.

2. Responses to Scenarios

2.1 The Urban Freight Task

The first task for the study was to establish which scenarios representing outcomes of policy and/or industry action, should, and equally importantly could, be modelled. That is, we wanted an initial assessment of likely policies/actions and likely impacts, in terms of who would be affected and by how much. If detailed disaggregate data, about shipper and carrier preferences and activities, were available, likely responses to a scenario might be predicted with a behavioural model. In the absence of such data, a process for judging the likely responses to scenarios using a mix of available quantitative data and market intelligence is needed. Thus the project commenced with a review of available TPDC data and supporting data, such as information from the Australian Bureau of Statistics (ABS), plus a market study comprising formal and informal interviews with experts augmented by information from local and international reports and papers.

The market study demonstrated the diversity of the freight industry and its people. The freight industry, in general, and the urban freight industry, in particular, is a set of multiple markets. The consideration set of the study was constrained by:

- The definition "Urban Freight" i.e. we were to consider carriage of goods not provision of services; and
- Available data. TPDC data excludes some categories of freight. Particular exclusions are household freight such as mail delivery and "consignment" of household garbage".

The study thus relates particularly to the consignment and delivery of goods by business and industry. This aspect of the freight task has seen significant changes in recent years. While the concepts of supply chains, and associated logistics services date from the time carriage was by camel train, developments in information communications technologies have led to a revolution in the management of the supply chain from "suppliers' supplier to customers' customer". Table 2.1 summarises some key changes to the freight task.

Table 2.1 Changes to the Freight Task

Change In Practice	Impacts
Supply chain change from supplier push model to customer pull model	Goods are built to order, in contrast to production of goods to warehouse then sell. This results in, low inventories, the movement of smaller quantities more frequently and "just in time" (JIT) (Fine and Raff, 2000).
Integrated Logistics	Customers (shippers) are demanding integrated logistics services. Third party logistics services control the whole supply chain affecting mode choice on delivery decisions (Vandermerwe, 2000).
E-procurement:	Firms or groups of firms procure products directly from suppliers. To win contracts, sellers offer high service frequency, including delivery to firms across the city. (Teresko, 2000).
De-materialisation	Although the trend is not evident in Australia yet, the USA has reported a drop in paper use (Romm et al, 2000). This would impact both urban couriers and transport of office supplies.

Moreover changes have been rapid, especially after 1996/97 onwards, as e-business, the use of electronic commerce between firms and the use of electronic transactions within firms, has grown. There is now broad agreement that the way business is transacted is changing and the effect on freight transport will be significant (Smith et al., 2001). This affects the issues under study here in a variety of ways as freight supply and demand influences change.

In the light of changes in logistics practice, Europeans have developed SMILE (Tavasszy et al., 1998) to model impacts of policy measures on freight flows and the environment in terms of logistics families based on a detailed description of product and market characteristics. The approach integrates choice of ways and means of distributing freight with choice of what is shipped. Closer to home, Fuller and Tsolakis (2001) produced a scoping study, which argued the need for viewing road transport as part of the logistics chain.

However, there are arguments in favour of suites of linked modelling procedures rather than single integrated models. Foremost among these is the need to bind the level of integration. The supply chain, of which the freight task is but a component, can be linked up to the socio-economic system of the nation (Zografos, 2002) but this does not mean that all the processes must be modelled simultaneously. Additionally, the most important direction for a later extension of the model is likely to be in the area of commercial travel for services, which is increasing. TPDC has already recognised this trend by adding a service vehicle study to the CTS.

On the basis of interviews and literature we thus selected the following procedure:

1. Identify the policy variables of interest,
2. Establish the relevant segments of the freight task from the literature and expert advice,
3. Establish the likely outcome of the policy and model its traffic and hence GHG impacts.

2.2 Insights from the literature

Economic Indicators & Elasticities

The process established during the market study of first identifying the range of outcomes or measures that may influence urban freight operations and then investigating their relative effect, was also applied in a document and literature scan to inform the study. Before considering specific policies, the initial review focused on: economic indicators and logistics trends; demand elasticities, and the relative significance of factors affecting emissions from urban freight.

The economic significance of freight transport has been studied in a number of reports most recently by Bureau of Transport and Regional Economics (BTE, 2000; BTRE, 2002). A key finding for understanding responses to policy outcome scenarios is that the cost of transport and logistics as a percentage of the final price is highly variable. It averages 10-20% overall but can range from less than 5% for high value goods (such as electronics) to more than 30% for low value goods (such as building materials). This means that for most types of urban freight, a change in transport costs by say 10–20% will translate into a change in final price of only 1-2%. As a result, the impact of pricing measures on urban freight behaviour tends to be swamped by other commercial and logistics imperatives of the type reported above.

Literature on urban freight elasticities is very thin and elasticities for long distance freight are unlikely to apply in the very different urban situation. Table 2.2 summarises our findings:

Table 2.2 Elasticity of Demand for Urban Freight

Elasticity (with respect to):	Effect and Explanation
Fuel Price	Low short-term substantially higher long-term due to the slow fleet turnover, limits on the rate of technology development and deployment as well as the over-riding imperative of customer needs.
Vehicle Purchase Taxes	Changes did not appear effective instruments for reducing energy consumption.
Road Pricing	Mixed impacts. Volume of demand unchanged with costs, passed on to shippers, possible changes in route, timing and vehicle type dependent on local circumstances.
Traffic	Traffic conditions have a significant impact on freight operations. Estimated price elasticity with respect to traffic (−0.81) is considerably higher than the elasticity with respect to transport (−0.47).
Freight Costs	The UK national road traffic forecasts adopt an elasticity of –0.1 for length of haul with respect to freight costs. Transport is a small proportion of overall price and freight transport is a derived demand.
GDP	Most studies have found that urban LCV activity is growing faster than GDP. The UK national road traffic forecasts assume an elasticity of 1.23 for light goods vehicles.

Sources: Bjorner (1999), Greene and Plotkin (2001), Greening et al (1999)

Factors Affecting Urban Freight Emissions

An OECD (2001) study conclusion is particularly important. As much as 60% of the effort to significantly reduce CO_2 emissions will need to come from non-engine-technical measures. This emphasised the need for a combination of both technology and management measures. Two British studies support these findings. Table 2.3 summarises literature findings by factor category.

Table 2.3 Impacts of Policy / Industry Measures from Literature

Change Type/ Issue	Expected Emissions Effects & Comments
VEHICLE TECHNOLOGIES	
Penetration rate	Impacts depend on incentives for retiring and replacing vehicles. Av age Sydney Fleet= 10.7 years (RTA, 2000).
Fuel cells	Estimates of 60% emissions reduction by 2015 IF 40% of fleet (Caceres & Richards, 2000).
CNG & LPG vehicles	Already in service. CNG most promising. (Saricks et al, 2000).
Electric vans for city deliveries	Development accelerated by Californian requirements for "zero emitting vehicles" by 2003 (Burke and Kurani, 2001).
Vehicle maintenance /standards	Inspection & maintenance can impact GHG emissions. More stringent standards for new vehicles are improving efficiency.
Other vehicle technologies	Emission reduction from low rolling resistance tires 1-3% Aerodynamic devices 2-5% (on highway), Lightweight vehicles less fuel & extra payload reduces VKT (Environment Canada, 2001).
VEHICLE MOVEMENTS	
Better logistics practices	At the individual firm level with better scheduling and routing. Green Logistics & City Logistics specifically seeks to intervene in planning city supply chains to limit environmental damage (Taniguchi et al., 2001). Options include advanced travel information systems, transhipment centres & load factor controls.
Mode change	Underground freight systems (Netherlands) Sprinter trains (Germany) (Van Binsbergen, 1999), or mooted Melbourne freight tram unlikely to be significant. Impacts from movement of inter-urban freight from road to rail will be dependent on the distribution of original and replacement trips.
Right size fleet	The freight industry already responding to a demand by moving to larger vehicles (Hassall, 2001). In contrast vehicle size restrictions leading to growth in LCVs could increase GHG (Kockelman, 2000).
Loading	Better use of vertical space rather than just floor space in vans can reduce VKT by around 20% (OECD, 2001). Most urban freight vehicle kms are at less than full load due to return empty or partially loading later in multi-drop trips.
Traffic management & Intelligent Transport Systems (ITS)	Growing traffic congestion in urban areas is increasingly affecting freight efficiency (Bell and Cassir, 2000; Van Schindel and Dinwoodie, 2000; Golob and Regan, 2000). Increased connectivity between ITS for traffic management and operators route planning systems have significant potential (Taylor et al, 2001).
Driver performance	Vehicle tracking and improved vehicle logging identify "heavy footed" drivers. Smoother driving = fuel savings of 5 –10% (OECD, 2001).
INFRASTRUCTURE AND LAND USE TRANSPORT PLANNING	
Removing bottlenecks linking terminals	Can produce savings in both congestion and GHG and have the advantage of affecting 100% of the fleet in the area immediately.
Longer term land-use changes to limit need for travel	Co-location of industry in freight parks and mixed-use residential areas, multi-centred cities to limit cross regional trips will all produce GHG savings.
Zoning related measures and tax and regulatory measures	Can encourage land-use change but the modelling structure required to encompass testing such measures is outside the scope of this study.

The outcomes of the literature and document search has been stored in a searchable database format with full reference information, details of content, and key words to assist in searches. It is provided on a CD with a manual describing its use.

2.3 Selection of Scenarios

Candidate abatement measures were identified based on the literature review. Table 2.4 summarises these by category.

Table 2.4 Summary of Candidate Emission Reduction Measures

Category	Measures
VEHICLE TECHNOLOGY MEASURES	More fuel efficient engines and related technologies, Regenerative braking, Refrigeration improvements, Aerodynamic Design Features; Low rolling resistance tyres, CNG/LPG, Electric vans, Higher emission standards/ low emission vehicles, Emissions testing, cash for bangers, feebates for vehicle efficiency, Better vehicle maintenance.
VEHICLE MOVEMENT MEASURES	Driver education programs, Driver Incentive scheme, Better match of vehicle to task, Higher load factors, Reduced empty running/ more backloading, JIT, City Logistics, Smarter routing and scheduling, Real-time traffic information, Mode shift for inter-urban freight, Mode shifts for urban freight trips, Relax time restrictions on pickups & deliveries, Increasing the mass density of freight consignments.
INFRASTRUCTURE & PLANNING MEASURES	General Reduced Congestion, Improved Traffic Management, Specific Large-scale road projects, freight lanes, emission based charging. Cluster industry and transport, Freight villages, Satellite freight terminals for ports, Mixed-use residential areas.

A qualitative estimate of expected impacts of these emission abatement measures was tabulated. It first noted what the measure would reduce: number of vehicles, number of trips, VKTs for the given freight task, fuel consumption and/or non-GHG emissions per litre of fuel. It then rated likely magnitude of the potential effect in terms of market impact. For each measure, the possible performance was rated against the following criteria: relative size of the GHG effect, market size affected, then overall GHG emissions/non-GHG emissions.

These estimates together with proposed modelling strategies informed a knowledge transfer workshop with project stakeholders. Considerations included the particular strength of the TPDC data and modelling structure in its ability to analyse impacts at the road network link level. This can allow for variation in roads, in passenger traffic and in demand for both passenger and goods movements in different parts of a large and complex city.

It was noted that there are a wide range of possible policy measures that could, in principle, be applied, but many of these are, from the greenhouse abatement perspective, just different ways of achieving the same outcome. For example, improved fuel efficiency and reduced emissions from each litre of fuel consumed could be achieved by a range of vehicle, engine and fuel technologies. Similarly, a reduction in traffic congestion that would benefit the efficiency of urban freight operations and reduce emissions, might be produced by policy instruments ranging from on-road parking restrictions to road pricing. As a result, a focus on identifying scenarios representing operational outcomes of policy instruments (or combinations of policies) and modelling the effects on emissions was recommended[1].

A final set of model scenarios, as shown in Table 2.5, representing policy outcomes from a broad range of policies was agreed upon. Modelling methodologies used and model results are presented in the following sections.

1 This study does not consider the overall cost-effectiveness for the community of any of the underlying policy instruments. See BTRE (2002) for discussion along these lines.

Table 2.5 Scenarios Tested and Example Policies Represented

Policy Outcome	Scenario Modelled	Example Policy Measures Represented
Improved fuel consumption	Base case traffic with all commercial vehicles operating with fuel and emission efficient engines.	Stricter emissions standards, new vehicle technologies, new fuels, policies to encourage scrappage of older trucks, special emission requirements for vehicles operating in urban areas.
Less congestion	15% reduction in car use in AM and PM peaks.	Reduced passenger vehicle traffic due to any combination of policies such as improved public transport options, encouragement of PT use, parking restriction on roads or at key destinations, road user charges.
Better traffic management	5% extra capacity on arterial roads and speed increased 3kph at saturation.	Intelligent Transport Systems to improve road capacity by regulating flow, fast response to incidents, removal of traffic bottlenecks.
Logistics changes/Higher load factors	Same quantity of goods moved between same places but with higher load factors and some transfer of goods to larger vehicles.	Higher load factors and load consolidation can be produced by a series of logistics measures: better vehicle scheduling by carriers, measures restricting access by time of day to discourage multiple small loads, use of larger vehicles in line with industry trends. The results of this scenario might also give an indication of the impacts of an absence of policy measures in view of current trends to "just in time" small loads.
Real-time traffic information	Major approaches to CBD and Parramatta and major orbital routes modified as per "better traffic management".	Improved network performance by providing drivers with information via a range of methods from on-road variable message signs, and broadcast information to specific subscriber information services beamed into the vehicle.
Infrastructure improvement	Sydney Orbital route at freeway standard added to 1996 road network for Sydney.	Since major changes in infrastructure are location and scope specific this scenario cannot be implemented in multiple ways, however, it does provide a general indication of the impacts of major road infrastructure improvements.
Infrastructure improvement with land-use change and distributional feedbacks	Sydney orbital route added; plus westward shift of employment assumed, thus modified freight trip patterns.	Like Scenario 6, this is a specific case but it does represent the feedback effects between transport and land-use changes. It also gives some indication of the likely impacts of industry location/land-use change.

3. Transport Modelling

3.1 Model Context & Framework

Sydney was chosen for the case study because the NSW Transport and Population Data Centre (TPDC) has been developing a commercial vehicle model that converts forecasts of dollar flows in the economy into forecasts of commercial vehicle trips:

- Between individual travel zones within the Greater Metropolitan Area (884 zones in Sydney and the Central Coast, and more covering the Lower Hunter and Wollongong)
- By time of day (four time periods), and
- By commercial vehicle type (light, rigid and articulated).

This is not yet operational. At the time of this study, a historical database of 1996 commodity flows had produced a detailed estimate of freight vehicle movement in Sydney in 1996. The Commercial Travel Study (CTS) figures were the best estimates available. *Consequently, this meant that the study needed to test all policies as if they were effective in 1996.* The value of the results therefore lies, not in their absolute values, but as strategic level indications of the potential magnitude of impacts relative to the base “business as usual” scenario and to each other.

It would be very unrealistic to assess the on-road performance of vans and trucks without considering other traffic on the road. Fortunately the TPDC also holds a Strategic Travel Model (STM), which forecasts personal travel on the same spatial basis as the CTS, from which estimates of passenger vehicle trips in 1996 could be drawn.

A procedure using advanced assignment techniques was developed to combine outputs of the two processes – trip matrices of light, rigid and articulated commercial vehicles from the CTS, and trip matrices of passenger vehicles from the STM, and put them both onto the same road network but in such a way that the effects on each type of vehicle can be distinguished. Model assumptions were applied to the basic 1996 travel patterns of cars and commercial vehicles and produced detailed link-by-link estimates of traffic volumes, speeds and composition.

Figure 3.1 compares the contents of the CTS and STM modules that are implemented in different transport modelling packages. Figure 3.2 describes the integration process where assignment was carried out on the EMME/2 model platform. As Figure 3.2 shows, the policy interventions applied in the scenarios enter the modelling framework either by changes to the CTS tables, changes to the passenger car matrices or changes to the road network. The implementation of the scenarios is briefly described in the next section.

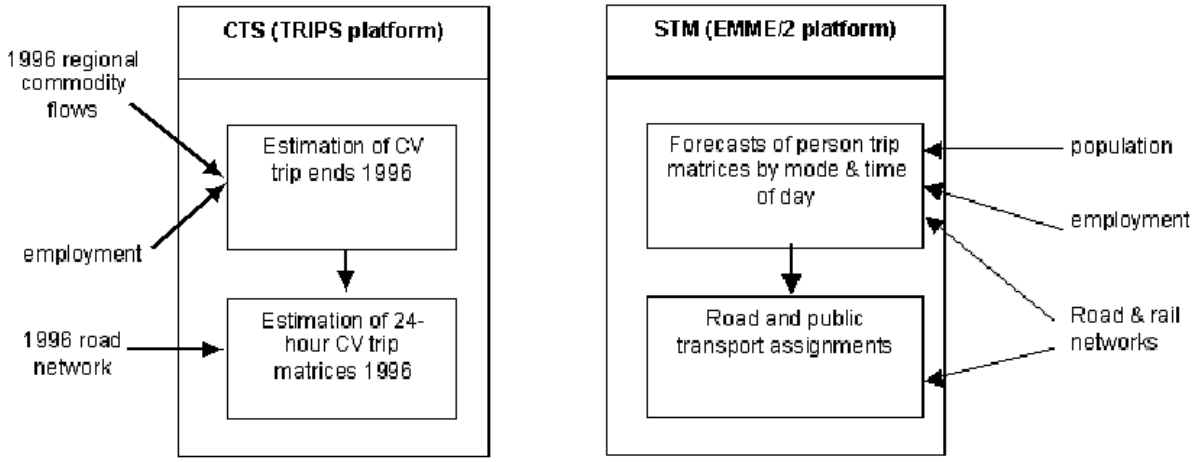


Figure 3.1 Comparison of CTS and STM processes

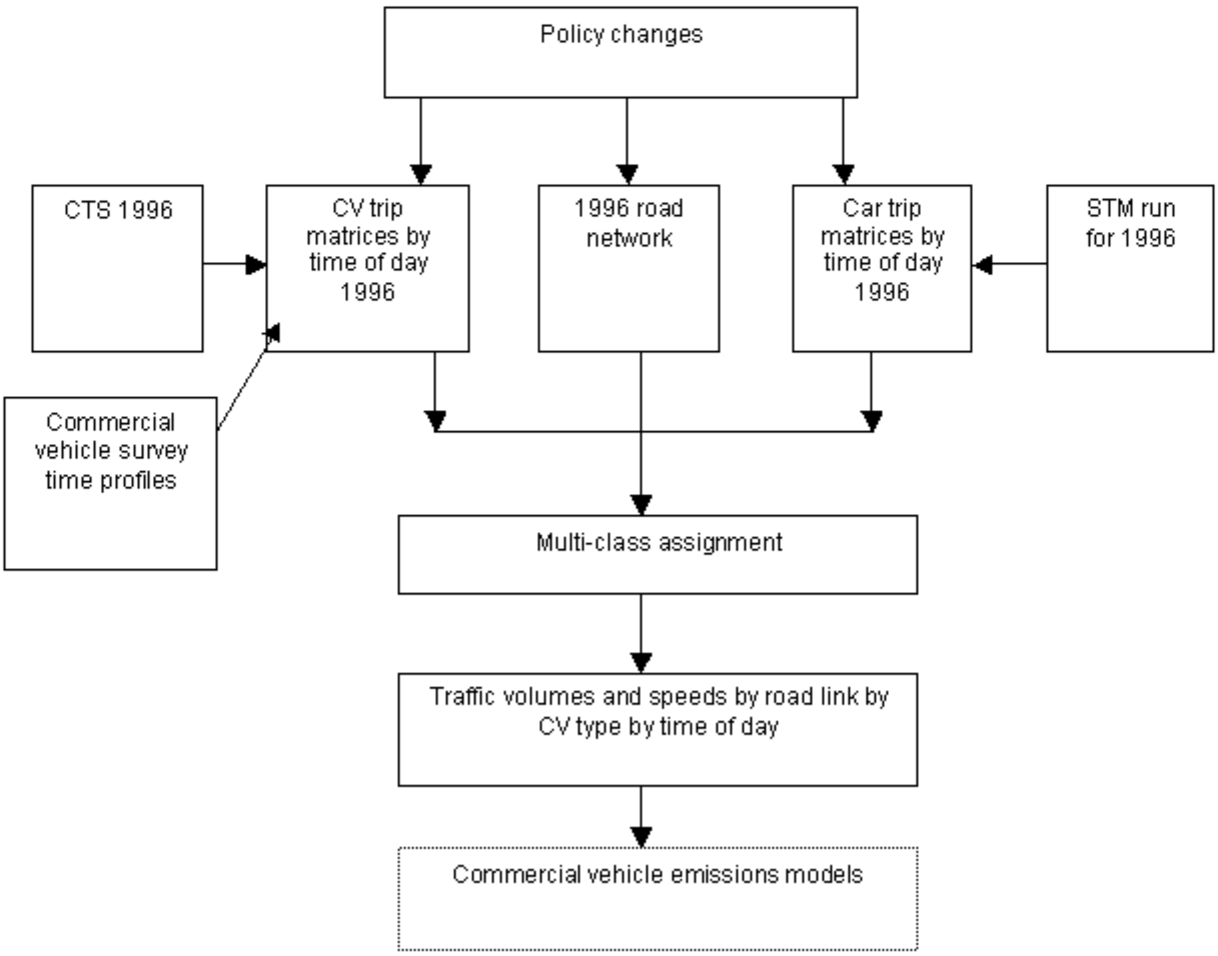


Figure 3.2 Use of CTS and STM processes in Policy Outcome Scenarios

3.2 Modelled Scenarios

Base Case

The 1996 Base Case gives the benchmark against which scenarios will be compared. As noted previously, the purpose of modelling is to obtain strategic level estimates of impacts and compare possible options rather than produce absolute values for forecasting purposes. Note the CTS provides total daily figures. Estimates by time of day to match STM time periods (AM peak = 7 to 9am, Business hours, PM peak = 4 to 6pm and Evening were obtained using factors derived from TPDC Commercial Vehicle Survey data.

Table 3.1 shows the number of vehicles by vehicle type and time period, for the 1996 base case.

Table 3.1 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%*

*Discrepancy in totals due to rounding

Less 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.

Improved Fuel Efficiency

For the purposes of modelling, we assumed that improved fuel efficiencies in the commercial vehicle fleet would only affect the emission outcomes, not the amount of travel. Thus the impacts are estimated in the emissions modelling stage. 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.

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 that factor 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.

Improved Logistics

In this scenario, load factors are increased. 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.

As discussed further in section 3.1, the scope for this sort of change varies from industry to industry. The 1996 commercial vehicle trip matrices were factored to take account of feasible changes in such practices, given the location of industries and the types of vehicle 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.

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 CBDs and the main ring routes.

Infrastructure Improvement

This 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 3.3 shows a sketch map of the orbital route.

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 3.2 summarises the average percentage changes to the base model under the various policy scenarios.

Table 3.2 Summary of effects of scenarios relative to 1996 base

	Scenario	Less congestion	Better traffic management	Higher load factors	Real-time traffic information	Infrastructure improvement	Infrastructure improvement with feedbacks
Trips (000)							
	Cars	-6%	0%	0%	0%	0%	0%
	LCVs	0%	0%	-22%	0%	0%	0%
	Rigids	0%	0%	-22%	0%	0%	1%
	Artics	0%	0%	-8%	0%	0%	+20%
	All vehicles	-5%	0%	-2%	0%	0%	0%
VKT (000)							
Daily vehicle kilometres of travel	Cars	-7%	0%	0%	0%	+1%	+1%
	LCVs	0%	0%	-20%	0%	0%	0%
	Rigids	-1%	0%	-27%	0%	+1%	+5%
	Artics	0%	0%	-18%	0%	0%	+27%
	All vehicles	-6%	0%	-2%	0%	+1%	+1%
VHT[2] (000)							
	Cars	-11%	-3%	-1%	-4%	-3%	-2%
	LCVs	-4%	-3%	-11%	-5%	0%	0%
	Rigids	-3%	-3%	-27%	-3%	0%	+4%
	Artics	0%	0%	-18%	0%	0%	+35%
	All vehicles	-10%	-3%	-10%	-4%	-3%	-2%
Average Speed (kph)							
	Cars	+5%	+3%	+1%	+4%	+4%	+3%
	LCVs	+3%	+3%	+1%	+5%	+1%	+2%
	Rigids	+2%	+3%	0%	+3%	+1%	+1%
	Artics	-1%	0%	0%	0%	0%	-6%
	All vehicles	+5%	+3%	+1%	+4%	+4%	+3%

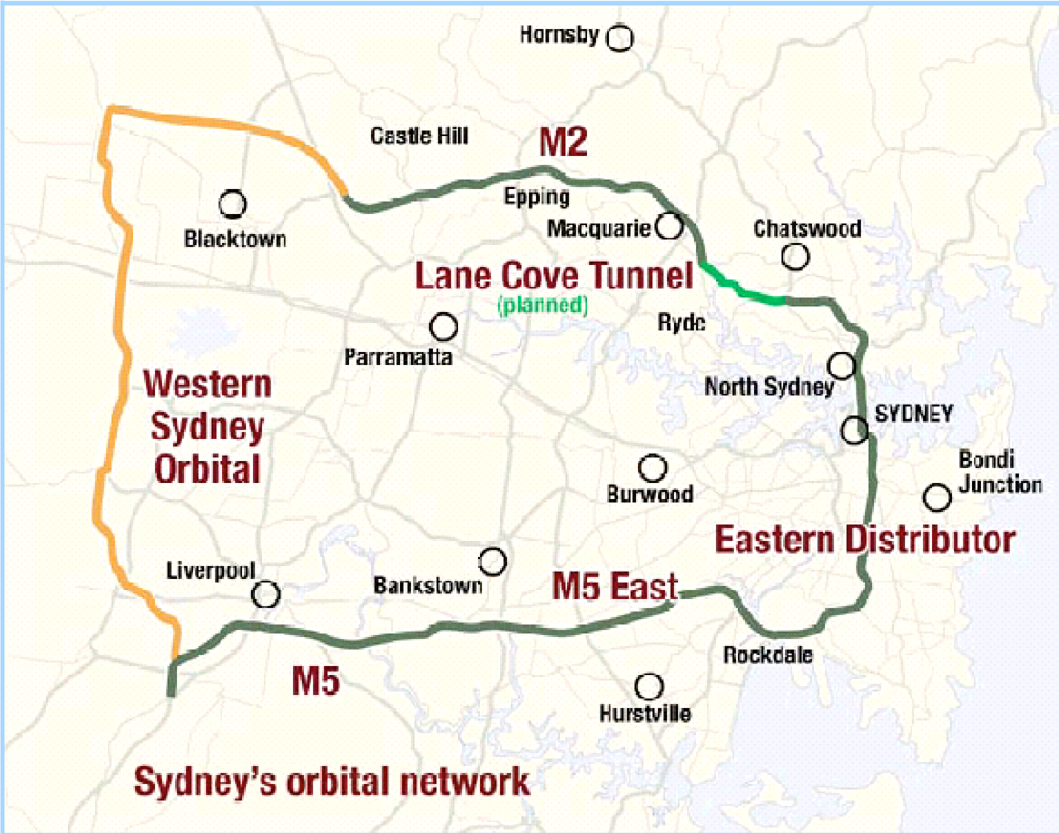


Figure 3.3 Sketch Map of the Sydney Orbital

It should be recognised that these results show only the effects on travel distance and time. Moreover, the averages hide the wide variation of impacts by time of day and across the city. Technical Paper 2 (Smith & Kilsby, 2003) shows detailed modelling results with time of day variation. The project scenario viewing software, see Technical Paper 4 (Marquez, 2003), allows "zooming in" on locations of interest. Thus, we stress the results summarised in Table 3.3 are only impact averages for reporting purposes. Results for specific times and localities will vary. Additionally, the emission modelling results in the next section are needed to give a more complete the picture of the impacts.

Table 3.3 Transport Effects of Scenarios

Less 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 but the overall effect is small, because the better-performing roads tend to attract more traffic, which slows them down again.

Improved Logistics

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. 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 freight terminals are needed when industry is moved.

4. Emissions Modelling

4.1 Approach and Functional Form

The transport model provided the volumes of vehicles (on a link by link basis) for each scenario to be tested. These outputs essentially define the transport task by vehicle type. The raw model output consisted of the eleven attributes, as shown in Table 4.1, being associated with every link in the network (over 15,000 one way links). The challenge of the emissions modelling approach was to add the total amount of emissions produced for each emission listed in Table 1.1 for all of these links.

Table 4.1 Link attributes

Link Number
Geographical Coordinate Information
Link Length
Link Type
Link Travel Time
Link Travel Speed
Volume/Capacity (V/C) ratio
Volume of Passenger Vehicles
Volume of Light Commercial Vehicles
Volume of Rigid Trucks
Volume of Articulated Trucks

In order to assess the environmental benefits and/or dis-benefits of various freight vehicle scenarios being considered, emission models were required that were sensitive to factors such as:

- Vehicle Kilometres Travel (VKT), by vehicle type and by fuel type
- Variations in the loads carried by freight vehicles
- Average travel speeds for vehicles on each link in the network under different traffic conditions and congestion levels
- Effects of changes in engine and fuel technology for freight vehicles.

While some Australian data did exist for the required emission factors, a complete picture could not be formed solely on the basis of the available Australian data. Other data sources were required to expand and enrich the database of emissions factors. Given the requirements of the emissions modelling approach adopted for the study and the results of the literature review conducted in its initial stages, the European Emissions Inventory

Guidebook (European Environment Agency, 2002), was used to complement the available Australian data.

The following generic formula was used to calculate the total amount of emissions produced by all vehicles travelling on each link in the network. The formula is such that it enables the emissions results to be sensitive to parameters such as increasing load factors, *changing proportions of vehicle and fuel types in the vehicle fleet, and different congestion levels*. This is an important feature as many of the policy options being tested vary these and other parameters in different ways on a link-by-link basis.

The total amount of emissions for any link *a* is given by:

$$\text{Link Emission}(a) = \sum_{\text{Fuel Type } j}^{\text{Vehicle Type } i} \text{Volume} * \text{Fleet Proportion}_{ij} * \text{Emissions Factor}(a)_{ij} * \text{SCF}_{ij} * \text{LCF}_{ij} * \text{Length}$$

where:

Link Emission (a)	= Total amount of emission type a_{ij} produced on link (a)
Volume	= Total number of vehicles on link
Vehicle Type i	= All vehicle types being considered
Fuel Type j	= All fuel types being considered
Fleet Proportion ij	= Proportion of vehicle type i and fuel type j on the link
Emissions factor ij	= Base emissions factor for type a emission for vehicle type i and fuel type j
SCFij	= Speed correction factor for vehicle type i and fuel type j
LCFij	= Load Correction Factor for vehicle type i and fuel type j
Length	= Length of the link (km).

4.2 Emission Factors

In all, 132 emission streams were created for use in this project, with a total of 12 emissions (including fuel consumption) for the four vehicle types each with three fuel types. Emission estimates were not obtained for LPG fuelled articulated vehicles since the available vehicle fleet data (ABS, 1999) indicated that there were only three of these vehicles registered in the Sydney metropolitan area. The differential contribution of these three vehicles to overall emissions would be quite insignificant, and they were treated as being diesel powered vehicles in line with the 99 per cent of such vehicles in the AT vehicle class.

Table 4.2 shows the emissions, vehicle types and fuel types that were modelled and includes a description of the Australian information sources used to derive the Australian calibration point, i.e. NGGI refers to AGO (1998), NPI refers to Environment Australia (2001) and TF 2000 refers to Apelbaum Consulting Group (2001). A particular advantage of the method adopted in this study is that it can be refined over time. As better Australian emissions data become available these calibration points can be updated and extended to reflect the changing performance of the Australian vehicle fleet.

Table 4.2 Summary of the emissions models, indicating sources of data

Emission by Fuel Type/Vehicle Type	Passenger Vehicles	Light Commercial Vehicles	Rigid trucks	Articulated Trucks
Petrol				
FC	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value
CO2	Euro FC\NGGI	Euro FC\NGGI	Euro FC\NGGI	Euro FC\NGGI
CO2e	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
CO	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
VOC	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
CH4	Scaled from VOC	Scaled from VOC	Scaled from VOC	Scaled from VOC
NOx	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
N2O	Euro\Euro FC	Euro\Euro FC	Euro\Euro FC	Euro\Euro FC
PM	Euro FC\NPI	Euro FC\NPI	NPI	NPI
Benzene	Euro FC\NPI	Euro FC\NPI	NPI	NPI
Butadiene	Euro FC\NPI	Euro FC\NPI	NPI	NPI
SO2	Euro FC\NPI	Euro FC\NPI	NPI	NPI
Diesel				
FC	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value
CO2	Euro FC\NGGI	Euro FC\NGGI	Euro FC\NGGI	Euro FC\NGGI
CO2e	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
CO	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
VOC	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
CH4	Scaled from VOC	Scaled from VOC	Scaled from VOC	Scaled from VOC
NOx	Euro\NGGI	Euro\NGGI	Euro\NGGI	Euro\NGGI
N2O	Euro\Euro FC	Euro\Euro FC	Euro\Euro FC	Euro\Euro FC
PM	Euro\NPI	Euro\NPI	Euro\NPI	Euro\NPI
Benzene	Euro FC\NPI	Euro FC\NPI	Euro FC\NPI	Euro FC\NPI
Butadiene	Euro FC\NPI	Euro FC\NPI	Euro FC\NPI	Euro FC\NPI
SO2	Euro FC\NPI	Euro FC\NPI	Euro FC\NPI	Euro FC\NPI
LPG				
FC	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value	Euro\TF 2000 96 Value	Neg
CO2	Euro FC\NGGI	Euro FC\NGGI	Euro FC\NGGI	Neg
CO2e	Euro\NGGI	Euro\NGGI	Euro\NGGI	Neg
CO	Euro\NGGI	Euro\NGGI	Euro\NGGI	Neg
VOC	Euro\NGGI	Euro\NGGI	Euro\NGGI	Neg
CH4	Scaled from VOC	Scaled from VOC	Scaled from VOC	Neg
NOx	Euro\NGGI	Euro\NGGI	Euro\NGGI	Neg
N2O	NGGI	NGGI	NGGI	Neg
PM	NPI	NPI	NPI	Neg
Benzene	NPI	NPI	NPI	Neg
Butadiene	NPI	NPI	NPI	Neg
SO2	NPI	NPI	NPI	Neg

CO_2 Estimates: Fuel consumption figures were obtained from Apelbaum Consulting Group (2001) and interpolated for the base year 1996. In order to convert total fuel consumed into CO_2, the NGGI workbook for mobile sources (AGO, 1998) provides CO_2 emissions factors and energy density for various fuel types.

Speed Correction: Analysis of the average speed distributions for the different scenarios lead to the conclusion that a continuous measure of emissions performance/ emissions rate versus average speed on the link was required. The European Emissions Inventory Guidebook presents continuous emission rate versus average link speed functions derived from general test cycles. These were scaled to accommodate the differences between the Australian and European fleets

Load Correction The European Emission Inventory Guidebook also provides a formula for the calculation of correction factors to fuel consumption for different loading levels. In the absence of better loading data, we assumed in line with European data, an average 50% loading on freight vehicles for all except scenario 4, where adjustments were made to the emissions factors for the vehicles that were assigned extra loads in line with logistics improvements.

Fleet Fuel efficiency Scenario: As noted earlier, while all other scenarios involved vehicle movement or traffic changes and so required transport modelling, this scenario is modelled during the emission estimation process. The fuel consumption and emissions characteristics of the freight vehicles in the base scenario were changed on the basis of the following assumptions

- LCVs have the same emissions performance as passenger vehicles
- For RT and AT, scale factors were derived from the Diesel NEPM preparatory project 2.

4.3 Emissions Results

Figure 4.1 graphs the emission totals from all traffic over a 24-hour study period for each pollutant. Further results that distinguish the impacts on freight emission by freight vehicle type for each scenario are presented with our discussion of policy implications in Section 6.

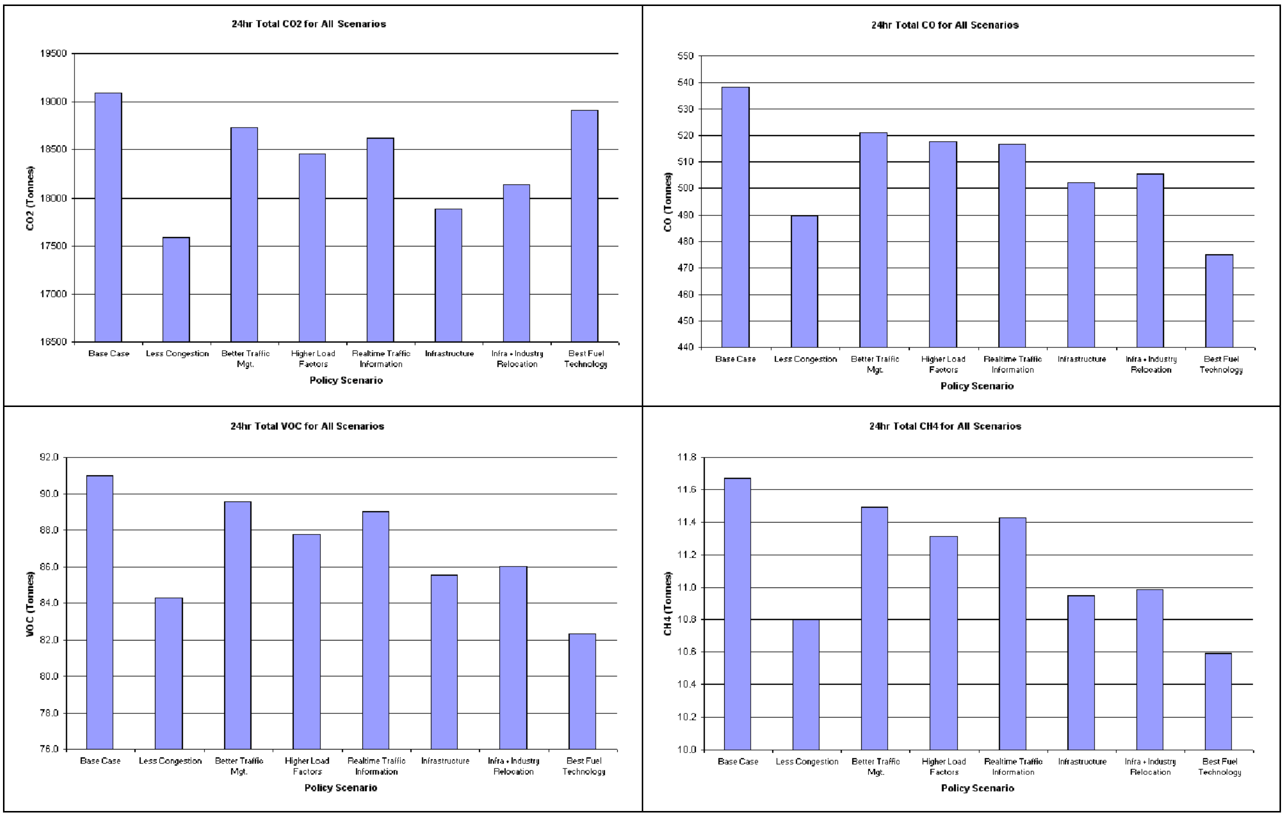


Figure 4.1 24-Hour emission totals of each pollutant under all scenarios

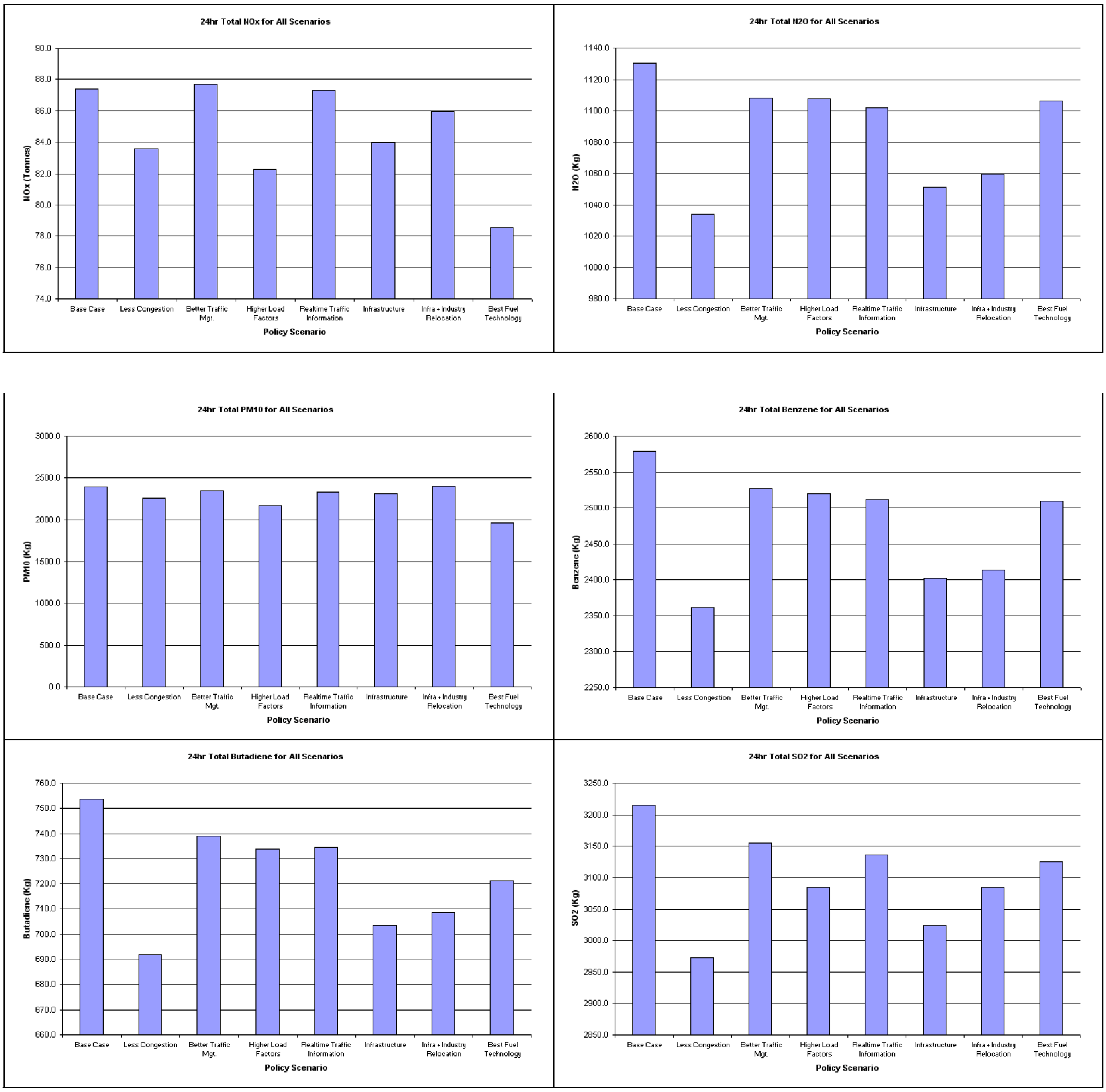


Figure 4.1 (Continued)

We note again that a major strength of this study is the production of detailed results. As might be expected, impacts of measures vary across the day from morning peak, daytime, evening peak and night. Detailed emission results by time period can be found in Technical Paper 3 (Zito & Taylor, 2003). However it is impossible to provide the local level detail of scenario impacts in a printed report thus a software results viewing tool was developed.

The Scenario Viewer: The emissions database package includes a free viewer that allows different ways of looking at the raw data through maps, tables, queries and searches. Thematic maps can be produced so that the results can be seen in their spatial context as shown in Figure 4.2. The map shows the darker links having the higher total CO_2 emissions while the lighter ones give lower total CO_2 amounts. Moreover the viewer provides the facility for the user to "zoom in" to see impacts on emissions right down to individual road link level. Technical Paper 4 (Marquez, 2003) provides further details of the Scenario Viewer's features and procedures.

The importance of the spatial location of emissions is shown in the next section, where the dispersion of the air pollutant emission is modelled and the effects of policies on population exposure to pollution is estimated.

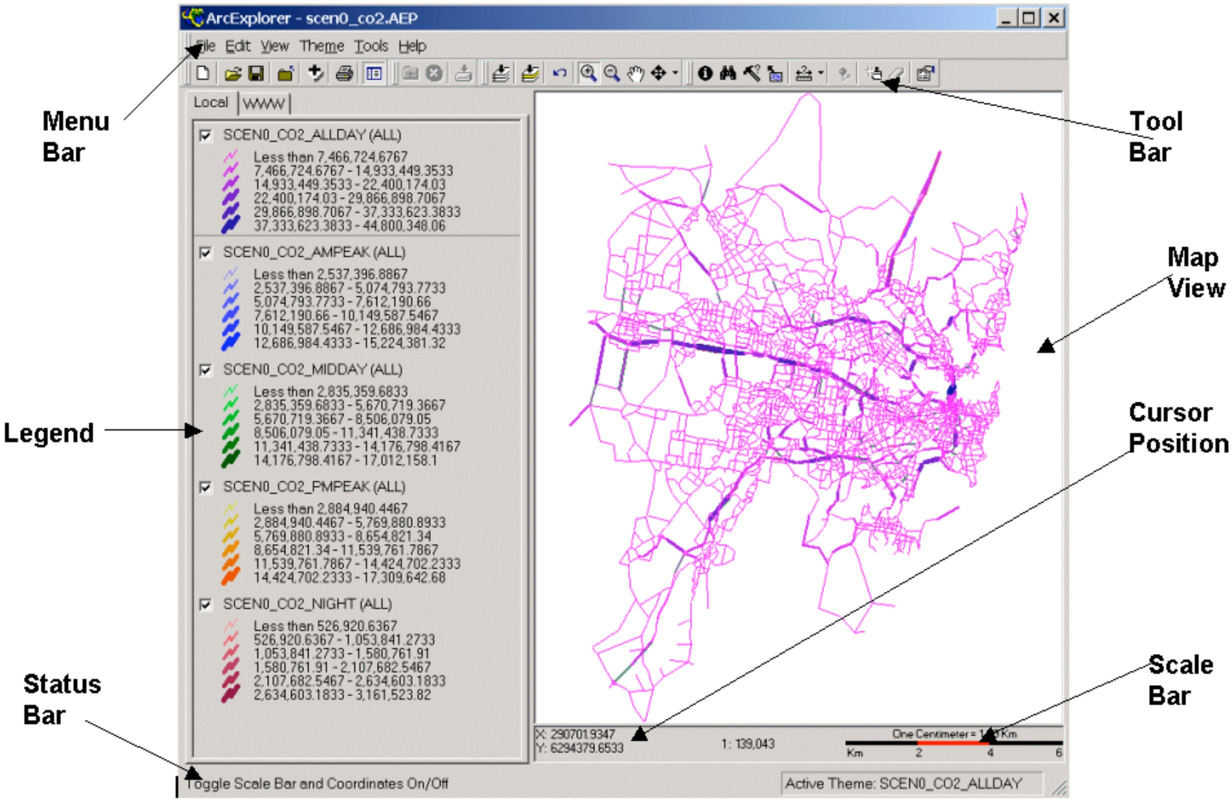


Figure 4.2 Viewer window with sample thematic map

5. Air Pollution Impacts

5.1 Exposure to Pollution

Air pollution can have many adverse impacts in urban areas ranging from physical damage to buildings and vegetation to loss of amenity with haze obscuring views but by far the most important impacts in the eyes of urban communities are effects on human health. Thus this study focuses on population exposure to air pollution. Exposure depends upon first emissions, then concentrations of pollution as emissions are dispersed and are subject to the chemical changes in the atmosphere and finally location of the population in relation to pollution concentrations. The investigation was undertaken for two reasons:

- Extension of the estimation to air pollutant emissions as well as GHG emission would allow the added benefits from reduced air pollution to be considered together with improved GHG outcomes but exposure rather than just emission is the appropriate metric where health is an issue;
- Earlier studies (AATSE, 1997) had showed that better greenhouse gas outcomes do not necessarily mean better exposure outcomes. For example, high urban population densities may result in less travel and hence lower emissions from motor vehicles. This will mean less GHG but if population is concentrated under a polluted airshed, exposure to pollution could be higher.

As this study links the location of measures to location of impacts it is particularly well suited to demonstrating the value of locating measures to improves air quality outcomes and of seeking measures which are advantageous for both reducing GHG and reducing population exposure to pollution.

We note that this extension to the study was carried out to *demonstrate* the value of considering population exposure issues and the option for basing such a study on the emission estimates of the type provided by this study. Dispersion of pollutants varies daily throughout the year with changing weather. At the same time, population exposure to pollution varies by time of day and season of the year as activity patterns change Thus, in order to obtain an accurate picture of the relative impacts of the policy scenarios on population exposure, pollution day-by-day and season-by-season, together with population activity for matching time periods would needed to be modeled. Such an extensive modelling exercise was outside the scope of this study where the main emphasis must be placed on GHG impacts. Thus, we present illustrative results based on estimated pollution outcomes on a DEMONSTRATION day combined with estimated population location on an AVERAGE weekday.

The TPDC Household Travel Survey (HTS) collects information about origins, destinations and times of all travel by all members of surveyed households, by all modes for all purposes. Thus, the data can be used to estimate the location of the survey respondents and the midpoint of every hour of the day. The TPDC data provides an expansion factor for each respondent representing the number of “similar” people in the entire population performing the same actions. These were used to calculate hourly locations for the entire Sydney population. Location was analysed at Statistical Local Area (SLA) level and the results were grouped into the 14 Statistical Sub-division (SSD) in Sydney.

In Figure 5.1, a graph of variations in hourly population densities, where population is divided by land area for comparability, suggests that the 14 SSDs can be classified into three groups in terms of hourly population variation.

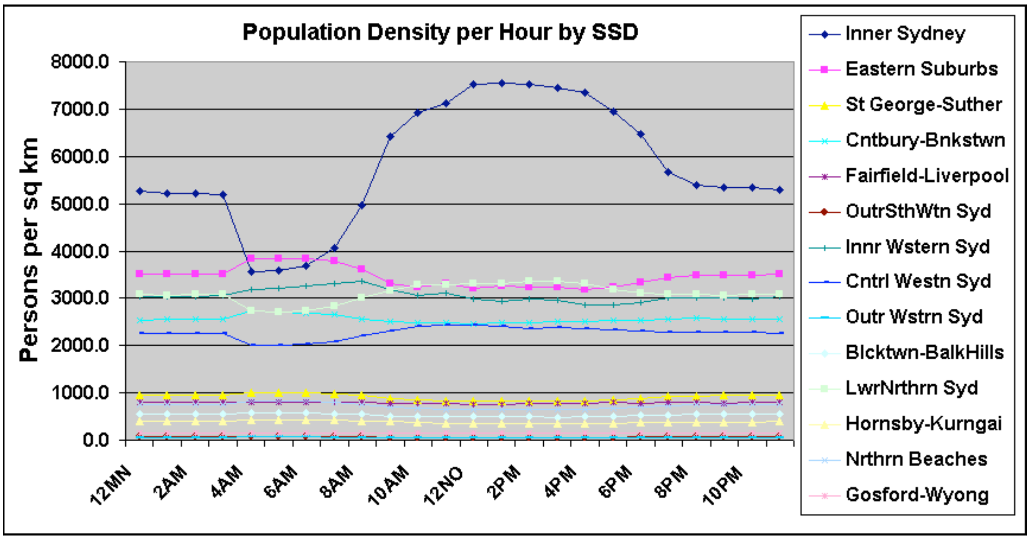


Figure 5.1 Sydney SSD Population Densities over a 24-hr Period

The first group consists of the 8 SSDs at the bottom end of the chart (St George-Sutherland, Fairfield-Liverpool, Northern Beaches, Blacktown-Baulkham Hills, Hornsby-Ku-ring-gai, Gosford-Wyong, Outer South Western Sydney and Outer Western Sydney). These SSDs are designated LD/LV (low density/low variation) since they exhibit low average densities (around 1000 pers/sq.km or less) and produce minimal population variation during the day.

The second group is designated MD/MV (for medium density/medium variation) with densities of 2000 to 4000 pers/sq.km per hour and exhibits moderate to high population movement typically between 4 am and 8 pm. This group is composed of Lower Northern Sydney, Inner Western Sydney, Canterbury-Bankstown, Central Western Sydney and the Eastern Suburbs.

The final group is HD/HV (for high density/high variation), represented solely by Inner Sydney, with high densities and even higher fluctuations. Inner Sydney contains the central business and commercial district and thus can contain up to 7500 pers/sq.km at the peak of a business day. Workers, shoppers, visitors and other participants in the day activities start arriving at 6 am and continue to come in until the population peaks at midday, The population starts to decrease at 3 pm as workers leave and continues to do so until 8 pm, when the population stabilises as participants in the night activities arrive. This continues until 3 am when the night activities close and the last night visitors leave returning the area to its residents. This brief lull ends at 6 am when the new business day begins and the cycle starts again.

5.2 Pollution Modelling

The CSIRO airshed model TAPM uses the forecast meteorological conditions and the forecast of emissions to track the movement of contaminants and calculate the rate of chemical reaction that leads to the formation of photochemical smog and secondary aerosols (Hurley et al, 2001).

TAPM is a Eulerian grid model which simulates the transport and transformation of air pollutants over an urban area. Figure 5.2 shows the grid system coverage of the 14 Sydney SSDs under consideration.

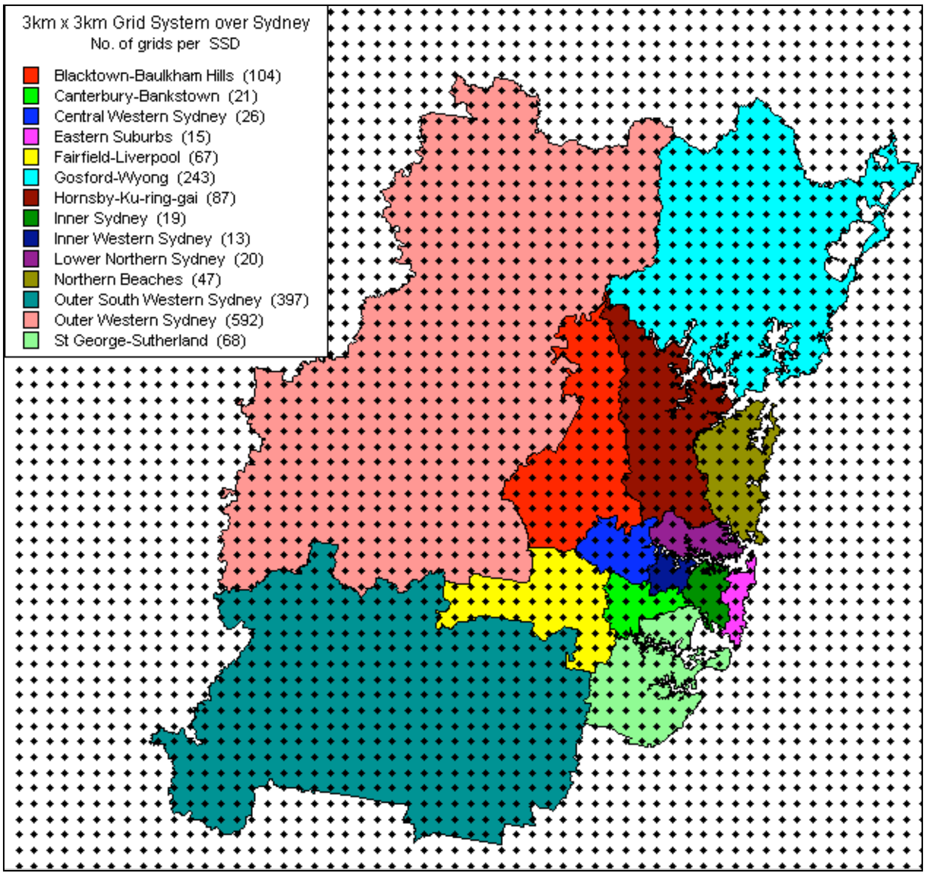


Figure 5.2 Grid system coverage for Sydney SSDs

To obtain a picture of pollution for a “demonstration day”, model runs were performed to produce hourly pollution concentrations and exposure levels for the base case and each of the seven policy scenarios. Typically, each model run performs a simulation of pollution dispersion for a period of three days for each policy scenario for a region consisting of 100 by 100 9-sq.km. grid cells. Three “event periods” were chosen where typically the last day contained Ozone (O_3) at a high level from historical observations: January 20-22 1997, February 6-8 1997 and October 25-27 1997.

Since, in general, the important health-related air quality impacts from pollution are human exposure to photochemical smog, NO_2, carbon monoxide and fine particles, we report the results of modeling the population’s exposure to ozone (O_3), nitrogen dioxide (NO_2), carbon monoxide (CO) and fine particles of size 10 microns (PM_{10}).

CO and PM_{10} were run in tracer (direct) mode where only motor vehicle emissions were modelled while O_3 and NO_2 were run in photochemistry mode where the effects of other anthropogenic and biogenic sources were also included. These other sources must be included because photochemical reactions in the atmosphere are dependent on total pollutant loads.

The results are reported for ONE demonstration day (October 26 1997) of the 9 days covered. It is worth noting again that the dispersion modeling results are not meant to provide absolute forecasts in terms of magnitudes of pollution concentration for any SSD at any given hour. Meteorological conditions will be quite different between seasons. As a result, the spatial distribution of the concentration field will be different and thus the population exposure will be markedly different. Nor can the results definitely measure the different impacts of scenarios since no one day can adequately represent all pollutants at their peak concentration levels. However, the results CAN show, via a set of indicative impacts, that exposure to air pollution will vary with policies and that impacts will vary by location. Figure 5.3, as an example, shows dispersion of NO_2 across Sydney at 8 am for the base case.

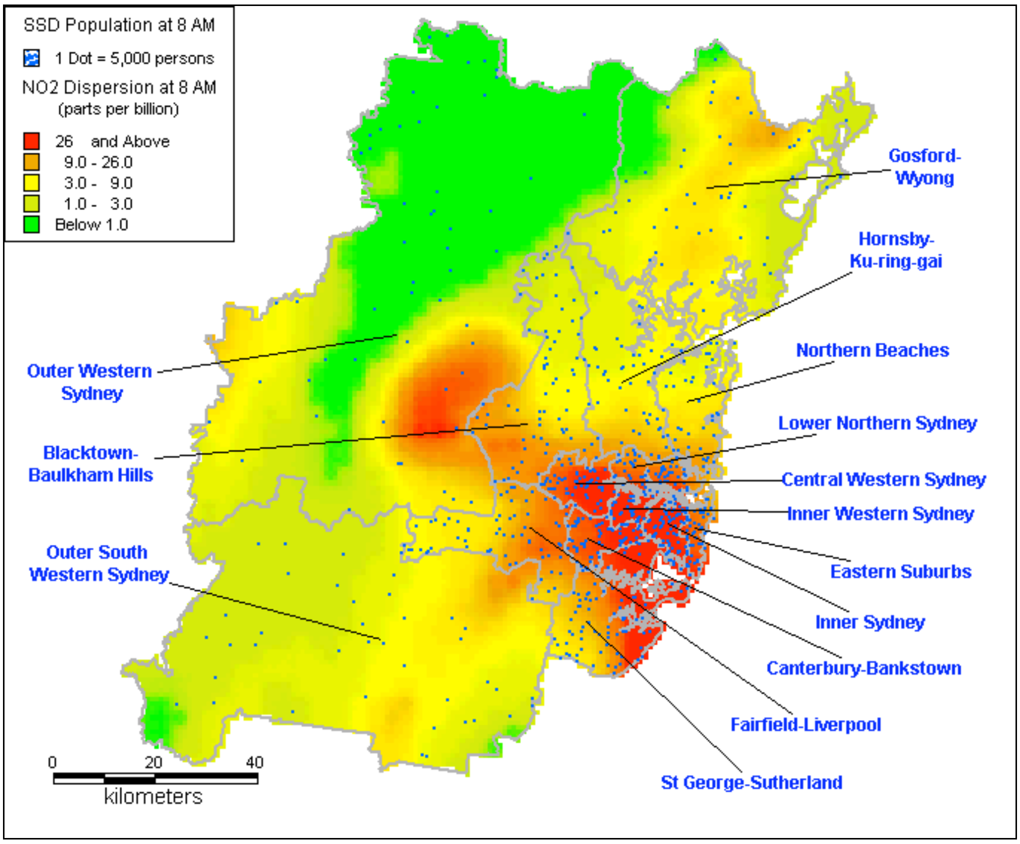


Figure 5.3 Estimated NO_2 Dispersion at 8 am over Sydney (Base Case)

5.3 Indicative Exposures with GHG Scenarios

The procedure for assessing the impact of the various policy outcome scenarios focuses on the relative changes in peak daily concentration of pollutants per SSD for a "demonstration day" produced by the scenarios with respect to the base case. The peak daily concentration of pollutant per SSD is a discriminating and efficient criteria for evaluating the relative impacts of the policy measures. In addition, the peak daily concentration is a widely accepted metric for evaluating the risk posed by pollution on health and the environment.

As with the previously reported results for transport and emission modelling, summary results hide the detail that the models provide. More details are available in Technical Paper 5 (Marquez & Smith, 2003).

The results of the seven scenarios for the demonstration day show overall reductions in peak CO, NO_2, and PM_{10} concentrations for all the SSDs. Figure 5.4 shows the comparative impacts of the scenarios for these three pollutants.

CO

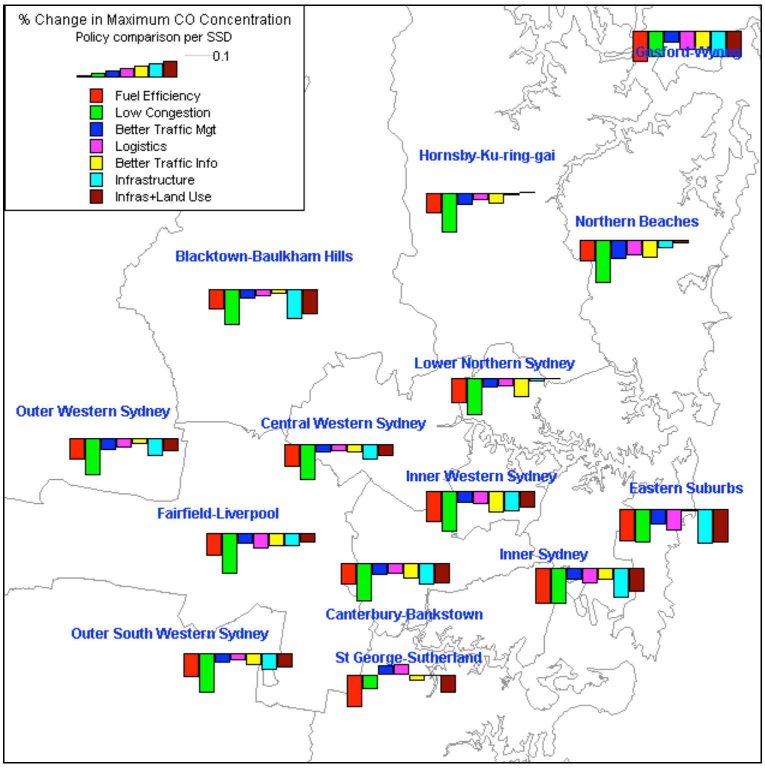
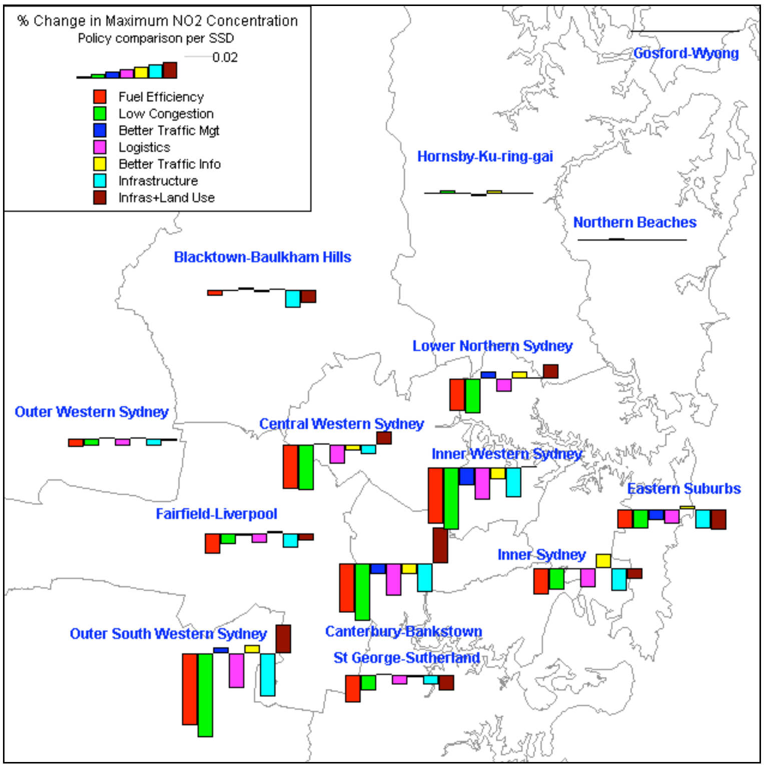


Figure 5.4 Relative impact of scenarios on peak pollutant concentration per SSD

NO_2



PM_{10}

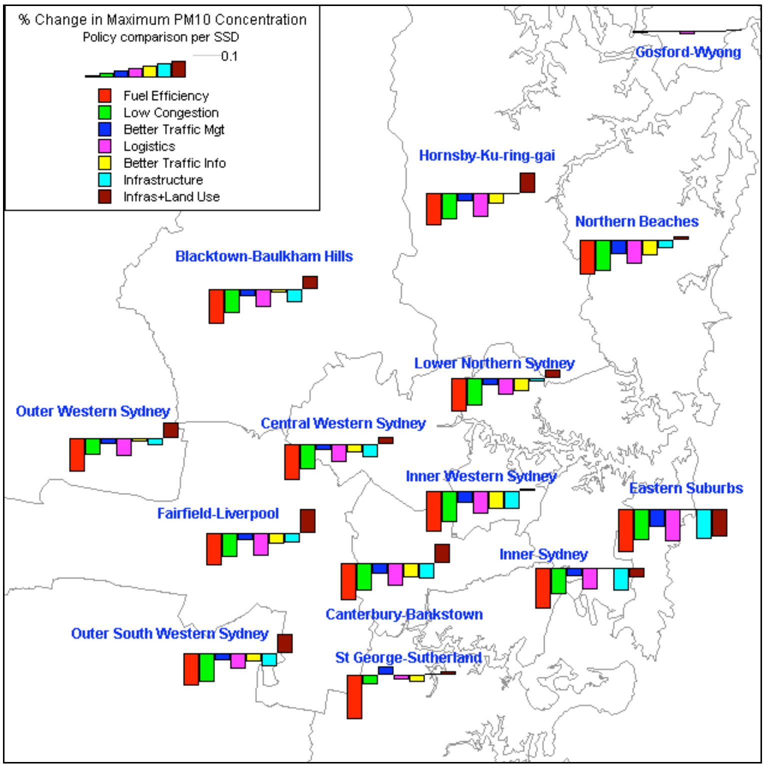


Figure 5.4 Continued

The highest reduction rates for CO were produced by the Less Congestion (15.71%) and Fuel Efficiency (11.45%) scenarios.

The results for PM_{10} were similar to those of CO. Six of the seven scenarios resulted in overall reductions to peak PM_{10} concentration for the SSDs. The highest reduction rates for

PM_{10} were produced by policies for Fuel Efficiency (14.96%), Less Congestion (10.37%) and Better Logistics (8.31%). Only Infrastructure with Land-Use produced an overall increase at the rate of 3.24%.

For NO_2, five of the seven scenarios resulted in overall reductions to peak concentration for the SSDs. The highest reduction rates for NO_2 were produced by policies for Fuel Efficiency (2.27%), Less Congestion (2.23%), Infrastructure Improvement (1.26%) and Better Logistics (1.23%). The rest of the scenarios had minimal and perhaps insignificant effects.

The performance rates achieved for ozone were quite small, mostly less than 0.50%. The highest reductions were achieved through Real-time Traffic Information with 1.67% for Inner Sydney. Comparison of this figure with the overall reduction rate of only 0.29% shows the importance of considering spatial variation in impacts.

The best performing scenarios for CO, NO_2, and PM_{10} actually resulted in slight pollution increases for ozone although these were minimal and maybe insignificant.

If these results were to be borne out by long-term population and exposure patterns, then, the ozone results notwithstanding, policies and strategies for Better Fuel Efficiency, Less Congestion, Better Logistics and Infrastructure Improvement appear to present the best opportunities for reducing peak daily concentrations as well as average hourly concentrations of O_3, NO_2 and PM_{10}.

6. Policy Implications

6.1 Reviewing Results

The study provides policy implications of two types:

- *Implications of Scenario Results*: The study results provide comparative greenhouse gas abatement impacts of policy outcomes and hence comparative impacts of a wide range of potential policy measures as each outcome represents multiple measures; and
- *Viability and Value of the Process*: The study showed that it was possible to model the impacts of greenhouse abatement scenarios for urban freight in Australian cities at a fine grained network level by making best use of available data sources; and also showed analysis at that level is worthwhile since location of the scenarios impacted both locations of outcomes and their total impacts.

This section first reviews the study scenario results, discusses the implications and concludes with a consideration of broader implications of the value of the methodology for policy testing. Table 6.1 recaps the scenarios tested.

Table 6.1 Urban Freight Scenarios Tested

Scenario	Description
S0	Base scenario – from 1996 traffic patterns for which TPDC freight trip data was available
S1	Improved fuel consumption – base case traffic with all commercial vehicles operating with fuel and emissions efficient engines
S2	Less congestion –15% reduction in car use in AM and PM peaks
S3	Better traffic management – 5% extra capacity on arterial roads and speed increased 3kph at saturation
S4	Logistics changes/Higher Loads – Same quantity of goods moved between same places but with higher load factors and some transfer of goods to larger vehicles
S5	Real-time traffic information – Major approaches to CBD and Parramatta and major orbital routes modified as per "better traffic management"
S6	Infrastructure improvement – Sydney Orbital route at freeway standard added to the 1996 road network for Sydney
S7	Infrastructure improvement with land-use and distributional feedbacks – Sydney orbital route plus westward shift of employment assumed and modified freight trip patterns

Scenarios 2, 3, 6 and 7 affected all traffic demands and movements, i.e. private vehicles as well as freight vehicles. Scenario 5 – real-time traffic information systems – was set to affect all traffic in our model but could be directed explicitly at the freight vehicle fleet only. Scenarios 1 and 4 affected freight vehicles only.

In all scenarios except 4 and 7, the freight vehicle travel demand was the same as that in the base case, in terms of vehicle trip O-D patterns in space and over time. In scenario 4 (higher load factors), the number of freight vehicle trips was reduced, although the total freight movements (in terms of tonnages) were the same as in the base case. In scenario 7 (industry relocation with infrastructure improvements) spatial patterns of freight vehicle trips and private vehicle trips were modified as some industries moved west from their present eastern area locations in the metropolitan area, although the total numbers of vehicle trips remained unchanged. In scenario 2 (reduced peak period congestion), the numbers of peak period private vehicle trips were reduced but off peak private vehicle trips and all freight vehicle trips were unaltered. In scenarios 3 (better traffic management) and 5 (real-time traffic information) all travel demand remained the same as in the base case.

Consideration of the model results for the different scenarios allows the exploration of the likely impacts of the alternative scenarios on greenhouse gas emissions, and on the emissions of air pollutants. **A starting point for this exploration is to consider the modelled contributions of freight vehicles in the base case 1996 Sydney network**, divided into the three vehicle classes of light commercial vehicles (LCV), rigid trucks (RT) and articulated trucks (AT), to travel demand and to overall greenhouse gas emissions. To visualise the overall impacts of freight transport in the study area network, it is also necessary to compare the freight transport task and the emissions from that task with the task and emissions from private vehicles (PV). Table 6.2 shows some summary statistics for the base case, in terms of the percentages of vehicle trips, vehicle-kilometres of travel (VKT), vehicle hours of travel (VHT), and total greenhouse gas emissions (GHG, in carbon dioxide equivalents, CO2e) for daily travel in the study area network.

This table indicates that, on a daily basis, freight vehicles make 7.9% of all vehicle trips and perform 9.4% of all VKT and 9.2% of all VHT. They generate 17.8% of all GHG emissions from road transport in performing their travel tasks. Using these results it is possible, as shown in Table 6.2, to develop a ‘passenger car equivalent’ (PCU) for each vehicle class, in terms of the contributions of each vehicle class to total GHG emissions.

Table 6.2 Percentage contributions to total travel and total greenhouse gas emissions by different vehicle classes on the Sydney 1996 base case network

Vehicle type	**Trips**	**Veh-km of travel**	**Veh-hours of travel**	**Total GHG emissions (CO2e)**	***PCU equivalent of GHG emissions***
Private vehicles	92.1%	90.6%	90.8%	82.9%	*1.00*
Light commercial vehicles	5.8%	5.8%	6.0%	6.6%	*1.24*
Rigid trucks	1.8%	2.8%	2.6%	7.3%	*2.85*
Articulated trucks	0.3%	0.8%	0.6%	3.2%	*4.37*
Totals	100.0%	100.0%	100.0%	100.0%	

Given that the PCU value for a private vehicle is 1.00, the PCU equivalent for LCVs is 1.24, whilst that for rigid trucks in 2.85 and for articulated trucks, 4.37. Thus, for instance, three LCVs may be considered as producing GHG emissions equivalent to about four passenger cars, on average, whilst one articulated truck produces GHG emissions equivalent to those of more than 4 passenger cars. These GHG-PCU values may be compared to the commonly assumed traffic-PCU values, predominantly based on vehicle lengths, of 1.0 for LCVs, 2.0 for RTs, and 3.0 for ATs, used in the assessment of traffic operating conditions and traffic capacity of roads.

The contributions of the four vehicle types to emissions of specific greenhouse gases, the 'direct' GHG emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), as well as the total CO_2e, in the base case network are shown in Table 6.3. This table indicates some differences in the relative contributions of freight vehicles to the emissions of specific gases, notably the significant emissions of methane by the LCV vehicle class (14.0 per cent of total CH_4 emissions compared to 6.6 per cent of CO_2e emissions and 5.8 per cent of VKT in the network. On the other hand, freight vehicles make smaller percentage contributions to total N_2O emissions, where the percentage contribution of private cars is 91.1 per cent (compared to the 82.9 per cent contribution of private cars to total CO_2e).

Table 6.3 Percentage contributions to total VKT, total GHG emissions & individual 'direct' greenhouse gas emissions by different vehicle classes on the Sydney 1996 base case network

Vehicle type	Vehicle-kilometres of travel	Greenhouse gas			
		CO_2	CH_4	N_2O	CO_2e
Private vehicles	90.6%	82.7%	84.6%	91.1%	82.9%
Light commercial vehicles	5.8%	6.6%	14.0%	2.9%	6.6%
Rigid trucks	2.8%	7.4%	1.3%	4.7%	7.3%
Articulated trucks	0.8%	3.3%	0.1%	1.2%	3.2%
Totals	100.0%	100.0%	100.0%	100.0%	100.0%

Table 6.4 provides similar summary output for the emissions of the air quality pollutants carbon monoxides (CO), volatile organic compounds (VOC), oxides of nitrogen (NO_x), fine particulates (PM_{10}), benzene, butadiene and sulphur dioxide (SO_2). The table indicates the relative contributions of the different vehicle classes to the emissions of the specific air quality pollutants, and also shows the VKT performed by each vehicle class. From the data in the table we can see that freight vehicles contribute significantly to the emissions of most of the pollutants, especially NO_x, PM_{10} and SO_2, while LCVs make more than proportionate contributions to CO and VOC emissions. For benzene and butadiene, the contributions to total emissions of these gases are effectively commensurate with the split of VKT between the vehicle classes.

Given these general results for the base case network, it is then possible to examine the effects on emissions of the various scenarios.

Table 6.4 Percentage contributions to total VKT & Air Pollutant Emissions by different vehicle classes on the Sydney 1996 base case network

Vehicle type	Vehicle-kilometres of travel	Air Pollutants						
		CO	VOC	NO_x	PM_{10}	Benzene	Butadiene	SO_2
Private vehicles	90.6	81.1	82.0	65.5	47.8	89.4	86.9	77.7
Light commercial vehicles	5.8	15.6	13.8	8.6	9.6	7.3	8.9	7.5
Rigid trucks	2.8	2.7	3.4	20.3	33.4	2.8	2.9	9.7
Articulated trucks	0.8	0.6	0.7	5.5	9.1	0.5	1.3	5.1
Totals	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

6.2 Greenhouse gas emissions

Figure 6.1 indicates the GHG emissions performance of freight vehicles on the study network under different scenarios as a percentage of the base case. This figure presents a set of bar charts for each of the direct greenhouse gases and for total GHG emissions in CO_2 equivalents. Note in this and subsequent figures, scenario 1 (best fuel technology) is shown last.

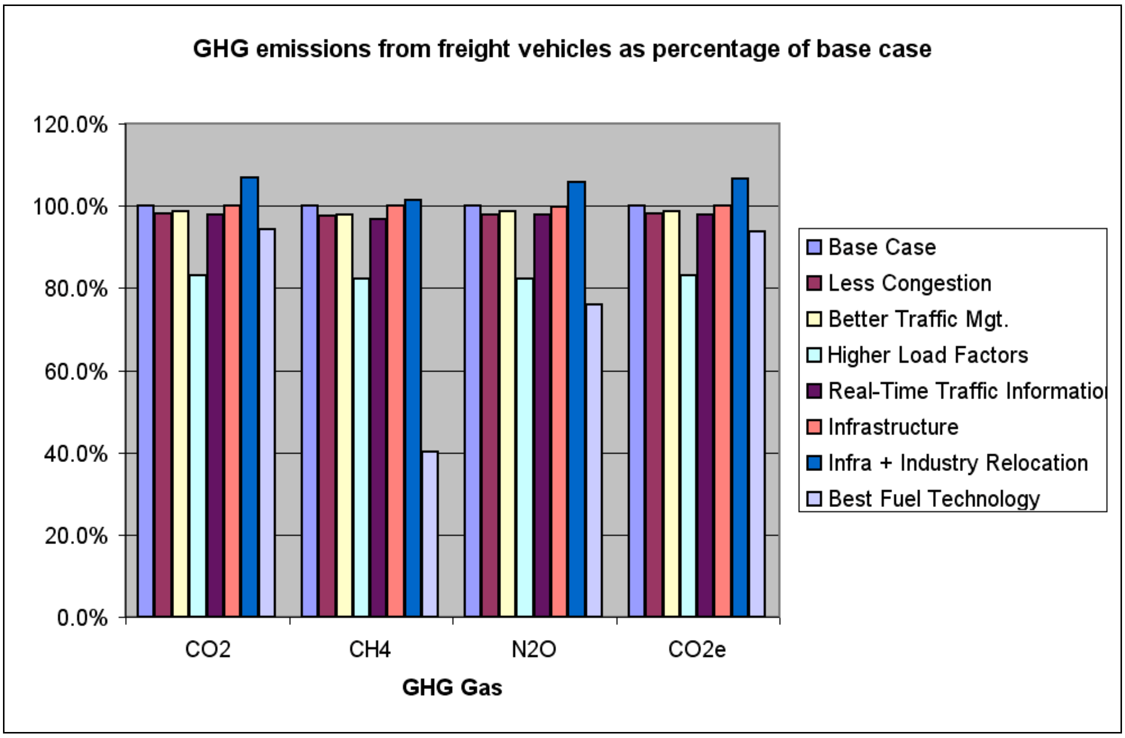


Figure 6.1 GHG emissions from freight vehicles by scenario

The following results, may be drawn from Figure 6.1:

- All of the scenarios, except for that of infrastructure improvements coupled with land use change through industry relocation, provide some positive benefit, in terms of GHG emissions. In the case of the land use change scenario, as will be discussed later, there are specific reasons why no positive benefit to GHG emissions from freight transport was achieved, which could potentially be overcome by complementary policies including other infrastructure improvements.
- The scenario that has the largest positive effect on GHG emissions from freight transport is that of higher load factors for freight vehicles. This produced a reduction of about 17 per cent in total GHG emissions when compared to the base case.
- The application of best fuel technology was the second best performing scenario, and indeed produced the largest reductions in emissions of CH_4 and N_2O from urban freight.
- For all of the other scenarios producing reductions in GHG emissions from urban freight transport, the percentage reductions in total GHG emissions from freight transport were relatively small, of the order of 3% or less.
- The scenario of infrastructure improvement coupled with industry relocation, for the case of the Sydney Orbital, led to an increase in overall GHG emissions from freight transport of about 6.5 per cent. This increase was almost entirely due to a singular effect, the doubling of the work tasks of articulated vehicles (as measured in terms of VKT performed), which led to an increase of about one-third in GHG emissions from this vehicle class. The reason for this increase in vehicle work is the major role played by articulated vehicles in transporting commodities and goods between the port and the industrial complexes. The location of the port obviously remains fixed, whilst the industrial sites have shifted a considerable distance to the west. Modelling for this scenario reasonably assumed that the port-factory movements would continue to be made by road using the largest freight vehicles (i.e. articulated vehicles), as no alternative transport mode was available. Complementary measures, such as constructing new railway infrastructure, to provide a direct connection to the port, would mitigate GHG emissions from this particular freight task.

It is also important to examine the effects of the scenarios in the context of all traffic on the network. The total picture of GHG emissions on the study area network, from all transport sources including passenger vehicles, is provided in Figure 6.2. This chart is similar to Figure 6.1, but shows the relative GHG emissions performance of each scenario including emissions from private vehicles.

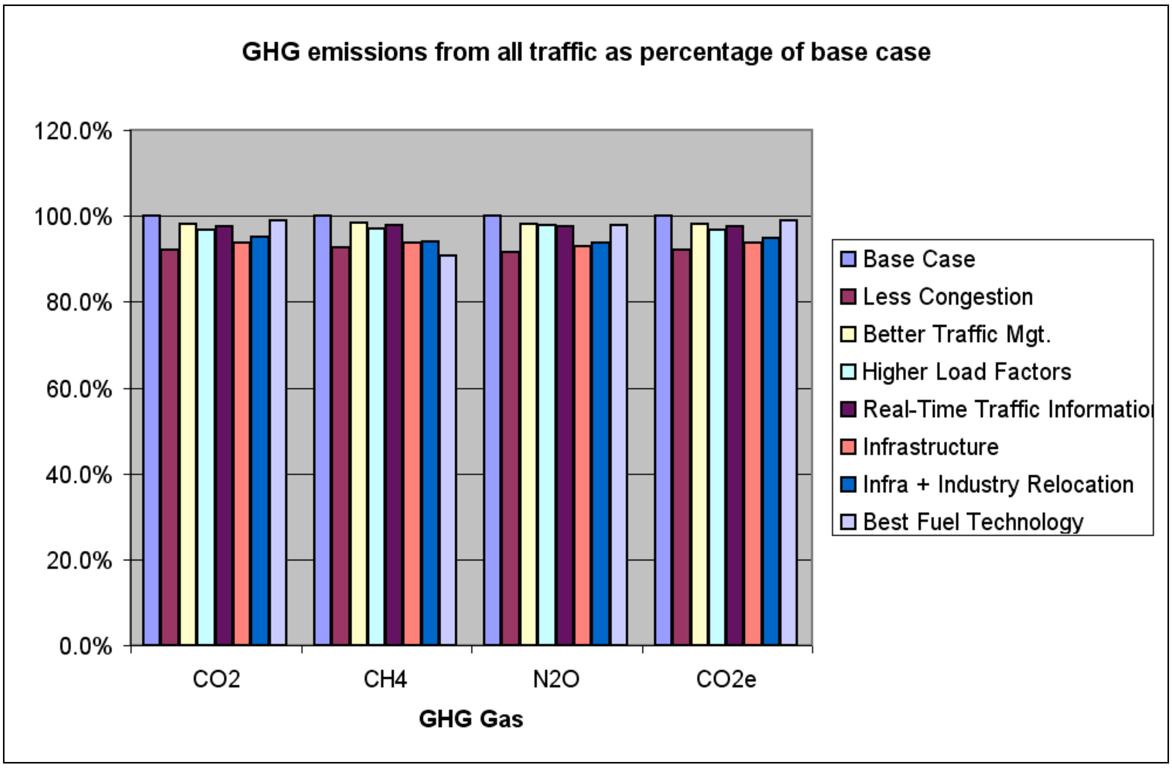


Figure 6.2 GHG emissions from all vehicles by scenario

Figure 6.2 shows that all of the scenarios have positive effects on GHG emissions when total emissions from all road transport sources are considered. This includes the scenario with industry relocation and infrastructure provision, which yields a total GHG emissions reduction of 5 per cent. The reductions in GHG emissions from private vehicle travel outweigh the increased emissions from the freight vehicles.

The scenario with the greatest effect on total GHG emissions from transport is that of reduced peak period traffic congestion. The 20 per cent reduction in private vehicle trips assumed under this scenario leads to an overall decrease of around 8 per cent in total GHG emissions. The decrease in GHG emissions from freight vehicles in this case is around 2.3 per cent, indicating that the substantial benefit comes from reductions in the GHG emissions of private cars.

The policy question is how to achieve reductions cost-effectively? One potential answer is the application of congestion charging ('road pricing') for peak period motor vehicle trips, as adopted in Singapore (with electronic road pricing) and now in central London (through a cordon charge licensing scheme enforced by video surveillance). Other previous studies – see for example May et al (1996), AATSE (1997), Bray and Tisato (1997) and Taylor (1999a,b) – have suggested the potential for congestion charging to reduce air pollutant emissions from urban road transport.

The infrastructure improvement option (without industry relocation) provided the second best result in terms of total GHG emissions (6.2 per cent). The benefit is derived from free flowing traffic. However it is important to remember that such an effect will only apply if the new infrastructure does not induce extra passenger vehicle trips. We believe evidence from the literature supports our assumption that the new infrastructure will not induce extra freight trips but that assumption would not hold for passenger trips, although as numbers of the links on the Sydney orbital are, or will be, subject to tolling, induced demand could be dampened.

The other scenarios affecting general traffic activity (i.e. better traffic management and real time traffic information) led to reductions in total GHG emissions of about 2 per cent.

The freight transport-specific scenarios of higher load factors and best fuel technology found to offer the most promise in reducing GHG emissions from freight vehicles provided reductions in the total GHG emissions of 3.3 per cent and 1.1 per cent respectively, because these scenarios solely involved urban freight transport. Private vehicle emissions were not directly affected by these scenarios except at the margin—higher load factors mean slightly fewer freight vehicles on the road.

The modelling results also permit a more detailed view of the emissions impacts on each vehicle class under each scenario. For the case of the total GHG emissions (measured in terms of CO_2 equivalents), Figure 6.3 shows the overall emissions impacts for each freight vehicle class.

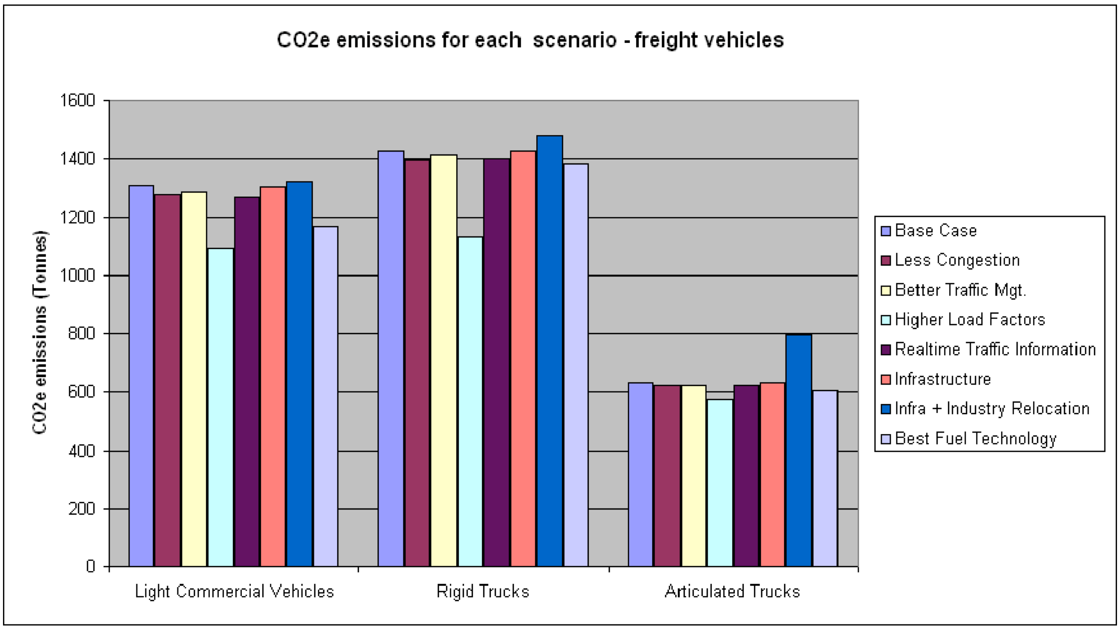


Figure 6.3 Total modelled CO_2 e emissions (in tonnes per day) for each freight vehicle type under the different scenarios

This figure indicates that the different scenarios can have different effects on the freight vehicle classes. Higher load factors have most effects (both absolutely and proportionately) on the GHG emissions performance of light commercial vehicles and rigid trucks. The impact of this scenario on articulated trucks is much less, probably reflecting the more specialised freight tasks undertaken by this vehicle type in urban areas. Similarly, best fuel technology has most effect on the emissions performance of light commercial vehicles.

The impact on GHG emissions from articulated vehicles in the scenario with industry relocation following the construction of the Sydney Orbital is also clearly apparent, whilst this scenario has only a small effect for the other freight vehicle classes. We note again that while the size of this impact may be overestimated, due to modelling simplification in moving only manufacturing west, the direction of the impact is likely to be correct.

The other scenarios show slight decreases in total GHG emissions for all freight vehicles.

Context is again important when examining these results and the emissions performance of private vehicles under the same scenarios also needs to be considered. Figure 6.4 provides a similar chart to Figure 6.3, but with the inclusion (in absolute terms) of the total GHG emissions from private vehicles as well as freight vehicles. The data for freight vehicles are exactly the same as those in Figure 6.3, but the scale of the plot is changed because of the inclusion of the emissions from private vehicles. Private vehicle CO_2e emissions are just over four times the total CO_2 e emissions from all freight vehicles.

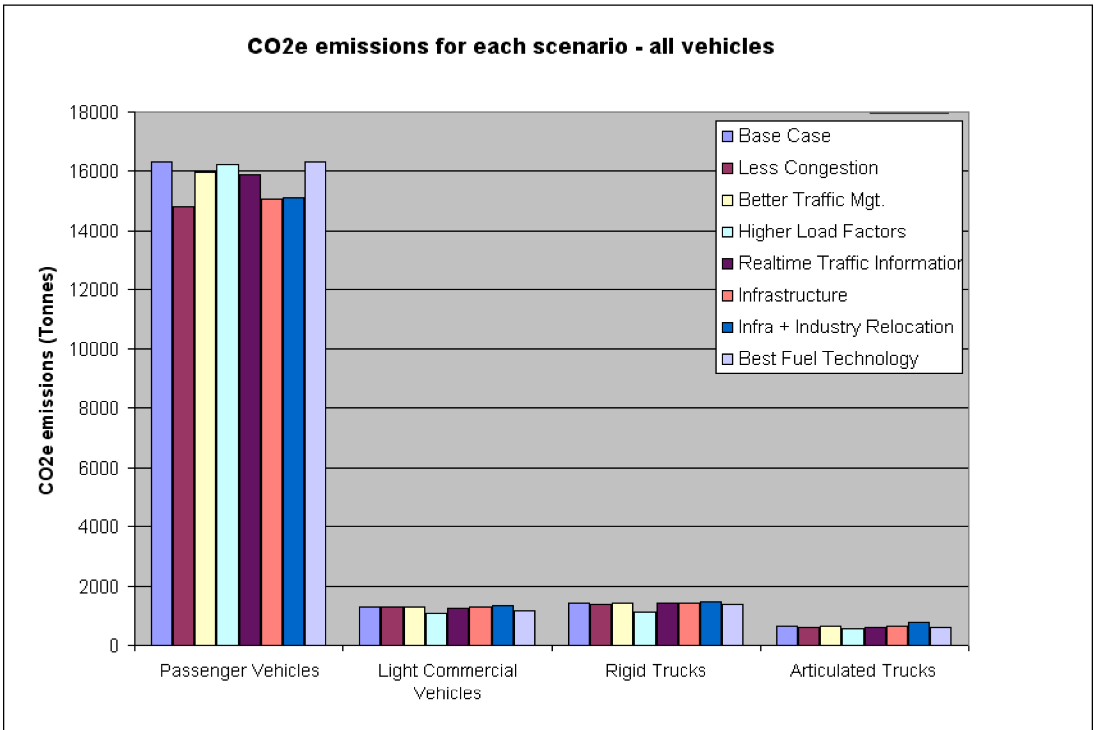


Figure 6.4 Total modelled CO_2 e emissions (in tonnes per day) for all vehicle types under the different scenarios

As discussed previously, the 'reduced congestion' scenario has the most impact on reducing CO_2e emissions because this has a major effect on the emissions from private vehicles. All of the scenarios have positive effects on GHG emissions, with the two infrastructure improvement options having the next best effects again due to improvements in private vehicle emissions. 'Better traffic management' also provided a noticeable effect on private vehicle emissions, more so proportionately than for freight vehicles. 'Best fuel technology' was applied to freight vehicles only. Higher load factors/larger vehicles had the largest effect on emissions from LCVs and trucks.

In terms of the individual greenhouse gases, CO_2 emissions performance was virtually the same as that for CO_2e, not unexpectedly given that CO_2 is the dominant component of CO_2e. 'Higher load factors" reduced CO_2e emissions from freight vehicles by 17.0 per cent, with a 16.6 per cent reduction for LCVs, 20.6 per cent reduction for RTs, and 9.2 per cent for ATs. The corresponding reductions from 'best fuel technology' were, respectively, 6.3, 10.8, 3.2 and 4.2 per cent. The emissions performances for the other components of CO_2e, i.e. CH_4 and N_2O, are worthy of some attention because there are some relative differences in outcomes for the different freight vehicle classes.

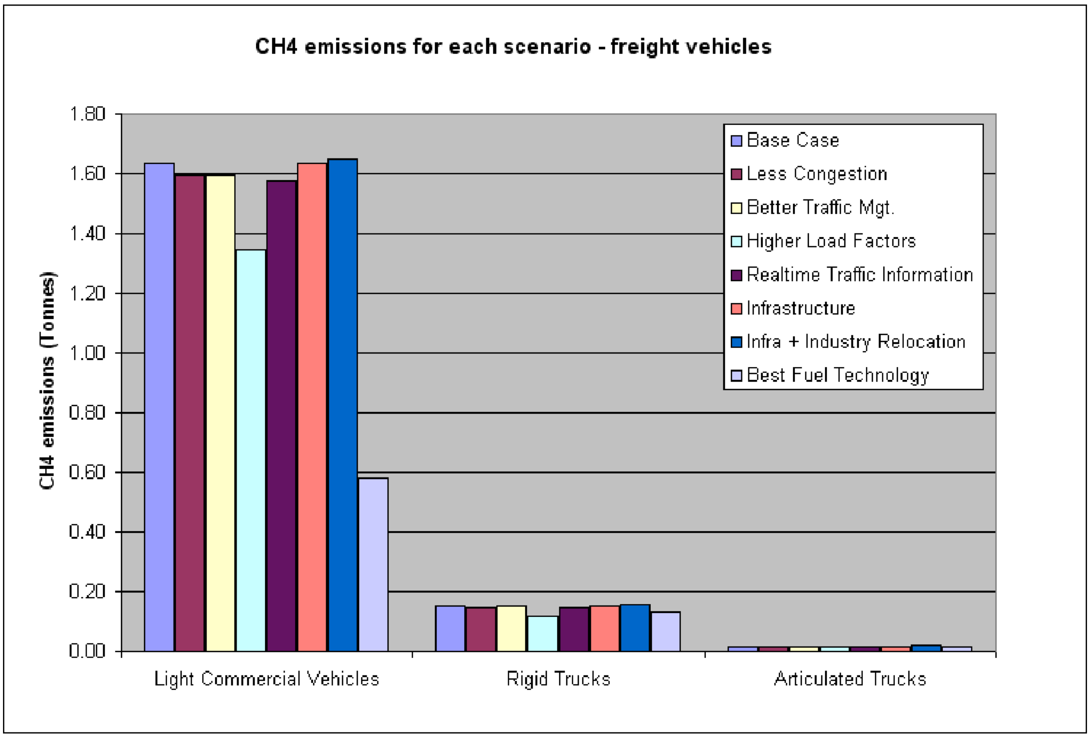


Figure 6.5 Total modelled CH_4 emissions (in tonnes per day) for each freight vehicle type under the different scenarios

Figure 6.5 shows the emissions of CH_4 for freight vehicles under the different scenarios, and Figure 6.6 shows the equivalent plot for N_2O.

Methane emissions from freight vehicles (Figure 6.5) are dominated by the LCVs. The 'best fuel technology' scenario achieved a significant reduction in CH_4 emissions from this vehicle class (64.5 per cent) and therefore from freight vehicles generally (60 per cent). 'Higher load factors' has the second best impact, 17.6 per cent reduction in CH_4 emissions from LCVs, 17.8 per cent from all freight vehicles. All but one of the other scenarios offered small reductions in CH_4 emissions, of the order of 1 – 4 per cent. The exception was the 'infrastructure and industry relocation' scenario, which for the modelled case yielded a small increase (1.4 per cent for all freight vehicles).

For the N_2O emissions, as shown in Figure 6.6, the rigid truck class was the largest contributor amongst the freight vehicles. 'Higher load factors' and 'better fuel technology' had roughly equal impacts on N_2O emissions from RTs (20.7 per cent and 21.0 per cent respectively), but over all of the freight vehicles 'higher load factors' reduced N_2O emissions by 17.7 per cent whilst 'best fuel technology' reduced them by 24.0 per cent.

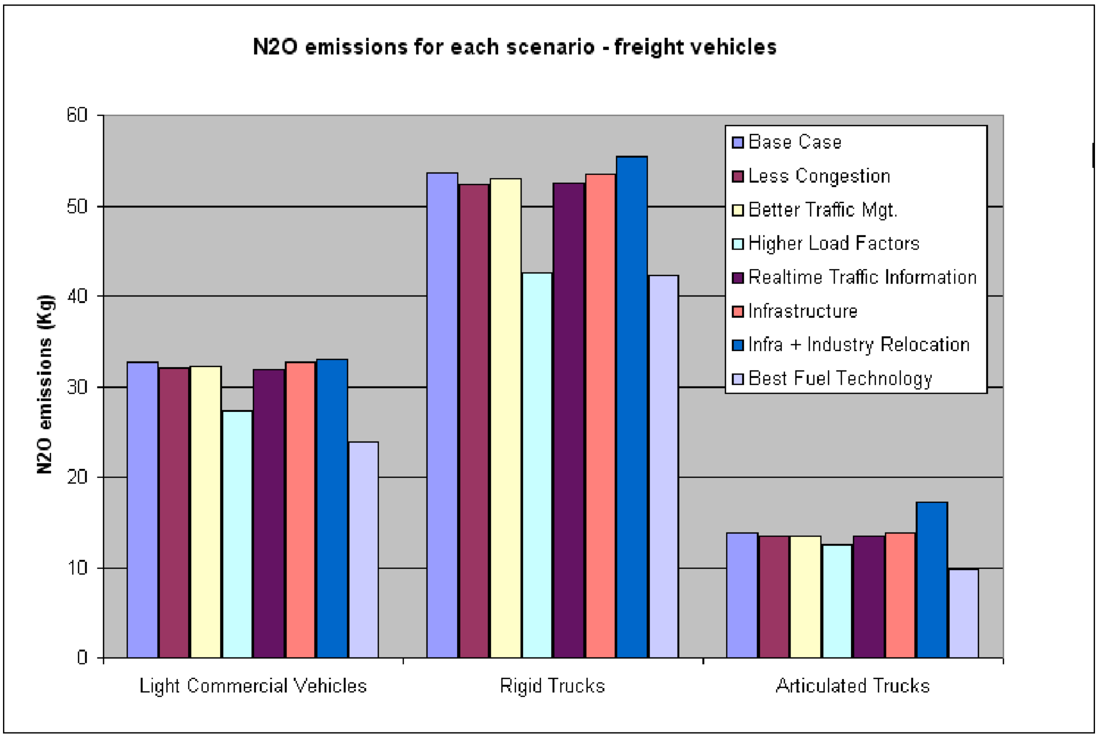


Figure 6.6 Total modelled N_2O emissions (in tonnes per day) for each freight vehicle type under the different scenarios

6.3 Air Quality Impacts

The outcomes of the modelling study with respect to air quality emissions generally follow the results found for the greenhouse gas emissions. Figures 6.7 and 6.8 provide similar plots for air quality emissions to those of Figures 6.1 and 6.2, for the GHG.

In Figure 6.7, which indicates the relative performance of each scenario on the emissions from freight vehicles only, the best performing scenario is ‘best fuel technology’ for all except SO_2 emissions. ‘Higher load factors’ is the next best performing scenario, except for SO_2 where it outperforms ‘best fuel technology’.

As with greenhouse gases (see Figure 6.1), all other scenarios offer small reductions in air quality emissions, except for ‘infrastructure improvement with industry relocation’.

Figure 6.8 shows the relative performance of each scenario in terms of total air quality emissions from road transport, including both freight vehicles and private vehicles. ‘Reduced peak period traffic congestion’ is the scenario offering the best reductions in air quality emissions, as it was for the greenhouse gases. All other scenarios lead to small reductions in these emissions, except for emissions of NO_x and PM_{10} under the scenario of ‘infrastructure improvement with industry relocation’. These two pollutants increase slightly under this scenario. It should be noted (see Table 6.4) that these are the two pollutants to which freight vehicles make the largest contributions. Fine particulate matter (PM_{10}) is the only pollutant for which freight vehicles produce the majority of the total emissions (52.2 per cent from all freight vehicles combined compared to 47.8 per cent from private vehicles). NO_x emissions are split 65.5 per cent from private vehicles and 34.5 per cent from freight vehicles (Table 6.4). This table indicates that all other air quality emissions are dominated by private vehicles, with at least 80 per cent of the total emissions from that vehicle class – a similar picture to the GHG situation described previously.

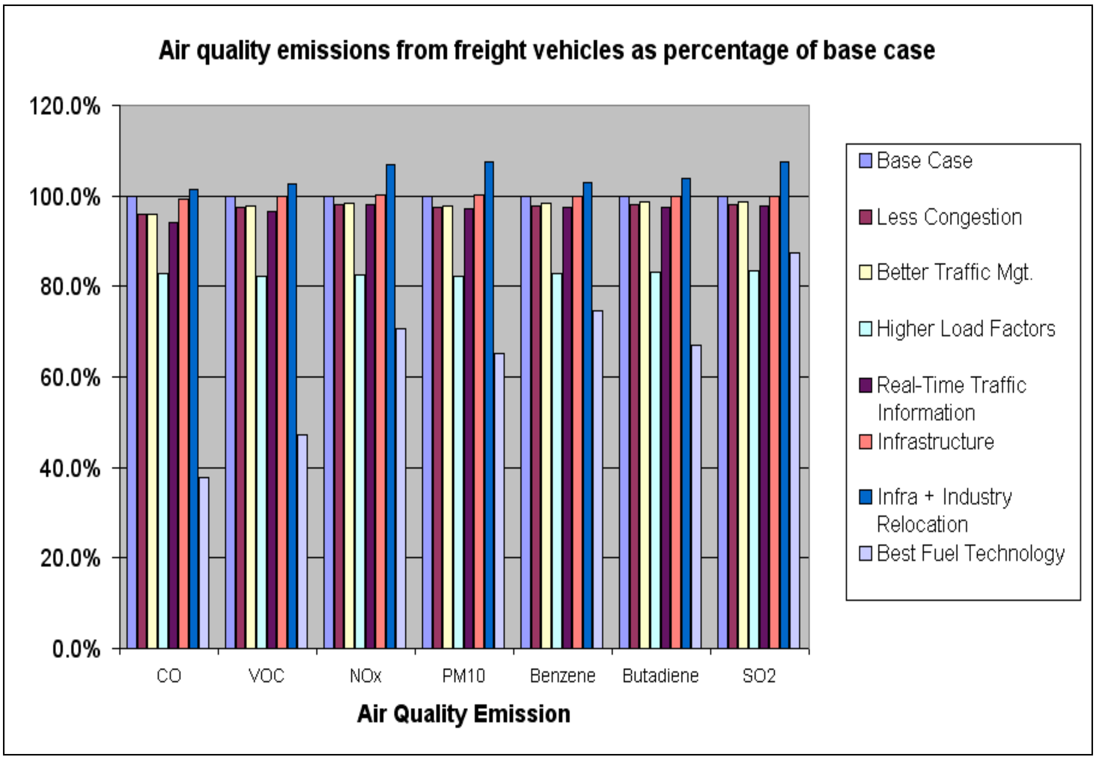


Figure 6.7 Air quality emissions from freight vehicles for each scenario

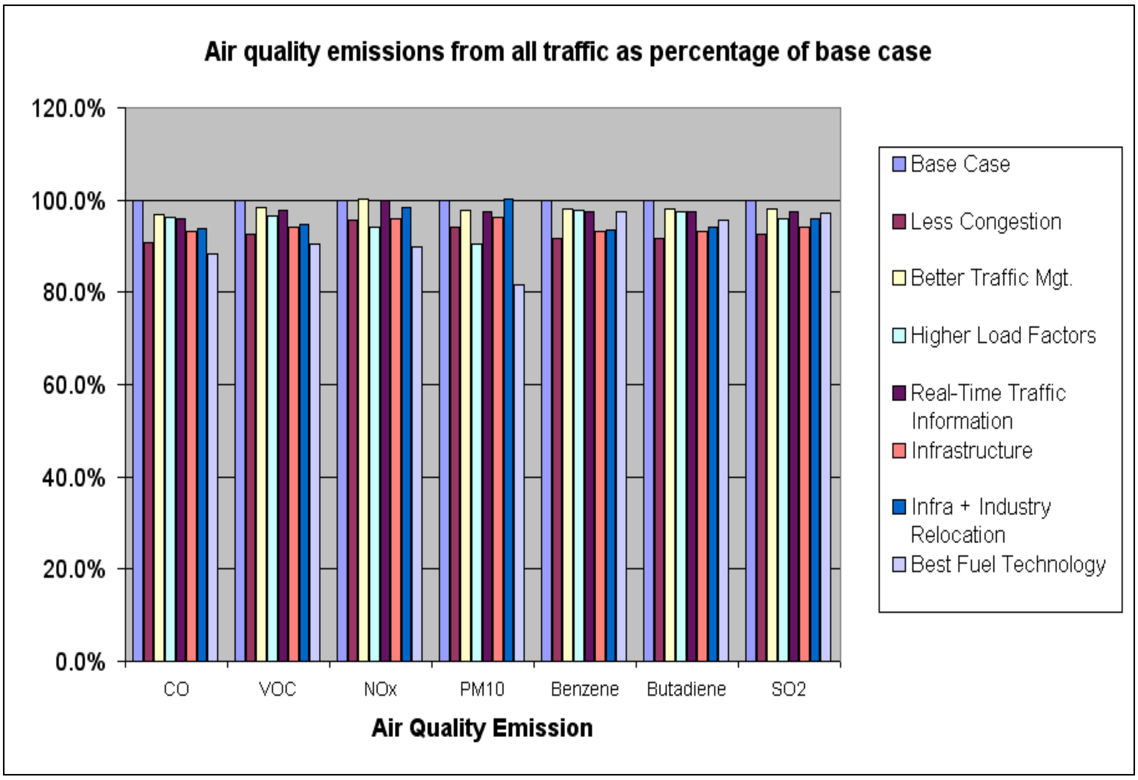


Figure 6.8 Air quality emissions from all vehicles for each scenario

Thus it is worth considering the emissions of NO_x and PM_{10} from freight vehicles in more detail.

Figures 6.9 and 6.10 show, respectively, the PM_{10} and NO_x emissions performance for all vehicle types.

When we consider PM_{10} emissions from all vehicles, including private vehicles – as in Figure 6.9 – we can see that the best performing scenario is 'best fuel technology' (total reduction 18.2 per cent compared to a total reduction of 5.7 per cent for 'less traffic congestion'), a reflection of the domination of this emission by freight vehicles. 'Higher load factors' lead to a 9.6 per cent reduction in PM_{10} emissions across the entire vehicle fleet. Remember that 'best fuel technology' and 'higher load factors' are scenario options that apply to the freight vehicle fleet and not to the private vehicle fleet.

The other air quality pollutant to which freight vehicles make larger contributions is NOx. Figure 6.10 shows that 'best fuel technology' and 'higher load factors' are again the scenarios of most interest in terms of reductions in NOx emissions from freight vehicles (with reductions of 29.4 per cent and 17.5 per cent respectively, for freight vehicles). 'Less traffic congestion' has an overall impact of a decrease in NOx emissions of 4.4 per cent, just less than the total decrease in NOx emissions of 10.1 per cent from 'best fuel technology'. This indicates the importance of freight vehicles as a source of this emission.

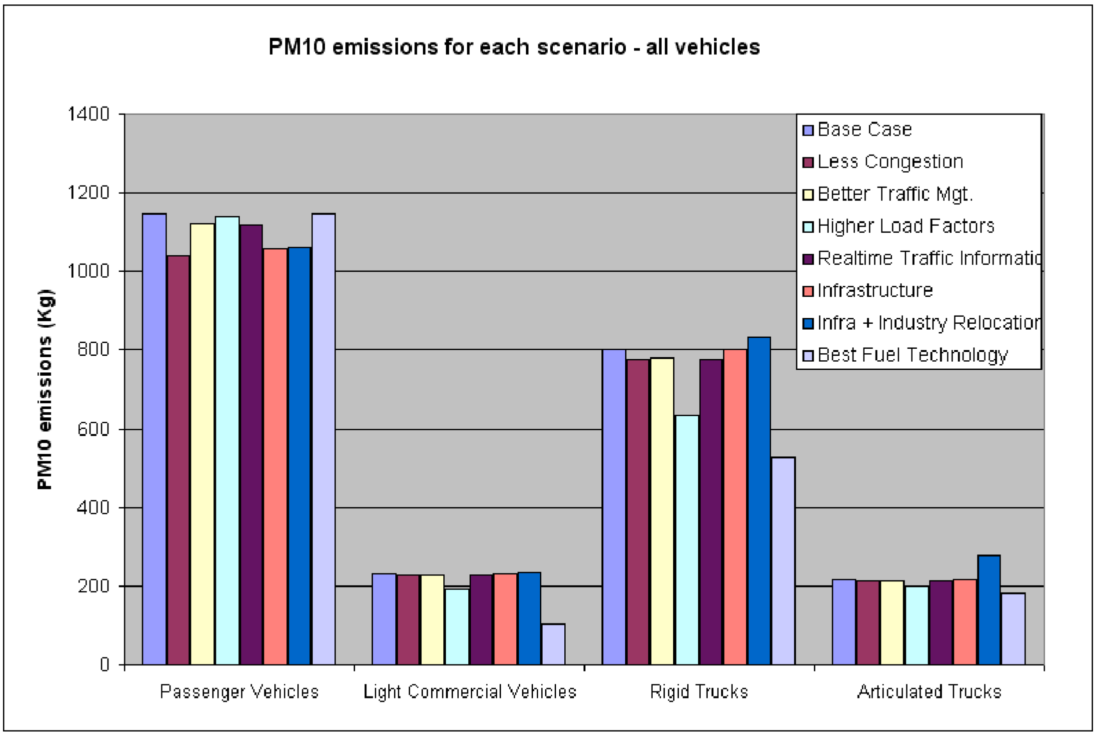


Figure 6.9 Total modelled PM_{10} emissions (in kg per day) for each vehicle type under the different scenarios

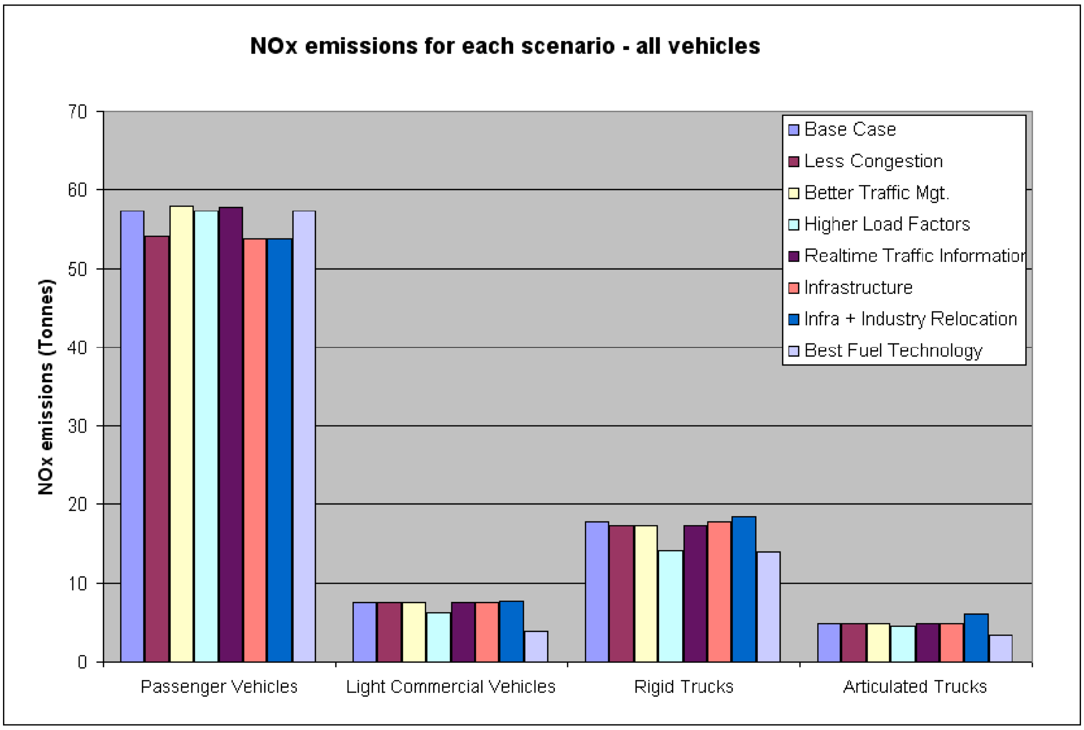


Figure 6.10 Total modelled NO_x emissions (in tonnes per day) for each vehicle type under the different scenarios

Figure 6.11 shows CO emissions for comparison. As can be seen freight vehicles are less important as a source of CO.

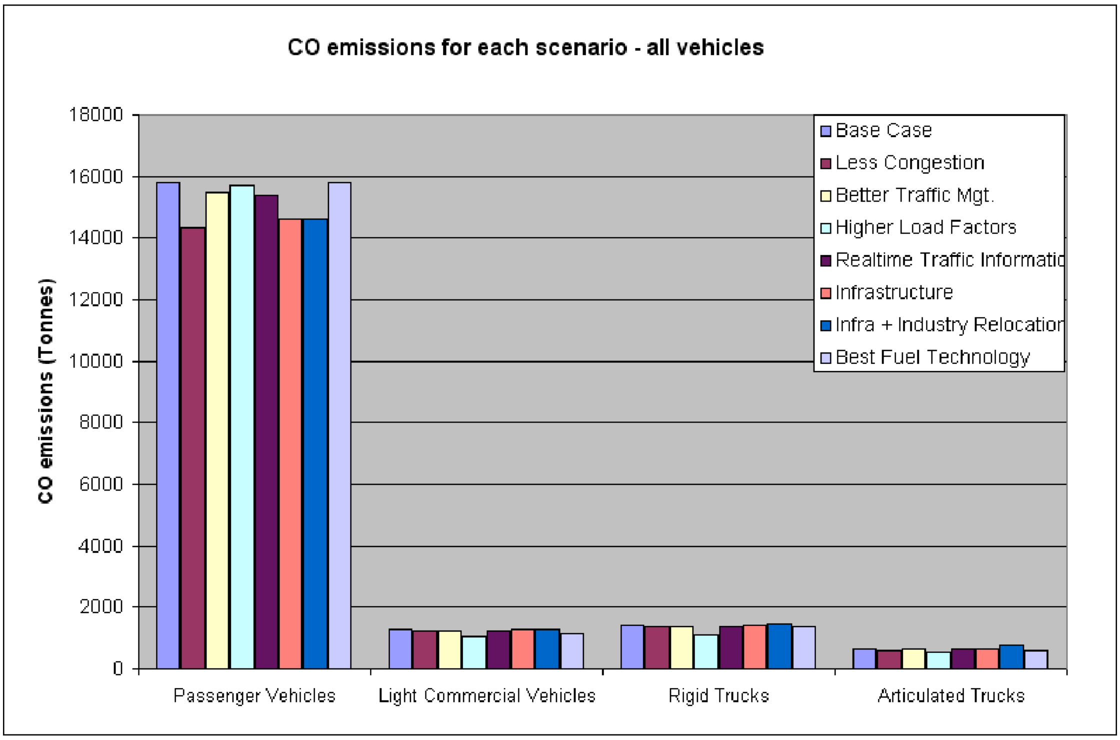


Figure 6.11 Total modelled CO emissions (in tonnes per day) for all vehicle types under the different scenarios

All the preceding figures in this section show total impacts over the urban area and over the entire day. As such we believe they are representative of the total impacts of the scenarios. Variation in scenario impacts by time of day together with further comparison of emissions by freight vehicle type can be found in Technical Paper 3 (Zito & Taylor, 2003). .

Variations in emissions are particularly important when **emission estimates** need to be converted to **population exposure estimates** to assess impacts on human health. Variation of emissions with time and their spatial distribution affect both the subsequent dispersion of pollutants and hence the exposure of the population.

However the dispersion of pollutants is also affected by weather patterns and the impacts of pollution from sources other than motor vehicles thus varies across the week and across the year. As the extended modelling required to check impacts of emission on exposure over time was outside the scope of this study we are only able to provide demonstration results**. It therefore is very important that our demonstration exposure results are not given the same weight as our more representative emission estimates.**

However one major policy implication can be drawn from the demonstration estimates. Scenarios do not impact uniformly across the city.

Figures 6.12 and 6.13 show respectively % change in the peak concentrations of NO_2 and PM_{10} compared to the base case by location for the different scenarios for four example Statistical Sub-Divisions of Sydney. Figure 6.12 shows four example SSDs;, Inner Sydney, Eastern Suburbs, St George-Sutherland and Canterbury Bankstown selected from areas having high peak concentration of NO_2. Figure 6.13 shows four example SSDs, Inner Sydney, Inner Western Sydney, Canterbury-Bankstown and Central Western Sydney selected from areas having high peak concentration of PM_{10} (The relative locations of the areas can be found in Figure 5.4 in the previous section).

These figures show that **there will be no one best scenario for all areas**. Despite all caveats about the representativeness of our exposure estimates, it could be expected that differences in scenario impacts in different parts of the greater urban area will apply.

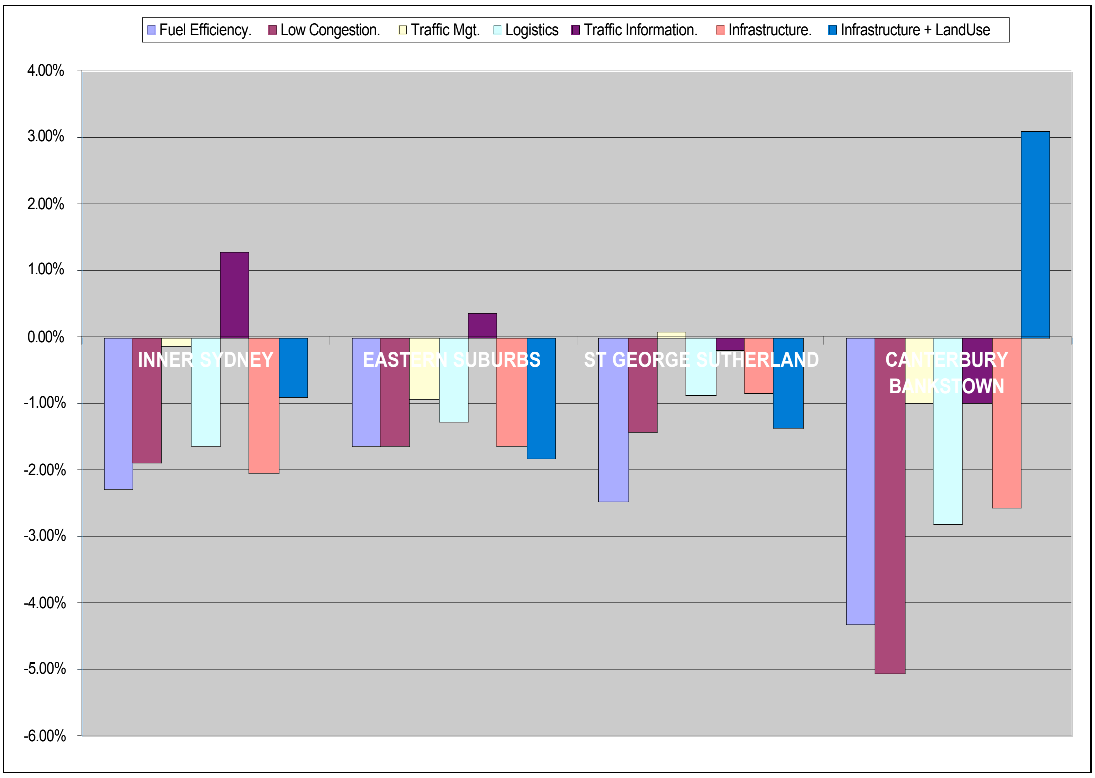


Figure 6.12 Percent Change in Peak NO_2 Concentration by Scenarios for 4 SSDs

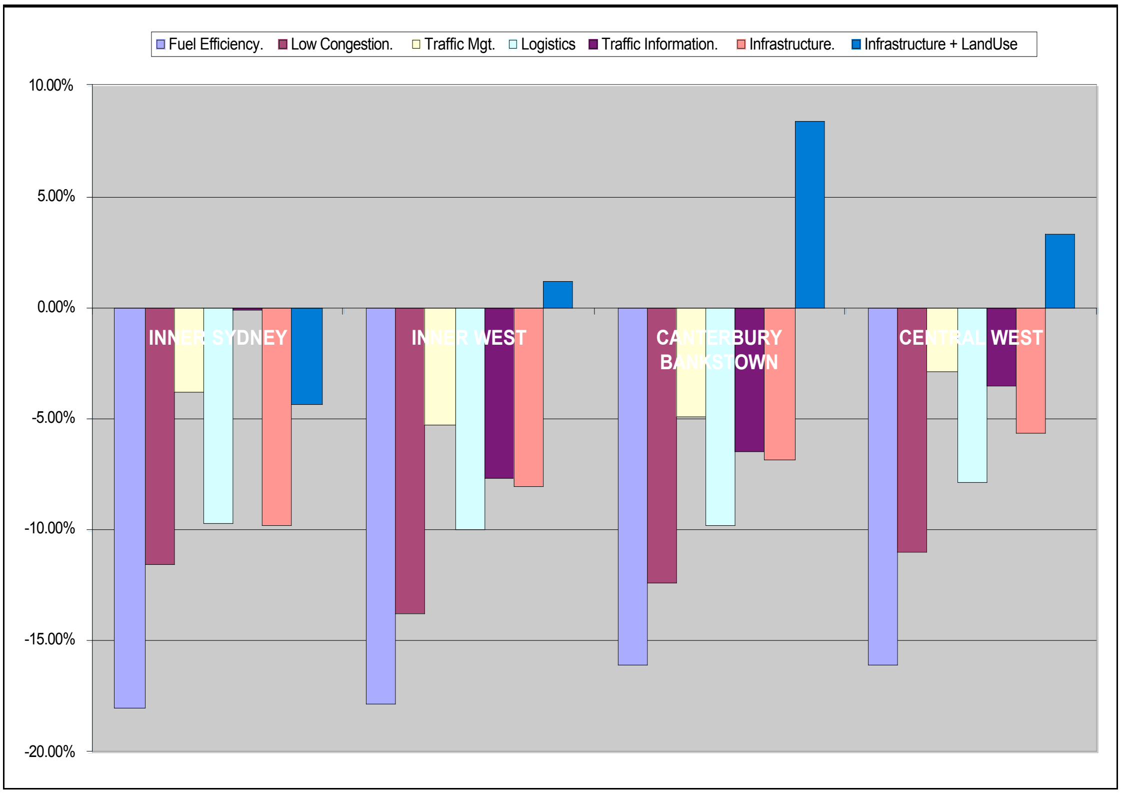


Figure 6.13 Percent Change in Peak PM_{10} Concentration by Scenarios for 4 SSDs

6.4 Implications for Urban Australia

The study has important implications both for policies and the way their impacts might be modelled: These can be summarised into the following categories:

Conclusions

Relative Impacts of Scenarios on Urban Freight Emissions: While all but one tested scenario produced some improvements in GHG emissions, the scenarios that had the greatest impact in reducing GHG emissions from freight transport were 'higher load factors' and 'best fuel technology'. These two scenarios also lead to the best performances in the air quality emissions.

Both were directed at freight transport alone and could, in principle[2], be encouraged by incentives for carriers and shippers. A range of essential policies from city logistics to new fuel standards is available. Moreover consideration of the model structure by the study team leads us to expect that a combination of these two scenarios would be additive and could lead to quite significant reductions in GHG emissions from freight vehicles[3]. Policies to encourage replacement of vehicles could lead to more fuel efficient and larger vehicles capable of carrying high loads in line with trends to larger vehicles. At the same time positive impacts of higher loadings signal potential GHG increases due to low loadings from just in time operation.

Impacts on Total Fleet Emissions: In terms of total GHG emissions from road transport, the scenario leading to the largest overall reductions in GHG was that of 'less peak period traffic congestion'. This scenario was proposed as a means of improving the emissions performance of freight vehicles. There is measurable reduction of GHG from free flowing freight traffic but the major reduction stems from less passenger vehicles. Note that the assumed 15% reduction in peak hour traffic may be assisted by incentives to shift some travel from the peaks. Peak road use pricing might possibly produce such a shift. However it also might be produced by a basket of measures from improved public transport to parking restrictions at destinations.

As an overall reduction in congestion represents another largely independent dimension of policy "higher load factors" and "best fuel technologies" would be additive on top of the effect of reduced congestion. A range of freight management practices, to increase loads should be easier to implement and more successful if there was less congestion. For example, fitting in more pickups and deliveries and thus getting better load factor while still meeting time constraints would be easier if there was less congestion.

Variability with Location and Time of Day: The study showed that the impacts of scenarios vary with location and with time of day. Such variation is clearly important for air quality outcomes since the location of emissions in part determines location of air pollutant concentrations and hence population exposure. However it can also be important for GHG. Location of measures, such as new traffic management measures or new infrastructure will help determine the total GHG impact of the initiative. Similarly targeting time of day

2 Before deciding whether such incentives are warranted, the cost to the community should be assessed relative to the benefits, as far as possible in quantitative terms. BTRE (2002) suggests that benefits generally do not exceed costs.

3 Again, the full costs and benefits of such policies would need to be assessed. See BTRE (2002).

initiatives can result in more GHG savings   Thus time and location should be considered in assessment of potential policies.

Modelling Implications

Modelling Outcomes: Modelling outcomes, through the seven scenarios, both allowed us to make use of data which only provided numbers of freight vehicle trips by OD and provided a rich set of results for strategic level modelling, as each outcome scenario may imply multiple policies and/or industry actions.

What If Scenarios: In view of current rapid changes in urban freight, modelling based on trends from past behaviour could be unreliable. A "what if" model which looks at the effect of particular initiatives is of value in that situation.

Network Level Modelling: The study successfully demonstrated that impacts of potential policy measures are spatially sensitive and therefore a network level model is more useful for policy assessment. This is true for all traffic but particularly true for freight traffic.

Applicability to Urban Australia: It is very likely that the results of the major scenarios are broadly applicable to other large Australian cities. It is certainly likely that better logistics leading to trip reduction and better fuel efficiencies would apply. While Sydney is currently more congested than other cities, Brisbane and Melbourne are catching up, so it is also likely that congestion reduction would have a significant effect. However to model spatial and temporal variation in GHG emissions and exposure of population to air pollution it would be necessary to specifically apply the modelling framework. The detailed base results for Sydney provide the opportunity for data transfer to compensate for lack of data elsewhere.

Applicability today: As emphasised throughout this report our study could only look at scenarios as if they were applied in 1996, the year for which data was available. If updated data or, better, a model to forecast freight demand was available the current framework could be easily applied to update results. Such an update would be likely to show that the scenarios have even greater impacts than shown here as freight vehicles now make up a larger proportion of the fleet than they did in 1996. This means that selection of cost-effective urban freight policies for GHG amelioration will be increasingly important. A key message from this study is that there is no single solution but that, subject always to threshold cost-effectiveness tests, a mix of policies directed to a mix of outcomes will have significant potential impacts.

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