CHAPTER 3: Transport Logistics

INTRODUCTION

Transport logistics, in the context of this Inquiry, encompasses urban transport systems operations and their impacts on air pollution. The range of technological, regulatory, management and economic measures for reducing unnecessary travel and/or the unwanted impacts of urban travel, collectively known as 'Travel Demand Management' (TDM), are receiving wide interest and concern in urban and transport planning and are a central feature of this study.

As road vehicles are the major pollutant source, the major focus was on the operation and use of the road-based transport modes (eg bus, tram, freight delivery, private vehicle driver, private vehicle passenger, cyclist and pedestrian) and their emissions of air pollutants. An examination of these issues includes the following:

- the nature of travel in urban areas;
- traffic congestion;
- congestion and emissions;
- traffic management and control;
- travel demand management;
- induced traffic;
- fleet characteristics; and
- interactions between the transport system and the land use system.

The last two of factors fall more directly into the areas of other Inquiry Task Groups (Chapters 2 and 5) but an examination of them from the perspective of the use of transport systems is a necessary adjunct.

The Nature of Travel in Urban Areas

An examination of how urban transport systems are used requires some knowledge of why that travel occurs and the processes that manifest themselves into observed travel activity. Account needs to be taken of the interactions between the characteristics of the various forms (or modes) of transport provided in an area, the characteristics of the travelling population, the spatial configuration of the area and the activities undertaken by its inhabitants that lead to the movement of people and goods.

Like many social systems, urban transport systems are very complex entities. Travel decisions are made by very large numbers of individual decision makers, who act to meet their specific needs for travel or information transfer and who react to the states of available transport systems and to outcomes of decisions made by their fellow decision makers.

A central tenet of this process, which has serious repercussions for the manner in which transport systems may be managed to achieve specific goals, is that travel is a derived demand. It is rarely undertaken for its own sake. Travel activity occurs almost entirely as a response by individuals or groups of individuals to their need to participate in some activity at a different place from their initial location. This requires individuals to organise their activities into schedules and to choose sequences of locations that can be reached within the time available using the forms of transport and transport services (and perhaps communications) available to them.

Conditions on the transport system (eg service availability and congestion levels) play some part in the decision making processes adopted by individuals, but do not dictate the outcomes of that process. Conventional transport analysis has dealt with travel decisions as activities in their own right, but in recent times some transport planners have adopted an analytical framework that considers activity sequences first and then derives trip making behaviour from those sequences.

This study is based largely on the analytical tools presently available to address transport planning problems, with certain extensions and recent research innovations used to include considerations of air pollutant emissions and the likely effects of alternative transport policies on emissions.

Modelling Emissions from Transport Systems

Airshed modelling including emissions from transport ('mobile sources') is now widely used by environmental protection agencies. Such modelling is based on considerations of a region and usually on a 'grid' basis, in which the emissions contributions of small areas ('cells') to the total emissions loads are determined. These models usually base emissions calculations on the amount of vehicle kilometres of travel (VKT) in each cell and then apply a standard average rate of emissions per unit VKT.

This approach, whilst useful for airshed investigations, is less useful for transport systems analysis. It does not consider the effects of temporal and spatial variations of travel demand (and hence levels of traffic congestion) on emissions rates. These variations are of concern in transport planning, where network-based approaches to modelling are adopted.

In the network based approach, the links and nodes of the network are treated as line and point sources of emissions. The emissions rates of these sources may be varied in accordance with traffic flows on those network elements, the corresponding traffic congestion levels and the composition of the traffic streams. Network based modelling was used in this study.

The nature of a vehicle journey through an urban road network may be described by its speed-time profile, a plot of instantaneous vehicle speed against time of the vehicle as it traverses its route. This provides the necessary data on speed, acceleration and idling required by the models of vehicle fuel consumption and emissions. From this and vehicle and fuel parameters, vehicle emissions under the traffic conditions that it encounters whilst making its journey may be calculated. A family of mathematical models for emissions of vehicles and traffic streams (comprising many vehicles of different vehicle types) is available (Biggs and Akçelik, 1986). These provide suitable model formulations for use at different scales and levels of detail of road networks; eg road sections (links), intersections (nodes), routes and areas. Coupled with models of traffic loads and distributions in a network, emissions modelling accounting for different levels of traffic congestion, traffic control systems and traffic and transport management policies is possible.

Traffic congestion

Traffic congestion presents a common if not inevitable facet of traffic activity in a region, particularly an urban area. The spread, duration and intensity of congestion, the processes that lead to it and the consequences of it are of special concern in urban policy making and transport planning.

Knowledge about congestion and its extent and intensity is important for urban transport systems. A first consideration is to define just what congestion is. Congestion is an integral part of a transport system, but its specific definition and identification are not immediately obvious. The following definition of congestion was adopted:

Traffic congestion is the phenomenon of increased disruption of traffic movement on an element of the transport system, observed in terms of delays and queuing, that is generated by the interactions amongst the flow units in a traffic stream or in intersecting traffic streams. The phenomenon is most visible when the level of demand for movement approaches or exceeds the present capacity of the element and the best indicator of the occurrence of congestion is the presence of queues.

This definition recognises that the capacity of a traffic systems element may vary over time, eg when traffic incidents occur.

It follows from the definition that congestion may always be present in any part of a transport system, but that the level of congestion may have to exceed some threshold value to be recognised. The threshold may be context specific, deriving, for instance, from incidents such as breakdowns, road works, or vehicle crashes. Peak periods are recognised as prone to congestion, it must also be recognised that congestion can occur at other times, due to different traffic management regimes in place off-peak, traffic incidents or unusual local traffic generating activity.

The Bureau of Transport and Communications Economics (BTCE, 1996) recently estimated that congestion in the mainland capital cities of Australia imposes direct annual costs of about $2.16 billion, with Sydney contributing some $0.92 billion and Melbourne some $0.81 billion of this total. These amounts do not include the costs associated with air pollution generated as a consequence of the congestion. For Melbourne, it is suggested that 10% of total VKT occurs in congested conditions. Sydney probably experiences a higher degree of congestion.

The contribution of traffic incidents to traffic congestion should not be underestimated. Incidents include accidents, vehicle breakdowns, traffic signal failures, and roadworks. There are indications that some 40-60 percent of congestion is incident based. Further, the effects of incident-based congestion may be quickly amplified (Rust-PPK, 1996). Recent US studies suggest that a one minute blockage of a road link may lead to a 6-10 minute episode of congestion. Incidents on multi-lane roads cause significant decreases in capacity during the congestion episode. Canadian studies suggest that the blockage of a single through lane leads to a 40-60 per cent reduction in capacity (depending on the number of through lanes available) whilst even the blockage of a road shoulder may result in a 15-20 per cent reduction in capacity. Incidents also contribute to the propagation of accidents, with Canadian research suggesting that there are perhaps 20 secondary crashes for every 100 primary (incident causing) crashes on freeways.

The possible network-wide effects of incidents were modelled by imposing a blockage on the in-bound lanes of the Tullamarine Freeway in the Melbourne network, for the morning peak period. This simulated blockage, even though restricted to a single link of the transport network, was still sufficient to cause observed changes in the overall system operation, including increases in fuel consumption and emissions.

For strategic transport planning purposes, a satisfactory measure of the level of congestion on a network component (eg a route, link or intersection) is the excess time incurred over and above the free flow travel time. Further, it is assumed that travellers may be able to trade off excess travel time (or indeed total travel time) for other components of the overall cost of travel on a trip. To do so requires the introduction of the concept of a generalised cost of travel for a trip. This trade off and its possible effects on emissions is explored.

Fuel and emissions modelling for traffic streams

A congestion function describes the relationship between the amount of traffic using a network element and the travel time and delay incurred on that element. The total travel time to traverse a network element is directly related to the traffic volume using that element. As volume increases, so delay increases. The rate of increase accelerates as volume approaches the capacity of the element. For most transport planning applications the network link is the typical level at which congestion functions are applied, but for traffic engineering applications functions for lanes and movements are more appropriate. The congestion function is used to estimate the travel time on a network element under specified traffic conditions. The estimated speed-time profile may then be used with a traffic emissions model to calculate emissions rates for different vehicle types in the traffic stream.

Four levels of fuel consumption and emissions modelling suitable for transport network applications were proposed by Biggs and Akçelik (1986). Of these the instantaneous, individual vehicle model is the most detailed. The other models are aggregations of this and require less and less information but are also increasingly less accurate. The running speed model can be used at the network link level. It gives emissions or fuel consumption for vehicles travelling over an extended length of road (perhaps representing a network link). This model was applied in the present network-wide emissions modelling. The application of the Biggs-Akçelik model to emissions modelling is described in Taylor and Young (1996).

Changing fleet composition and the contributions of different vehicle types and trip classes to fuel usage and pollution are important. The differences in energy and environmental performance between automobiles using alternative fuels such as unleaded petrol, leaded petrol, liquid petroleum gas, diesel fuel or electricity is one such issue. Trip class might include different categories of travellers, eg through traffic and local traffic, private, commercial and business travel, passenger and freight transport, etc.

Segmentation of vehicles into size and/or fuel type classes in the manner suggested provides the means to derive reasonably accurate estimates of fuel consumption and emissions in transport network models, using the procedures outlined above and described fully in SR3.

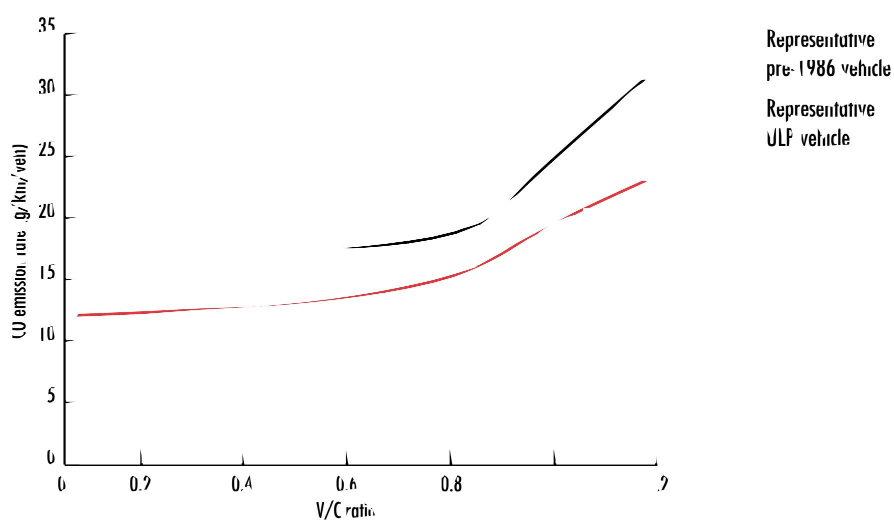

Figure 37: Effects of congestion: CO emissions as a function of volume/capacity ratio for dual carriageway arterial road; ULP and pre-1986 vehicles

Congestion and emissions

Pollution emissions and fuel consumption are tightly linked for a given vehicle technology. This is particularly so for carbon monoxide and VOCs. Figure 37 demonstrates the difference, in terms of CO emission, between a pre-1986 vehicle and a more recent model running on unleaded petrol. Emissions increase steeply for both as the volume capacity (V/C) ratio exceeds 0.8. The rise is more pronounced for the older vehicle.

Fuel consumption can be split into three categories of causation, namely idle, motion and accessories. Idle fuel consumption is that required to keep the engine rotating whilst stationary, motion consumption is that needed to move the vehicle from point to point, whilst the last category is that needed to keep accessories operating, in particular air conditioning.

Results of applying an instantaneous power demand model show that, at a steady speed of 60 km/h, the idle fuel is responsible for about 1/3 of total fuel consumption. It is easy to appreciate, therefore, that significant congestion will result in increased fuel consumption. This is demonstrated by Figure 38 which summarises fuel consumption of a Toyota Camry Sedan as a function of

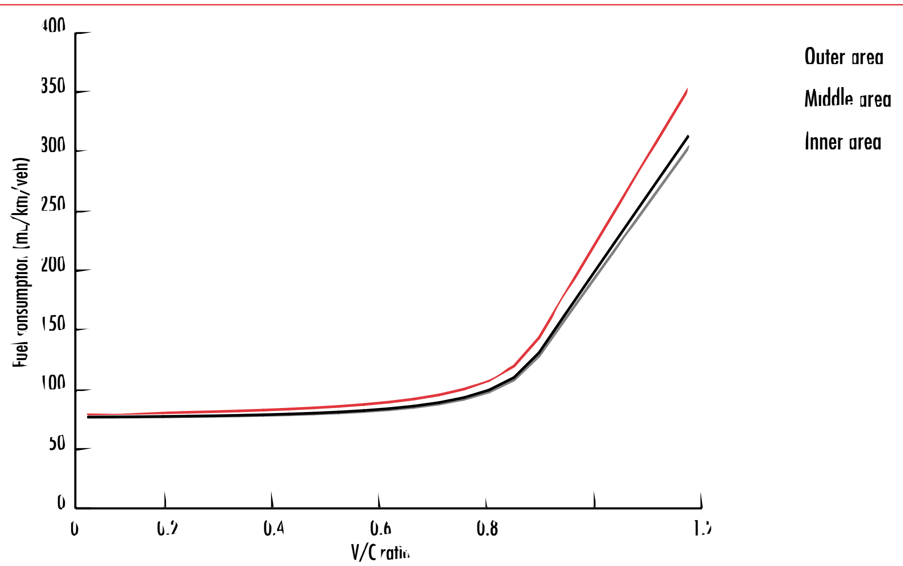

Figure 38: Effects of congestion: fuel consumption as a function of volume/capacity ratio for dual carriageway arterial road, representative ULP vehicle

congestion. As the V/C ratio increases beyond 0.8, fuel consumption rises steeply. A similar result is obtained for pre-1986 vehicles.

The link between congestion, fuel consumption and pollutant emissions is further underlined by Figures 17, 38 and 39. Both VOCs and NOx emissions rise steeply as the V/C ratio exceeds 0.8. This rise is far more dramatic in the case of VOCs. Similar results are obtained for other pollutant emissions and for other vehicles.

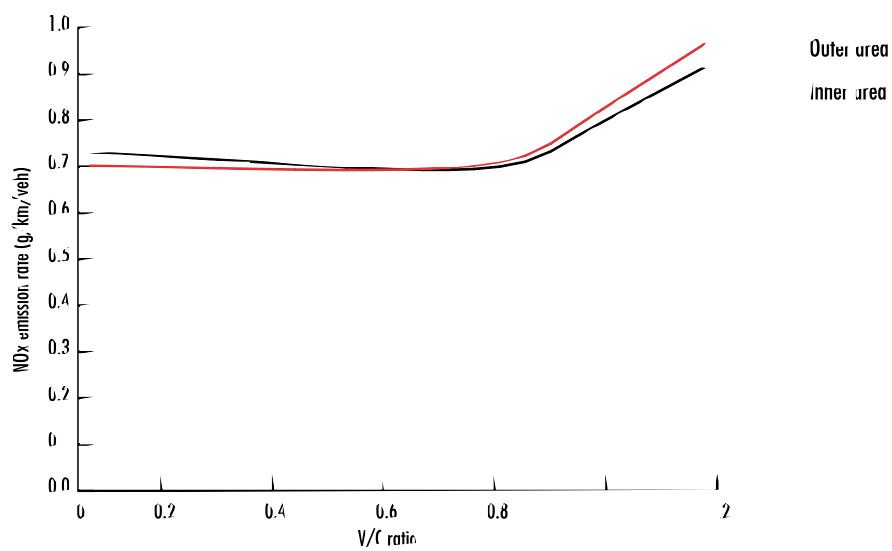

Figure 39: Effects of congestion: NOx as a function of volume/capacity ratio for dual carriageway arterial road, representative ULP vehicle

The instantaneous power demand model can also be used to model exhaust pollution emissions under a variety of traffic conditions. Because one is dealing with the remnant traces of unburnt fuel and low level combustion by-products, nominally identical vehicles can emit quite different quantities of pollutants. The model can only predict fleet average emissions.

The credibility of the model was assessed by CSIRO, applying it to the recent FORS (1996) data for 46 late model in-use cars. The model has been applied to each of the individual vehicles, according to their mass, engine capacity and the type of catalyst used. The comparison between the measured and predicted average emissions and fuel economy are described in SR3. The models performed creditably and considerations of pollutants emitted in the three phases of the ADR37 test cycle showed that the procedure also accounts for cold start emissions.

Limited experimental work was undertaken to test the ability of the instantaneous model to quantify the effect of road congestion on fuel consumption and exhaust emissions. The model was applied to measured speed-time profiles along a 8.7 km stretch of arterial road travelling away from the Sydney CBD. The road is busy but free flowing between peak hours, very busy in the morning, and becomes congested in the afternoon peak period. About six km of the road segment is subject to a speed limit of 80 km/h, the remainder is 60 km/h. The results, exhibited in Figure 40, clearly show the strong effects of congestion on emissions. The overall magnitude of the congestion effect into the airshed requires an estimate of the fraction of VKT that is undertaken during congested conditions.

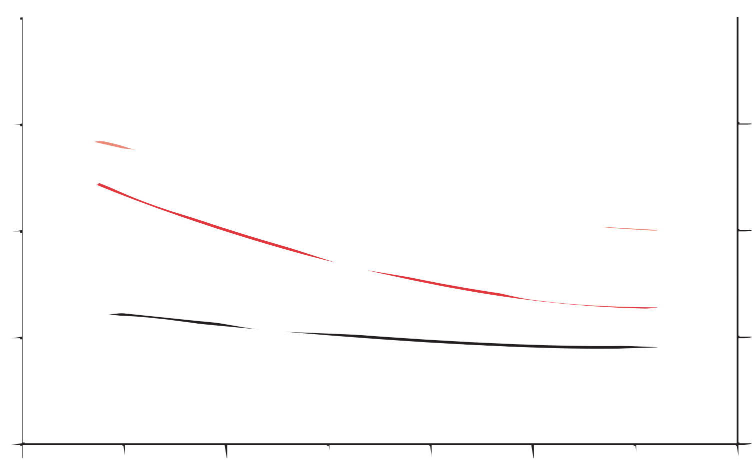

Figure 40: Effect of traffic speed on emissions

Managing Urban Transport Systems

A variety of traffic and transport systems management measures are available for modifying traffic behaviour and could offer the means for some reductions in emissions. These include established measures, such as Travel Demand Management (TDM), including high-occupancy vehicle lanes and public transport priority, and traffic signal coordination (but perhaps with specific emissions reduction objectives considered), as well as emerging measures based on Intelligent Transport Systems (ITS) technology such as incident detection and management systems, advanced traveller information systems, electronic road pricing and even automated driving. The application of ITS technologies is making road pricing more feasible and this was the focus of further modelling.

The basis of road pricing is as follows. Traffic congestion already provides a natural but partial restraining mechanism on travel demand. The additional costs (delays, queuing and inconvenience) resulting from congested conditions can act as a form of deterrent to the generation of further travel demand. However, the congestion 'price' is seen as inefficient as a demand management tool. Individual drivers may not be fully aware of the true costs that they impose on other travellers and the transport system on the basis of congestion delays alone. Some other pricing signal is required to this end.

Assume that travellers will respond to a composite generalised cost containing components such as travel time, travel distance, out-of-pocket expenses and fuel cost by trading off the different cost components in their travel decision making. The further step is to impose a congestion tax, toll or road pricing charge on travellers in an intelligent, selective fashion (eg for travel on some parts of a network at some times of day). The micro-economic theory of demand supply equilibrium may then be applied to suggest the effect of different road pricing charges on the levels of travel demand (link traffic volumes) under a road pricing scheme.

Use of ITS technology to monitor congestion levels, determine appropriate charges commensurate with those congestion levels and then apply those charges to vehicles in the road pricing area is an essential part of the application of road pricing. There are social and political questions, relating to equity and privacy amongst others, to be tackled before road pricing becomes a viable option for urban congestion management. Nevertheless, an important opportunity is presented by the economic theory and the technological possibilities for a substantial means to reduce emissions and offer other transport systems improvements.

Road pricing may be included as one measure in the methodology of (TDM), developed to provide the means for alternative solutions to urban transport problems that may not require intensive or extensive construction of new facilities. TDM is commonly seen as a suite of measures that provide alternatives to simply increasing the capacity of a transport system and is usually applied to the road traffic system. A useful definition of TDM is that adopted by the Institution of Engineers, Australia (IEAust), which is:

Travel Demand Management is intervention (excluding provision of major infrastructure) to modify travel decisions so that more desirable transport, social, economic and/or environmental objectives can be achieved and the adverse impacts of travel can be reduced (IEAust 1996).

This definition is not limited to resources and interventions that are strictly on the demand side of the travel equation, but can encompass supply-side measures (eg the allocation of dedicated road space to different road user groups). While infrastructure developments will continue to play a key part in the development of urban transport systems, TDM measures offer the capability to seek alternative solutions that can offer benefits in the amelioration of air pollution in an urban area. The broad objectives of TDM may be seen as:

- the development of an integrated transport and land use system that helps achieve an overall city vision which takes account of the lifestyle issues and needs of the different groups in society;
- the improvement of the accessibility of the transport system for all potential users, including the young, the elderly and the disabled;
- the provision of a safer transport system with higher levels of personal security for users;
- the provision of a transport system that is energy efficient by promoting the use of ecologically sustainable transport modes;
- the improvement of the overall effectiveness and efficiency of the transport system by developing techniques that provide a more optimal balance between the demand for travel and the capacity of the transport system, including more efficient utilisation of existing infrastructure;

- the provision of transport solutions that promote benefits in excess of costs and minimise negative externalities, and
- the reduction in the need to travel by developing non-transport communications systems that are socially acceptable for personal and/or business needs.

Several of these objectives impinge directly on issues concerning air pollution, and thus the investigation of TDM and its influences on the use of transport systems is important in the consideration of the effects of transport system operations on urban air quality.

Induced Traffic

An important and vexed question that has complicated considerations of the economic and environmental impacts of new transport facilities, especially road facilities, is that of the phenomenon of 'induced traffic'. There is a widespread belief that new road construction may lead to more traffic, ie that rather than alleviate congestion a new road may lead to the addition of more traffic load to a network. This additional traffic load (VKT) may bring some benefits, for instance there may be new economic opportunities, or previously suppressed opportunities may now be possible. It may bring some costs, for example new traffic will mean additional fuel consumption and concomitant emissions. Noting that travel is a derived demand, an increase in VKT probably indicates that some additional benefits are accruing to individuals using the road system — otherwise the new travel activity would not occur — but are these individual perceived benefits counteracted by increased community costs, such as pollution?

Alleviating high congestion levels would presumably have an ameliorating effect on the generation of air pollution, if all other factors remained constant. Given the phenomenon of induced traffic, however, the additional VKT that may result from reduced levels of congestion on network elements (eg through road improvements or construction of new facilities) will add additional emissions to the system. If improved traffic conditions induce more traffic to use the network, or existing traffic to travel to more distant destinations, then the extra VKT associated with the new traffic and its effects need to be compared and balanced against the improved fuel and emissions performance of the existing traffic flows.

The actual effects of induced traffic has been the subject of considerable investigation in the United Kingdom in the last few years, with a number of inquiries being undertaken in the past (SACTRA, 1994). The general conclusions of the UK investigations were that induced traffic was likely to be of greatest importance where: (a) a network was operating close to capacity, or (b) the elasticity of demand with respect to travel cost was high, or (c) the implementation of a given scheme would lead to large changes in travel cost. If none of these conditions were met, induced traffic was not likely to be of significance. On this score, it is interesting to note that a recent study conducted by ARRB Transport Research in Melbourne was unable to detect any evidence of induced traffic due to the upgrading of the South Eastern Arterial Road during the early 1990s.

Urban Freight

Urban freight transport plays a vital role in Australian cities but its contribution and impacts are often overlooked, partly because of the dominance of urban passenger transport as an environmental and political issue. Almost all freight in cities is carried by road. The diversity of the transport task in terms of types of goods and patterns of origins and destinations, the short distances and the time sensitive nature of many deliveries mean that road transport is the most appropriate technology. Other transport modes, such as pipelines, barges and rail, can make an important contribution in specific niche markets but overall, road freight is likely to be the dominant mode of urban freight transport for the foreseeable future.

Measures for reducing the emissions derived from urban freight transport activity can be grouped into three categories:

- engine technology and other mechanical aspects of vehicle design;
- land use planning issues; and
- transport logistics.

Many of the advanced technologies that are used to reduce emissions from passenger cars are currently not available or not installed on freight vehicles, particularly diesel powered trucks. There are opportunities for reduced emissions through improved engine and exhaust systems, vehicle aerodynamics, tyre technology and better vehicle maintenance. These opportunities and implications are examined in Chapter 2.

Emissions are also affected by the task performed by the freight vehicle in terms of the locations of origins and destinations. The locations of major freight generating activities such as transport terminals, distribution centres, factories and shopping centres will have a major effect on the pattern of urban freight transport and hence emissions from freight vehicles. These issues of land use planning, zoning, integration of complementary activities and urban infrastructure are examined in Chapter 5.

Opportunities for reduced emissions through improved transport logistics include:

- selecting the best mode of transport for the task;
- improved coordination of pickups and deliveries;
- using the most appropriate vehicle for the task;
- improved driver behaviour;
- increases in vehicle capacity; and
- improved traffic management and reduced stop-start driving.

Unladen road freight vehicles will be producing emissions without any freight transport output. Greater coordination of pickups and deliveries to improve vehicle utilisation has the potential to reduce emissions from road freight. Efficiencies can be achieved through improved routing and scheduling of vehicles, increased back-loading, driver communications and information systems and extended operating hours. Available technologies for vehicle location monitoring, computer aided routing and dispatch, and data and voice communications are discussed in SR3. There are also potential benefits from extended warehouse operating hours to enable trucks to make pickups and deliveries at times of lower road congestion. Most of these measures will be implemented by operators of their own accord in response to competitive pressures but there may be scope for policies that facilitate the uptake of technologies, such as electronic vehicle location and information systems, and provide greater flexibility in operating hours.

For larger transport companies with a diverse fleet, there is already an opportunity to match the vehicle with the task. Smaller operators typically target a specific transport niche and select vehicles accordingly. Therefore there appears to be little scope for external initiatives (policies, regulations, incentives) to facilitate efficient matching of vehicles and tasks.

Poor driving technique can increase fuel consumption by perhaps 10-15 percent, increase engine wear and maintenance costs and lead to increased vehicle emissions. The incidence and effects of poor driving technique can be reduced by training programs and through vehicle technology, notably electronic engine management systems and recording systems such as tachographs that provide monitoring and feedback on driver performance. Most large transport companies are aware of the potential to decrease costs and increase competitiveness through better driving technique. There is scope, particularly for smaller operators, for initiatives that facilitate driver training and promote the environmental and commercial benefits of better driving.

In general, larger road freight vehicles produce less emissions than smaller vehicles when measured on the basis of the tonne-kilometres of freight task. For example, carbon dioxide emissions per tonne-km from articulated trucks are about half those from rigid trucks and around one-tenth those of light commercial vehicles (LCVs). There is, however, limited opportunity to replace LCVs with larger vehicles for courier type operations. Road geometry and restricted access in many urban situations limits the use of articulated trucks.

Improved transport logistics has the potential to reduce emissions from urban freight transport but any package of measures aimed at reducing emissions must recognise that the industry comprises a small number of very large road freight companies, plus a large number of small companies and owner-operators. It is an extremely competitive and largely deregulated industry with low barriers to entry and efficiency on a par with world's best practice. Operators are quick to seize any opportunity that may lead to a competitive advantage so any policies that may lead to a reduction in costs or increase efficiency are likely to be taken up quickly.

Conversely measures that rely on good will and decrease relative competitiveness are likely to be avoided and/or have very slow uptake and hence are likely to be unsuccessful. It follows that a successful package of measures should be targeted at, and accessible, to large and small operators alike, and achieving reductions in emissions through market pressures of efficiency and competition between operators.

The most likely solution to the problem of reducing emission from urban freight is to create an operating environment with the following features: a road system that is conducive to road freight operations; a financial environment that facilitates investment in new technology and an economic environment with pricing signals that encourage operators to achieve reductions in emissions as a consequence of efficiencies demanded by competitive pressures in the marketplace. For example, increased prices for fuel or road use may encourage operators to introduce new technology to retain or enhance competitiveness, with consequent benefits for air quality.

Solutions

Given the influence of transport related factors on emissions in urban areas, a number of policy initiatives and programs for emissions reductions may be proposed. These include measures relating to :

- traffic control and traffic management strategies;
- the use of new (ITS) technologies in urban transport operations, for both freight and passenger travel;
- regulations and enforcement concerning vehicles, fuels and operations;
- traffic constraint and travel demand management measures; and
- economic signals for informed travel choices.

Traffic control and traffic management

Extension and improvement of urban traffic control strategies and a focus on environmental objectives (such as reduced emissions) offers the potential to reduce traffic congestion effects. A reduction of about 5-10 percent is likely in local emissions through improved quality of traffic flow.

The development and use of intelligent, multi-objective, real time, traffic control systems which include air quality measurements amongst their parameters should be encouraged, both as an instrument to improve urban air quality and as a potential export earner. This will build on Australia's previous achievements in area wide traffic control systems and lead the way in the development of new control systems of global interest.

Use of ITS technologies

Advanced technologies applied to traffic control, travel demand management, congestion monitoring and management, vehicle design and operation, fleet operations and scheduling and traveller information services offer potential for reductions in VKT and congestion that will have emissions benefits.

In particular, the following ITS measures should be considered: (1) the use of incident management systems to reduce the occurrence and effects of non-recurrent congestion; (2) the development of advanced traveller information systems to aid individuals in making choices about when, where and how to travel and (3) the application of electronic road pricing schemes to manage recurrent traffic congestion. Each of these measures is technologically feasible, and although the level of social acceptance of road pricing for example has still to be gauged, there are substantial environmental benefits, especially for air quality, to be gained from them.

Regulations and enforcement

Although there is great interest in market based measures to achieve environmental goals, well enforced regulations offer good prospects for reducing the damaging effect of motor vehicles on urban air quality. The United States continues to put major responsibility for controlling the harmful effects of economic activity on regulation, including stringent mandatory goals for vehicle emissions.

Although Australia lacks the body of experienced commissions which regulate much of America's economic activity, it does have competent transport, environment, and planning agencies capable of implementing and enforcing appropriate regulations. For example, Australian states enacted laws which prohibited the sale, on any individual retail site, of the old supergrade, 'leaded' petrol at a lower price than unleaded petrol. This did not interfere with discounting so long as unleaded petrol was discounted at the same time as leaded fuel. The oil companies and petrol retailing industries had no difficulty in conforming with this non-invasive regulation and enforcement required no more than some spot checks. Consequently, mis-fuelling in this country has been virtually unknown.

In contrast, the United States had experienced widespread mis-fuelling, which effectively destroyed catalytic converters, wherever leaded petrol was offered at a lower price.

Traffic constraint and travel demand management

Cars on congested roads are the most serious source of central city air pollution. A widespread and effective measure to limit traffic has been the creation of pedestrian precincts and malls. These encompass a number of blocks in the inner areas of some European cities but in Australia have generally been limited to one or two downtown streets. The Singapore cordon scheme also works as a physical constraint but is primarily a pricing scheme. More drastic constraints on car use have occasionally been applied in some cities (eg Los Angeles) when pollution levels are extremely high, but such measures are only accepted by the community under crisis conditions.

Economic signals for informed travel choices

The economic levers available to governments are primarily the various methods of making motor vehicle use more expensive. There is little evidence that sales taxes on vehicles have any effect on total vehicle kilometres in a community already well equipped with vehicles. Non-selective charges are applied to all vehicle use, primarily the general fuel tax and state fuel franchise fees. A number of charges are selective to some degree, mainly the penal charge on leaded petrol, tolls, congestion charges and parking charges.

The estimated long-run elasticity of demand for kilometres of vehicle travel is -0.3, considerably less price responsive than the demand for petrol. Part of the response to a petrol price rise, in the medium to long term, will be the adoption of more fuel efficient vehicles. Consequently, the fall in fuel consumption resulting from a price rise will be proportionally greater than the fall in kilometres of vehicle travel.

Despite the considerable body of work on price response, the effects of selective charges are not well understood. Price elasticities should be used with caution, for at least the following reasons:

- the impacts of tolls, parking charges or a more general road pricing system depend on the extent to which motorists are able to find ways of minimising the effects on themselves individually;
- one of the responses to peak charges will be to vary the time chosen to make some trips. These trips would not be suppressed but would be made under less congested conditions, with less pollutants per vehicle kilometre but no fewer kilometres travelled. The analysis of such behaviour involves dynamic traffic assignment and the field is a difficult one; and
- a relatively high proportion of the traffic on access roads to the central business district of a city consists of company cars, which will be less responsive to charges.

Commuter car drivers have been studied a great deal because of their influence in determining the required capacity of urban roads and in generating congestion, almost regardless of the road capacity provided. Consequently, they are the targets of most road pricing schemes. Recognition that commuter motorists constitute one of the major sources of urban air pollution is almost an afterthought.

Previous estimation of car travel price elasticity has had difficulty in taking account of the subtle interactions with public transport but current work in Sydney has taken into account the relationships between ticket types for public transport modes and demand for car travel. It turns out that a one percent increase in the cost of a journey by car will lead to a 0.024 percent increase in public transport usage. This suggests little scope for public transport alone to alleviate traffic induced emissions, however admirable a goal this might be.

Fuel taxes have both selective and general impacts on vehicle emissions. The one cent penalty on leaded fuel is a selective means of hastening the scrapping of old cars still using this fuel. The general fuel tax and State fuel franchise fees, comprising more than half of the pump price, are a substantial disincentive to wasteful fuel consumption, whether by driving inefficient cars or by excessive use of cars for commuting to work. Adoption of fuel efficient cars, as well as reduction in fleet size, are medium to long term responses to increases in the real pump price. Corporate and institutional new car buyers, who account for some 40 percent of purchases, may show less concern for fuel efficiency than private buyers who can be expected to include fuel efficiency as a significant factor in car choice. There is a possibility that the rate of adoption of more fuel efficient cars has been reduced as the real price of petrol has dropped. In contrast, the real price of new cars has been rising but this has had more effect on vehicle sales than on total vehicle kilometres of use

The imposition of direct charges for the use of specific roads at particular times has been attracting increasing attention because readily installed electronic technology is becoming available. Charging according to congestion level is now feasible and fairly easy to implement.

The purpose of road pricing is to make the cost that a motorist faces equal to the true social cost of his or her use of the road. As additional vehicles use a road, the quality of service to all users progressively declines. Traffic flows fairly smoothly at about the speed limit but, as the volume increases, each additional vehicle slows the flow and increases the travel time of other vehicles. The overwhelming weakness of such a system is that the individual driver does not pay the cost that he or she is thus imposing on other drivers.

Some recent Australian studies concerned with rectifying this weakness have calculated the following levels of optimal charges for congested roads:

- a uniform 7.6 cents per vehicle-kilometre (Meyrick, 1994);
- a range from 5 to 62 cents per peak vehicle-kilometre calculated by the ARRB model (Luk and Hepburn, 1993); and
- a range of average capital city morning peak charges from 3 to 17 cents per vehicle-kilometre calculated by the BTCE (1996), with maximum charges ranging from 8 cents to $1.26.

The calculated total effect of the BTCE optimal congestion charges in the morning peak in the six largest Australian cities is a reduction of 19 percent in traffic and 29 percent in fuel consumption.

From Figures 41 and 42 it can be seen that alternative road pricing systems applied to an inner area of Melbourne indicated the potential for reductions in emissions during peak periods of up to six percent (for full marginal cost road pricing). The more technologically feasible options of time-based and distance-based road pricing yielded emission reductions of between three and four percent. The optimum size of the road pricing zone could not be determined within the scope of the present investigations and will be the subject of future research and investigation.

Recommendations

The following recommendations are advanced on the basis of the above discussion.

The applications of new technology ('Intelligent Transport Systems', ITS) to the management and control of urban transport offers substantial potential benefits to air pollutant emissions and thus to air quality, and should therefore be pursued as a major priority in Australia.

Travel Demand Management (TDM) measures that indicate to travellers the environmental (and other) consequences of their travel decisions should be implemented. A criterion for the application of TDM measures should be that

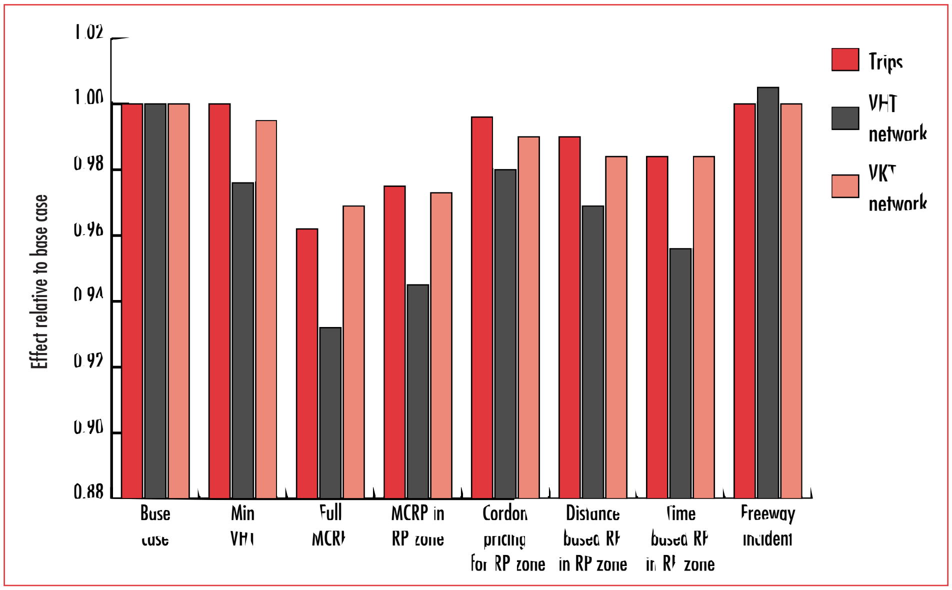

Figure 41: Effect of road pricing on number of trips, vehicle hours travelled and vehicle kilometres travelled: Port Phillip regional network

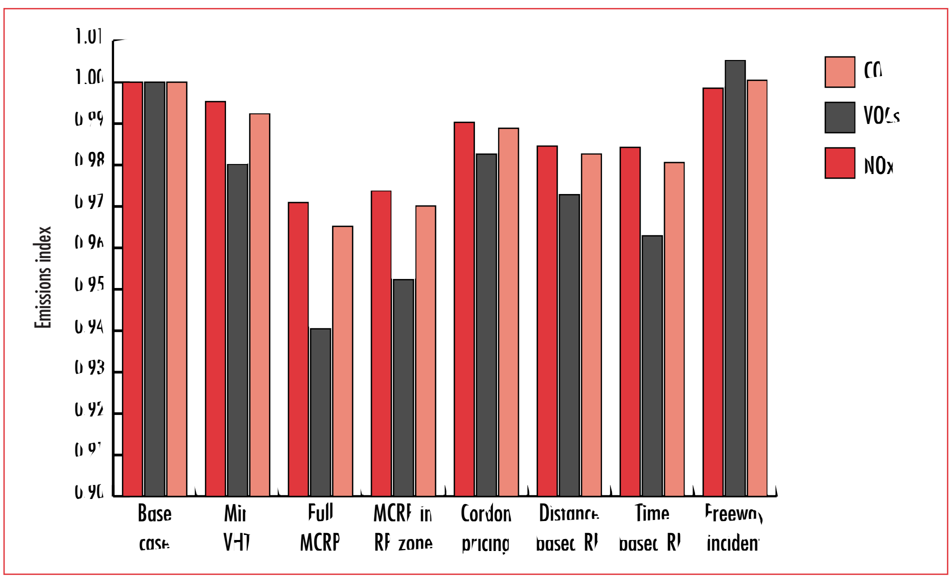

Figure 42: Effect of road pricing on emissions (effect on total traffic emissions into the airshed) for various road pricing regimes — relative levels versus no charges

each measure helps individuals to make informed and intelligent choices which are commensurate with the accessibility and mobility needs of those individuals. These measures will include advanced traveller information systems, real time dynamic traffic control and information (eg on parking availability in CBD areas) and congestion pricing regimes.

Of the ITS and TDM measures considered by the Task Group, electronic road pricing (ERP) is seen to fulfil necessary conditions and has been demonstrated to offer air pollution benefits. The Task Group therefore recommends that ERP systems be considered for Australian cities and that the potential for trial ERP projects in one or more cities should be investigated.

Policy measures to encourage the accelerated uptake of modern vehicle technology, which offer energy and safety benefits as well as substantial environmental benefits, should be formulated. In view of widespread current misconceptions about these benefits, any policy measures should include community education programs to explain and demonstrate the real benefits to be realised from new and forthcoming vehicle technology.

Given that freight transport systems for intra-urban movements will depend on road based transport for the foreseeable future and that there are projections of substantial growth in this area of transport activity, further measures are needed to control emissions from freight vehicles (especially light commercial vehicles). The Task Group recommends that traffic control measures aimed at improving freight vehicle operations should be adopted and that alternative fuels with less potential for emissions should be sought.