Chapter 8 MITIGATION MEASURES

8.1 Introduction

8.1.1 The Strategic Environmental Assessment of the Third Comprehensive Transport Study has demonstrated that air quality and noise environment is likely to deteriorate due to the envisaged expansion of transport infrastructure to meet the needs of the assumed levels of population growth. In order to provide an acceptable transport system while sustaining the economic growth of HKSAR, mitigation measures must be implemented to ensure the deterioration of air and noise are minimized to the maximum practicable extent.

8.2 Air

8.2.1 Introduction

Measures to tackle air pollutant emissions from road transportation can be broadly divided into four categories:

- Emission Control Technologies
- Traffic Control Measures
- Modes of Transport
- Transport Policies

Section 8.2.2 will identify and briefly describe various mitigation measures under these categories and rule out those measures which is not practicable or feasible. Section 8.2.3 will analyse the short-listed mitigation measures in more detail and quantify, where possible, the effectiveness of the short-listed options. Section 8.2.4 will formulate a hypothetical set of mitigation measures which could be implemented in the HKSAR.

8.2.2 Identification of Mitigation Measures

Various mitigation measures to tackle the pollutant emissions from road transport are described in Table 8.2a.

Table 8.2a
Mitigation Measures to Improve Air Quality

Mitigation Measures	Description	Short-list
Emission Control Technologies		
Engine Technologies		
Hybrid Vehicles	A hybrid vehicle is a mixture between traditional combustion engine powered vehicle and electric car. The car is powered by the electric motor whenever possible and hence reducing pollutant emissions.	Yes
Electric Vehicle	Electric vehicles are sometimes referred to as "zero-emission vehicles" because they produce no emissions from the tailpipe. The use of electric vehicles could reduce emissions of carbon monoxide and smog-forming pollutants in urban areas.	Yes
Fuel Cell Vehicles	Like Electric Vehicles, Fuel Cell Vehicles are also considered to be "zero-emission vehicles".	Yes
Tailpipe Emission		
Diesel Catalytic Converters	Diesel Catalytic Converters can reduce the particulate emissions of diesel buses and are mandatory in the USA.	Yes
Particulate Traps on Diesel Vehicles	Could reduce particulate emissions from light goods diesel vehicles.	Yes
Alternative Fuels		
Reformulated Diesel	Sometimes know as "ultra-low sulphur diesel" or "city diesel" depending on the composition. Reformulated diesel reduces pollutant emissions and is commercially available.	Yes
LPG	LPG as a fuel for road vehicles is very common in other countries and minimises particulates emissions and reduces emissions of some other pollutants. The Government has committed to introduce LPG as an alternative fuel for taxis. Introduction of LPG for other vehicles (petrol or diesel) to reduce pollutant emissions can also be considered.	Yes
Natural Gas	The only source of natural gas supply to Hong Kong at present is that used for power generation at the Black Point Power Station. To introduce natural gas as an alternative fuel in additional to the LPG infrastructure will be expensive and may not be cost effective.	No
Hydrogen	Hydrogen is used as a fuel in Fuel Cell Vehicles (see above).	Yes
Methanol	At present, only methanol produced from wood is able to give substantial reductions in pollutant emissions. Using methanol as a vehicle fuel only remains a long term option and is outside the time frame of the CTS-3 study.	No
Ethanol	Similar to Methanol.	No

Mitigation Measures	Description	Short-list
Alternative Power Sources (wind/solar)	Although they are the most environmentally friendly form of energy, these technologies are not envisaged to be commercially viable within the timeframe of the CTS-3 study.	No
Traffic Control Measures		
Traffic Control	The implementation of traffic control schemes can result in reductions in fuel consumption and vehicle emissions.	Yes
Parking Control	Studies have suggested that by doubling parking charges within a city, the car share of the number of trips could be reduced in the central business district by about 13%. However, parking spaces in Hong Kong are already very limited and parking fees are high. People generally will not rely on on-street parking if they decide to take the car to work and there is very little influence on parking fees charged by private companies. Parking control is unlikely to be an effective measure in Hong Kong.	No
Park and Ride	Park and ride schemes provide parking serviced by buses or rail on the fringes of city centres. The aim is to encourage transfers from private to public transport, particularly for journeys into city centres.	Yes
Bus-only Lanes	Bus-only lanes are intended to increase the attractiveness of buses and reduce journey times and hence emissions. Although the traffic speed increases within these priorities lanes, other traffic may be delayed due to less road space which can outweigh any benefits.	No
Car Pooling	Where average occupancies are less than 1.5, filling all car seats with other car drivers would yield a reduction in vehicle emissions of 80%. However, there are important obstacles, notably the inconvenience of scheduling activities, such as commuting, with other people. Since over 80% of journeys made in Hong Kong are already by public transport, car pooling is not a high priority measure.	No
Electronic Road Pricing	A separate study on Electronic Road Pricing (ERP) is currently being conducted and will address environmental issues. ERP is an effective means to control emissions in pollution "hot-spots".	Yes
Modes of Transport		
Maintain attractiveness of public transport	Encourage the use of public transport as a means of managing the growth in vehicle traffic volume.	Yes
Trolley Buses	Trolley buses are a form of "zero-emission vehicle".	Yes
Freight Transport by Rail	Use of rail for freight movement instead of goods vehicles which are one of the main contributors to pollutant emissions from road transportation.	Yes
River Trade Terminal	Marine Transport for goods can reduce the no of trips made by cross boundary made heavy goods vehicles.	Yes

Mitigation Measures	Description	Short-list
Transport Policies		
Vehicle Restraints		
Controlling Vehicle Growth by Capping Number of Vehicles or Applying Fiscal Measures	Any measures to reduce the number of vehicles will reduce pollutant emissions.	Yes
Areas Restrictions		
Areas Restrictions / Heavy Vehicle Restrictions	Reducing the number of vehicles in certain areas is an effective means of tackling air pollution "hot-spots".	Yes
Area Restrictions linked with Air Pollution Index	Area restrictions apply when the API is predicted to be high.	Yes
Others Policies		
Controlling Motorcycle Emissions	At present, there are no controls on emissions from motorcycles in Hong Kong. Introduction of stringent emission standards is planned for the end of 1999.	Yes
Limiting Vehicle Fleet Age	Older vehicles are more polluting due to less stringent emission controls and most often a lack of maintenance.	Yes
Inspection of Maintenance Programme	Significant reductions in pollutant emissions could be achieved with proper maintenance.	Yes
Cycling and Walking	Two of the most environmentally friendly modes of transport.	Yes
Pedestrianisation	In this manner, the sensitive receivers are isolated from the source of pollution.	Yes
Switch off Engines when Stationary	Pollutant emissions may cause nuisance to other road users when vehicles are idling.	Yes
More Frequent Street Cleaning	A large proportion of RSP emissions arises from the resuspension of dust on the road surface due to road/tyre interaction and vehicle movement.	Yes
Intergrated Land Use and Transport Planning	To encourage shorter trips from residential areas to the work place.	Yes

8.2.3 Discussion

Emission Control Technologies - Electric Vehicles

Electric vehicles, sometimes referred to as "zero-emission vehicles (ZEVs)", are gaining attention as an option for improving air quality. Zero tailpipe emissions are particularly attractive in urban areas with serious air pollution problems. Electric vehicles are powered by a battery or set of batteries. Whilst tailpipe emissions are eliminated by this technology, pollutants are released into the atmosphere where the electricity is generated. Other environmental issues include the disposal of end of life batteries. Notwithstanding these issues, electric vehicles and other ZEVs are seen as a way forward to tackle air quality problems in densely populated areas with heavy traffic.

A few electric vehicles are used in Hong Kong but are limited in capability by the available battery technology. The most common batteries in use today (lead-acid) offer a range of only 60 to 70 miles per charge. The typical cost is US$3000 to US$4000 per battery pack and they must be replaced every four years.

In order to encourage the development of electric vehicles, the state of California requires carmakers to sell ZEVs. California is requiring ZEVs to account for 10% of annual sales of vehicles by the year 2003.

Introduction of electric vehicles in Hong Kong is expected to be a viable long term option.

Emission Control Technologies - Fuel Cell Vehicles

Fuel cell vehicles are potentially ZEVs but also have overcome the same limitations of electric vehicles by providing a driving range comparable with that of conventionally fuelled cars with internal combustion engines.

A fuel cell is an electrochemical device that produces electricity from the reaction of hydrogen and oxygen. The only by-product is water. In an electric vehicle, the battery must be recharged on a regular basis whereas a fuel cell is recharged constantly in the sense that recharging the vehicle only requires refilling the fuel tank. The hydrogen fuel required to power the device can be stored directly on the vehicle in tanks or extracted from a secondary fuel such as gasoline or methanol. An onboard reformer would crack one of these fuels into hydrogen and carbon dioxide, venting the CO_2 and conveying the hydrogen to the fuel cell. In the case where a secondary fuel is used, the total pollution load would still be less than that of an internal combustion engine.

Carmakers have plans to launch volume production of fuel cell vehicles by as early as 2004 based on methanol as a secondary fuel. Introduction of fuel cell vehicles into Hong Kong becomes less attractive if fuel cell vehicles use methanol as secondary fuel. If the hydrogen fuel model becomes commercially available, the provision of infrastructure for the fuel and the potential hazards associated with storage and use in a densely populated city such as Hong Kong need to be addressed.

Fuel cell vehicles are not considered viable as a means to tackle air pollution problems in Hong Kong within the timeframe of the CTS-3 study.

Emission Control Technologies - Hybrid Vehicles

Hybrid vehicles are sometimes referred to as dual fuel vehicles. Such a vehicle it is powered by an internal combustion engine and a battery. The internal combustion engine also generates electricity to charge the battery. Depending on the driving conditions, the vehicle is either powered by the internal combustion engine or the battery. Other forms of hybrid are also available where the internal combustion engine is used as an on-board generator to generate electricity to power the motors (also known as Hybrid Electric Vehicles). Hybrid vehicles offer the advantages of both conventional engines and electric vehicles and compensate for the disadvantages of ZEVs in terms of driving range, although pollutant emissions are greater. Although hybrid vehicles are not ZEVs, the technology is ready for commercial application. For examples a Japanese car manufacturer is producing 2000 units per month, utilizing a gasoline combustion engine and a battery. This technology could be utilized as an intermediate measure.

Tailpipe Emissions - Diesel Catalytic Converters

Diesel catalytic converters reduce emissions by utilising chemical reactions on the surface of a the catalyst fitted in a housing through which exhaust gas is passed. Chemical reactions occur within the converters and transform pollutants into harmless gases by means of oxidation and hence this technology is also referred to as Oxidation Converters. In the case of diesel exhaust, the catalyst oxidizes carbon monoxide (CO), gaseous hydrocarbons (HC) and liquid hydrocarbons (HC). The liquid hydrocarbons are adsorbed onto the carbon particles. Studies have shown that oxidation catalysts can reduce total particulate emissions by 40 to 50%. Oxidation catalysts are also effective in controlling smoke and NO_x emissions. The sulphur content of diesel fuel is critical to the effectiveness of the oxidation catalyst technology as high sulphur content diesel can "poison" the catalyst.

Trials have been conducted to retrofit diesel catalytic converters to double decker buses in Hong Kong and positive results have been obtained. A converter which has been in operation for 2 years showed that reductions of CO, HC and particulate emissions by 18%, 33% and 37% could be achieved[1].

Diesel Catalytic Converters are considered to be an effective and viable measure to achieve emissions reductions and improve air quality, especially at the roadside.

Tailpipe Emissions - Particulate Traps

Particulate traps are an effective means of achieving particulates removal from diesel exhaust. Diesel particulates consists of soot (solid carbonaceous materials giving rise to black smoke), a soluble organic fraction (SOF) (unburned hydrocarbons from the lube oil and fuel) and oxides (mainly sulphate derived from sulphur in the fuel). Diesel Catalytic Converters are effective in reducing SOF emissions and particulate traps are effective in reducing soot emissions. Trials on Light Duty Diesel Vehicles

[1] Source: *The Trial of Diesel Catalyst on Double Decker Buses in Hong Kong* by Ha Kong, Hung Hin Wing, Shum Yuet Hung and So Hing Sum present at "Diesel Vehicle Exhaust Treatment Technology and Motorcycle Emissions Workshop 1999" held on 11-12 January 1999.

have been conducted and the results showed a reduction of smoke intensity from 10% to 50%.[2]

Particulate Traps are believed to be a viable means of reducing vehicle emissions, but their effectiveness need to be further studied and trial scheme is being carried out.

Alternative Fuels - Reformulated Diesel

Diesel has the same advantages as gasoline, including excellent quality, a high energy density, easy storage, low production costs and a well-developed distribution network. For these and other reasons, diesel is a popular fuel in the transport sector. In Hong Kong, about 60% of the vechicle-kilometer-travelled was by diesel-fuelled vehicles in 1997 (see Figure 5.2b). Reformulated diesel has a different composition from traditional grades - desulphurized diesel is an example. Table 8.2b shows the reduction in pollutant emissions when compared with traditional diesel. Another advantage of reformulated diesel is that it can be introduced on a relatively large scale within a short period of time, as existing refineries and infrastructure can be used for its production.

Table 8.2b
Practical Example of Exhaust Emission Reduction[3]

Emission	New Volvo Euro II bus + standard 0.05% sulphur diesel	New Volvo Euro II bus + 0.001% sulphur ULSD	Reduction
Hydrocarbons	1.05 gkm^{-1}	0.66 gkm^{-1}	37.1%
Carbon Monoxide	1.50 gkm^{-1}	1.38 gkm^{-1}	8%
Nitrogen oxides	15.44 gkm^{-1}	14.47 gkm^{-1}	6.3%
Particulates	0.38 gkm^{-1}	0.22 gkm^{-1}	42.1%

ULSD is considered a potentially viable and effective measure to manage vehicle emissions in Hong Kong and could be implemented within a short time frame.

Alternative Fuels - Liquefied Petroleum Gas (LPG)

LPG is an oil refinery by-product. It is a light, gaseous fraction that is liquefied by cooling. The advantage of LPG over petrol and diesel is the reduction of pollutant emissions particularly the emission of particulates (see Table 8.2c). Trials of LPG Taxis have been conducted in Hong Kong and the results are encouraging. The

[2] Source: *A Particulate Trap for Light Duty Diesel Vehicles* by C S Cheung, S L Chan, C W Chuen, H K Fung, K K Lo and W T Hung presented at "Diesel Vehicle Exhaust Treatment Technology and Motorcycle Emissions Workshop 1999" held on 11-12 January 1999.

[3] Source: Presentation of New World First Bus Services Limited at "Forum on the Future of Clean Bus Technologies" organised by *Clean The Air* held on 13 March 1999.

Government intends that all new taxis should operate on LPG fuel from the end of 2000, and will encourage all diesel taxis to be replaced with LPG taxis by 2005.

Table 8.2c
Comparison of Exhaust Emissions between New LPG and Diesel Taxis[4]
(Emission Test Cycle - Japan)

Pollutant	Model A		Model B	
	LPG Taxi	Diesel Taxi	LPG Taxi	Diesel Taxi
CO	0.41	0.59	0.33	1
HC	0.19	0.38	0.19	1
NO_x	0.04	0.73	0.01	1
Particulates	Negligible	1	Negligible	0.57
Smoke	Negligible	1	Negligible	0.48

The feasibility of introducing LPG as an alternative fuel for other vehicles will also be considered. LPG as an alternative fuel is an effective means of reducing emissions from selected elements of the vehicle fleet.

Traffic Control Measures - Traffic Control

The implementation of traffic control schemes, eg more effective traffic signals timing by an *Intelligent Transport System,* to reduce vehicle idle time and increase average speeds, can result in reductions in fuel consumption and vehicle emissions provided that additional traffic growth does not take advantage of the reduced degree of congestion. Studies have shown savings in fuel consumption and hence emissions of up to 15 to 18% can be achieved depending on the prevailing traffic conditions.

Traffic control schemes are progressively being implemented in Hong Kong and include the various Area Traffic Control (ATC) schemes. Significant improvements are not envisaged unless high-tech system linked to a satellite-type ERP system is considered.

The effect of traffic control measures is difficult to quantify within the scope of the SEA but such measures will reduce congestion and idling time at junctions and are considered to be a useful means to contribute to the management of air quality in Hong Kong.1

Traffic Control Measures - Park and Ride

Park and ride schemes provide parking facilities serviced by buses or rail on the fringes of city centres, with the aim of encouraging the transfer from private to public

[4] Source: *Consultation Paper - Proposal to Introduce LPG Taxi,* The Government of The Hong Kong Special Administrative Region, October 1998.

transport. However, there is evidence that such schemes may stimulate both additional and longer trips. For example, many trips formerly made entirely by public transport may in part be transferred to cars. Park and ride schemes have the potential to reduce car use within the central area. Some form of central area parking control or other form of traffic restraint will be required to encourage the use of park and ride facilities.

One of the transport scenarios assessed under the CTS-3 Study incorporated the provision of Park and Ride facilities. The air quality assessment based on an emissions inventory showed negligible effects in terms of reducing pollutant emissions (see Section 5.2.3). However, this may be due to the small scale of the Park and Ride facilities assumed in the analysis. The effect may be more apparent when these facilities are more widely used.

Provision of Park and Ride facilities alone is not considered to be an effective measure for reducing air pollution emissions in Hong Kong.

Modes of Transport - Maintain Attractiveness of Public Transport

Over 80% of commuting trips are already made by public transport and Hong Kong has an efficient public transport system which is under going continuous improvement and expansion, eg KCRC West Rail, MTR TKO extension, New World Buses taking over CMB etc. Switching the remaining commuting trips to public transport will be difficult. Nevertheless, it is considered important to maintain the attractiveness of public transport as a means of managing air quality in Hong Kong. The service quality of public transport should be kept at an acceptable level in order not to discourage its use.

Modes of Transport - Trolley Buses

Trolley Buses are buses which are driven by electric motors, with the electricity drawn from overhead power lines. It does not have the limitations as a fixed track (eg Trams on Hong Kong Island and Light Rail in Tuen Mun) and when fitted with an auxiliary engine, it can manoeuver away from the overhead power lines. Trolley buses have zero tailpipe emission under normal conditions and are an attractive and quite widely employed means of reducing emissions in the urban area. A hypothetical case has been tested to investigate the effectiveness of introducing trolley buses in Hong Kong. The traffic consultant has assumed a maximum penetration, up to 70% in some districts, and the results are shown in Table 8.2d. Although the overall reduction in pollutant emissions are relatively small, reduction in districts can be up to 13% (eg Wan Chai, Yau Tsim Mong).

Table 8.2d
Pollutant Emissions Reduction if Trolley Buses are Introduced.

District	% of vkt by Double Decker Buses replaced by Trolley Buses	Reduction in NO_x	Reduction in VOC	Reduction in RSP (Tailpipe)
Central & Western	70%	4%	2%	6%
Wan Chai	70%	9%	3%	13%
Eastern	30%	2%	1%	3%
Southern	0%	0%	0%	0%
Yau Tsim Mong	70%	10%	4%	13%
Sham Shui Po	30%	3%	1%	3%
Kowloon City	30%	2%	1%	3%
Kwun Tong	30%	3%	1%	4%
Wong Tai Sin	30%	2%	1%	3%
Kwai Tsing	30%	2%	1%	2%
Tuen Mun	0%	0%	0%	0%
Island	0%	0%	0%	0%
Yuen Long	0%	0%	0%	0%
Tai Po	0%	0%	0%	0%
North	0%	0%	0%	0%
Sha Tin	50%	4%	2%	6%
Sai Kung	0%	0%	0%	0%
Tsuen Wan	50%	7%	3%	7%
Overall		**2%**	**1%**	**2%**

In terms of environmental benefits, trolley buses are a viable option for tackling air pollution especially in pollution "hot-spots". However, the introduction of trolley buses has implications such as cost, provision of infrastructure, traffic management etc. The feasibility of trolley buses operating in Hong Kong also requires further study. For example, the peak period bus traffic volume is three times the maximum traffic volume faced by the existing trolley bus systems operating elsewhere in the world.

Modes of Transport - Freight Transport by Rail

Goods vehicles and private cars are the main contributors of pollutant emissions in the SAR (see Section 5.2.2). There are limitations on the effectiveness of current emission control technologies to reduce emissions, especially for heavy goods vehicles. A better alternative may be to replace the trips generated by heavy goods vehicles with a more environmentally friendly mode of transport, eg, rail. One of the transport scenarios tested the effectiveness of introducing rail as an alternative for heavy goods vehicles. The results indicated for a single port rail assessed that although the territory-wide reductions in pollutant emissions were relatively small, significant reductions were predicted in some districts where there are usually more journeys made by goods vehicles. However, it should be noted that there are limitations of freight rail transport, not least of which is that it cannot replace internal service deliveries of goods.

Encouraging freight transport by rail is considered to be a viable means of reducing emissions in Hong Kong. The feasibility of freight rail will be further studied in RDS-2.

Modes of Transport - Expand River Trade Terminal Operation

The river trade terminal operations could be expanded which in turn will reduce the no of trips made by cross boundary heavy goods vehicles. As heavy goods vehicles are the main contributors of air pollutants in the North-western New Territories, switch to marine transport can, al least, assist in reducing local air pollution in these areas. However, this will have implications on the operations of the River Trade Terminal and other economic implications which will required further detailed study.

Transport Policies - Vehicle Restraints

The environmental analysis conducted for various transport scenarios suggests that even with the latest vehicle emissions reduction technology, it is difficult to compensate for the anticipated continuous growth in the number of vehicle movement. There are a number of ways to cap vehicle growth, for example, by setting vehicle quotas. Less effective ways will be to increase fuel tax, vehicle registration fees and annual license fees. Capping goods vehicle numbers will also have implications to the Hong Kong economy.

Vehicle restraints are considered to be a viable and potentially valuable means of managing air quality in Hong Kong.

Transport Policies - Area Restrictions (for private vehicles and/or heavy goods vehicles)

An area restriction is unlikely to reduce the territory-wide pollutant emissions as vehicles will tend to bypass the restricted areas and may lead to increase in vkt. However, when area restrictions are implemented with other measures, such as electronic road pricing and pedestrainisation, it can be an effective means of addressing pollution "hot-spots". It is also a mean to encourage public transport as private vehicle will find it less convenient to access these areas. Alternatively, area restrictions could be implemented when the Air Pollution Index is predicted to be high. This is more effective when implemented with an economic instrument, such as electric road pricing. A separate study for ERP is currently being conducted which include environmental assessment which specifically relating to ERP.

Areas restrictions, when implemented with other measures, is considered to be a viable means of managing air quality in Hong Kong.

Other Policies - Controlling Motorcycle Emissions

Although the number of vehicle-kilometers-travelled by motorcycles is relatively small (<3%), the contribution to VOC emissions from motor vehicles is the highest (23% in 1997 and 37% in 2016) due to the current lack of emission control measures. The Government has proposed to impose emission standards on motorcycles by the end of 1999. All imported motorcycles will have to meet the emissions standards in place in either the USA, Japan or EU. This will reduce the VOC emissions from motorcycles by over 70% and hence reduce overall VOC emissions by 25% in 2016.

Controlling motorcycle emissions is a viable and effective means of managing air quality in Hong Kong.

Other Policies - Limiting Vehicle Fleet Age

Studies have shown that small numbers of old and badly maintained vehicles generate a large proportion of pollutant emissions. The principal reason may be that the new vehicles are cleaner and have better fuel efficiency. To benefit from the technological improvement, it is necessary to shorten the replacement time of the vehicle stock. One way to achieve this is to restrict the vehicle age. For example, Singapore only issues licenses to vehicles under 15 years of age. Table 8.2e shows the average vehicle fleet age and the percentage over 10 years and 15 years. The relatively high percentage of Buses over 10 and 15 years of age is due to the existing China Motor Bus fleet which will be phase out gradually since New World First Bus took over the operation from CMB. The scope of limiting fleet age in Hong Kong is restricted as a vehicle of 10 years of age could be still road worthy both in terms of usability and environmental performance assuming proper maintenance. It will be difficult to justify on cost-benefit analysis a mandatory premature retirement of older vehicles. Currently, incentives are given to private car owners to scrap cars over 10 years of age.

Table 8.2e
Vehicle Fleet Age

	Private Car	Public Light Bus	Bus	Light Goods Vehicles	Heavy Goods Vehicles	Taxi
Average Age	6.0	6.8	7.2	6.5	5.5	7.1
% over 10 years	12.8%	13.1%	27.9%	15.7%	16.2%	1.3%
% over 15 years	2.2%	0.2%	8.5%	0.2%	0.0%	0.0%

The attractiveness of this policy could be enhanced with other incentives/disincentives, such as a tax reduction when trading in old cars for new ones, variable annual license fees which increase with the age of the vehicle, and cheaper first registration fees for environmentally-friendly vehicles. To facilitate vehicle buyers in choosing more efficient and cleaner vehicles, a data bank of vehicle fuel and exhaust efficiency should be established and/or an eco-labelling scheme established, similar to the energy efficiency labelling scheme for electrical appliances.

Limiting vehicle fleet age is considered to be a viable means of managing air quality in Hong Kong; however, the scope of implementation requires further investigation.

Other Policies - Strengthening Inspection and Maintenance Programme

In the USA in areas where air quality standards are exceeded, vehicles are required to carry out enhanced inspection and maintenance (I & M) programmes. Emission testing on in-service vehicles is carried out on an annual or biennial basis along with supplementary on-road tests. If the vehicles do not meet the required standards then maintenance is required. The USEPA estimated that an effective I & M programme can yield a 28% reduction in emissions. In Hong Kong, the annual inspection for private car over six years old only includes the "smoke test" and no other emissions testing is required. To aid the implementation and strengthening of the I & M programme, heavier fines on smoky vehicles are planned to be introducted in Hong Kong.

Although the effect of I & M programme is difficult to quantify, it is considered is an effective means of managing air quality in Hong Kong.

Other Policies - Cycling and Walking

The traffic in Hong Kong has proved to be at such a level and intensity that many people consider it too dangerous to use bicycle as an efficient way of commuting across districts to arrive at their place of work. Other factors which will adversely affect the promotion of walking or cycling relatively long distances include the hot and humid summer weather in Hong Kong and the terrain. Nevertheless, the provision of pedestrian/cycle lanes is recommended when planning new town and rural area developments, where appropriate and possible, so that commuting locally within the district becomes more attractive e.g. Sha Tin, Tai Po.

Other Policies - Pedestrianisation

Pedestrianisation in urban areas is an effective way to reduce air pollution in "hot spot" areas; however, other considerations such as the diverted traffic may hinder the implementation of pedestrianisation. Pedestrainisation should be implemented with caution as the diverted traffic could potentially create "hot spots" in other areas. An alternative way to isolate the sensitive receivers (pedestrians) is by the use of enclosed walkways with air-conditioning. Pedestrianisation is discussed in more details in the CTS-3 Main Study.

Other Policies - Switching off Engines when Stationary

Turning off the engine when a vehicle is stationary for extended periods will reduce overall pollutant emissions. A public awareness programme is currently being implemented in Hong Kong to encourage this practice, eg TV commercials, posters/flyers to commercial vehicle drives etc.

Public awareness/education, on this matters or other environmental matters relating to transportation eg regular inspection and maintenance; driving habits, could be extended to new drivers through the driving tests (written).

Other Policies - More Frequent Street Cleaning

A large proportion of RSP is estimated to arise from the resuspension of dust on road surfaces due to road/tyre interaction and vehicle movement. More frequent street cleaning, e.g. street washing, especially at "hot-spots" areas can reduce the amount of RSP being resuspended.

Other Policies - Integrated Land Use and Transport Planning

To design employment centres in New Towns so that journeys made to workplace is minimised. This is a viable means to minimise journeys and hence pollutant emissions by transportation. Integrated Land Use and Transport Planning forms one of the initiatives of the Main Study and is discussed in more details in the main study report.

8.2.4 Possible Mitigation Measures

A summary of the mitigation measures discussed is presented in Table 8.2f.

Table 8.2f
Summary of Mitigation Measures

Mitigation Measures	Status
Euro III	Proposed
LPG Taxi	Proposed
Motorcycle Emissions Control	Proposed
Switch off Engine when Stationary	Proposed
Heavier Fines on Smoky Vehicles	Proposed
Diesel Catalytic Converters	Proposal
Particulate Traps	Proposal
Fare Policies to increase attractiveness of Public Transport	Proposal

Mitigation Measures	Status
More Frequent Street Cleaning	Proposal
Strengthening of Inspection and Maintenance Programme	Proposal
Ultra Low Sulphur Diesel/City Diesel	Proposal
Pedestrianisation	Proposal
Traffic Control Measures	Proposal
Incentive for scraping old cars	Proposal
Financial Incentives on Alternative Fuels	Proposal
Vehicle Restraints Measures	Proposal
Frieght Transport by Rail	Proposal
LPG for Public Light Buses	Proposal
Expand River Trade Terminal Operations	Proposal
Hybrid Vehicles	Proposal
Cycling and Walking paths in all New Towns	Proposal
Trolley Buses	Proposal
Enclosed air-con walkway for pedestrians at "hot-spots" Areas	Possible
Areas Restrictions	Possible
Limiting Vehicle Fleet Age	Possible
Incentives on Environmental Friendly Vehicles	Possible
Integrated Land Use and Transport Planning	Possible
Electric Vehicle	Possible

8.2.5 Analysis of Effective of Mitigation Measures

Various mitigation measures have been discussed and an analysis was undertaken to test their effectiveness. Some of the proposed mitigation measures, such as the Euro III, LPG Taxi and improved motorcycle emissions, have already been accounted for in the analysis presented in Chapter 5. The results indicated that further mitigation measures are required. The High Growth (High End) and Medium Growth scenarios have been analysed using the PATH model. The scenarios included the following set of measures (hereafter referred to as additional measures), which are considered to be practical but which will require further detailed assessment before they could be implemented in Hong Kong.

- 20% reduction in cross boundary traffic relative to the 2016 medium predictions of the Crosslinks Further Study;

- 10% of private vehicles having zero emissions (electric cars or hybrid vehicles);
- introduction of the Euro IV engine plus diesel catalytic converters with Ultra Low Sulphur Diesel to Heavy Goods vehicles and buses could reduce up to 50% of RSP emissions; 40% of Hydrocarbons (HC) emissions and 30% of NO_x emissions; and
- observed trends of vehicle emissions standards and assumed conservative standards for Passenger Vans, Public Light Buses and Light Goods Vehicles (0.49 gkm^{-1} for NO_x; 0.12 gkm^{-1} for VOC and 0.06 for RSP).

High Growth (High End) Scenario with Additional Mitigation Measures

This scenario was taken to represent the worst case conditions and, as such, may represent an upper bound estimate for vehicle and population growth in the SAR in 2016. An appropriate level of infrastructure was assumed in order to meet the objectives for mobility of goods and people within Hong Kong and between Hong Kong and its hinterland. The scenario assumed no constraints on vehicle growth. The above stated measures have been incorporated in addition to the proposed mitigation measures such as Euro III, LPG Taxis and improved motorcycle emission standards. The overall effects on air quality were assessed using the PATH model.

Annual Average Concentrations of Nitrogen Dioxide and RSP

Tables 8.2g and 8.2h present the changes in annual average concentrations of nitrogen dioxide and RSP predicted at each of the AQMS in the SAR in 2016. The results from the Mong Kok AQMS should be treated with caution as the observations are taken from a location within what is widely referred to as a street canyon, whereas the predictions generated by the PATH modelling system are considered more representative of conditions at the ambient AQMS.

Table 8.2g
Annual Average Concentrations of Nitrogen Dioxide (μgm^{-3})

AQMS	1997	Increment	Total
Central/Western	58	1.4	59.4
Mong Kok	85	1.5	**86.5**
Sha Tin	49	3.4	52.4
Yuen Long	61	6.9	67.9
Tsuen Wan	68	0.8	68.8
Kwai Chung	49	3.9	52.9
Sham Shui Po	71	0.5	71.5
Kwun Tong	74	3.1	77.1
Tai Po	50	-1.5	48.5

The assessment indicates that the predicted air quality under this scenario is likely to deteriorate at eight of the AQMS and that improvements are anticipated at the Tai Po

AQMS. In the absence of the additional measures, increases in nitrogen dioxide concentrations were predicted at all nine AQMS. The most significant deterioration is predicted at the Yuen Long AQMS, where the annual average concentration of nitrogen dioxide is predicted to increase by 11%, relative to levels observed in 1997. Without the additional measures assumed in this analysis, an increase of 17% was predicted. Levels at Sha Tin and Kwai Chung are also predicted to increase by about 8% (instead of 14% without additional measures) relative to 1997.

Figure 8.2a (c.f. Figure 5.3a) presents a contour map showing the predicted changes in annual average concentrations of nitrogen dioxide on a territory-wide basis. The figure indicates a general increase in concentrations by approximately 2.5μgm^{-3} relative to 1997 in the western half of the SAR. Such increases are predicted to be particularly marked in the vicinity of Tseun Wan, Tuen Mun and Yuen Long and Sheung Shui/Fanling, with increases of 5 μgm^{-3} anticipated. In the absence of the assumed additional measures, the increase in concentrations in much of the western half of the SAR was predicted to be 5μgm^{-3}. Reductions in concentrations are predicted to occur in Kwai Chung, Kowloon, the central part of Hong Kong Island and Lamma Island. These reductions are anticipated to be approximately 7.5 μgm^{-3} relative to 1997 levels. Similar reductions are also predicted in an area south-east of Sha Tin.

Table 8.2b
Annual Average Concentrations of RSP (μgm^{-3})

AQMS	1997	Increment	Total
Central/Western	51	3.0	54.0
Mong Kok	57	6.1	**66.1**
Sha Tin	49	6.0	55.0
Yuen Long	58	6.8	**64.8**
Tsuen Wan	54	1.7	**55.7**
Kwai Chung	46	3.8	50.8
Sham Shui Po	57	4.0	**61.0**
Kwun Tong	56	4.0	**62.0**
Tai Po	59	0.7	**59.7**

The total number of AQMS deemed to be out of compliance with the annual average AQO for RSP will be reduced to six, from the eight stations predicted to be out of compliance without the additional measures in place. Concentrations are still predicted to increase at all of the AQMS. At Yuen Long the annual average is anticipated to increase relative to 1997 by 12%, to approximately 65 μgm^{-3} (67 μgm^{-3} without additional measures.)

Figure 8.2b (c.f. 5.3b) shows the predicted changes in RSP levels on a territory-wide basis. Increases of 5 to 7.5 μgm^{-3} are predicted in the Mong Kok, Tuen Mun and Yuen Long areas. In most of the western part of the New Territories, concentrations are predicted to increase by between 2.5 and 5 μgm^{-3} relative to 1997 levels. As predicted for nitrogen dioxide, decreases in the predicted concentrations are anticipated in the southern tip of the Kowloon Peninsula (Hung Hom and Tsimshatsui). Concentrations are also predicted to decline in the Wan Chai and Causeway Bay areas on Hong Kong Island by up to 15 μgm^{-3}.

Daily Average Concentrations of Nitrogen Dioxide and RSP

Table 8.2i presents the changes in the daily average concentrations of nitrogen dioxide and RSP predicted to occur under conditions typical of a photochemical smog episode in the SAR. As episodes of photochemical smog are all slightly different from each other and attributable to slightly different factors, the results presented in this analysis should not be taken as being applicable to all episodes. The table also shows the threshold concentration for observations in 1997. The threshold concentration is used to determine the number of exceedances of the AQO anticipated in 2016. For example, at the Central/Western AQMS, an increase of 15.8 μgm^{-3} is predicted in 2016 for nitrogen dioxide. In order to result in an exceedance of the AQO, the concentration reported in 1997 would therefore have to be greater than 134.2 μgm^{-3}. The database for air quality in 1997 is therefore searched to identify the number of days in 1997 on which the daily average concentration was in excess of 134.2 μgm^{-3} and this statistic is used as the basis for estimating the number of exceedances.

Table 8.2i
Changes in Daily Average Concentrations (μgm^{-3}) under Typical Photochemical Smog Conditions

AQMS	Nitrogen dioxide	Threshold	RSP	Threshold
Central/Western	15.8	134.2	5.7	174.3
Mong Kok	-1.3	151.3	9.9	170.1
Sha Tin	-3.1	153.1	7.0	173.0
Yuen Long	-1.8	151.8	1.4	178.6
Tsuen Wan	-3.6	153.6	2.1	177.9
Kwai Chung	-4.5	154.5	6.0	174.0
Sham Shui Po	-1.6	151.6	5.6	174.4
Kwun Tong	-0.2	150.2	8.9	171.1
Tai Po	-2.8	152.8	2.1	177.9

The predictions indicate that nitrogen dioxide concentrations at most of these stations would be likely to decrease under photochemical smog conditions, relative to levels reported in 1997. In the absence of the additional measures, nitrogen dioxide concentrations were predicted to increase at all stations. The number of exceedances reported at Mong Kok is expected to reduce from 6 to 5; from 4 to 2 at Kwun Tong and from 1 to 0 at Kwai Chung. The numbers of exceedances at Sham Shui Po and Tai Po are predicted to remain at 3 and 1, respectively.

Figure 8.2c presents the predicted changes in 24-hour nitrogen dioxide concentrations during a photochemical smog event. When compared to Figure 5.3c, it can be observed that reductions are predicted across the New Territories and Lantau Island with additional measures in place, whereas increases are predicted across the whole of SAR without the additional measures.

Exceedances of the daily average AQO for RSP (180 μgm^{-3}) were predicted to fall from 3 to 2 at Mong Kok and remain the same (1 exceedance) at Sha Tin and Kwun Tong, thereby not reducing the number of non-complaint AQMS. Figure 8.2d presents the predicted territory-wide changes in RSP concentrations. The daily average RSP concentration is predicted to increase by approximately 15 μgm^{-3} in the Central/Wan Chai areas without additional measures (c.f. Figure 5.3d). The increase with the additional measures in place is predicted to be about 7.5 μgm^{-3}.

Maximum Hourly Average Concentrations of Nitrogen Dioxide and Ozone

Table 8.2j presents the predicted changes in the maximum hourly average concentrations of nitrogen dioxide and ozone under typical photochemical smog conditions. In addition to the presentation of predictions at each of the AQMS, the table also shows the threshold concentration and the maximum increase predicted in the model domain. The latter is considered particularly important for the ozone predictions as these are likely to be at a maximum some distance downwind of the urban area.

Table 8.2j
Changes in Maximum Hourly Average Concentrations (μgm^{-3}) under Typical Photochemical Smog Conditions

AQMS	Nitrogen dioxide	Threshold	Ozone	Threshold
Central/Western	19.5	280.5	-11.8	251.8
Mong Kok	5.4	294.6	4.3	235.7
Sha Tin	-4.1	304.1	7.0	233.0
Yuen Long	-7.7	307.7	0.9	239.1
Tsuen Wan	-12.7	312.7	2.3	237.7
Kwai Chung	-9.1	309.1	-0.1	240.1
Sham Shui Po	0.0	300.0	2.0	238.0
Kwun Tong	11.8	288.2	3.9	236.1
Tai Po	-7.4	307.4	0.7	239.3
Maximum	36.4 Chai Wan	N/A	15.2 Junk Island	N/A

The number of exceedances reported at Mong Kok is predicted to decrease from 5 to 4. The number of exceedances will remain the same at Sham Shui Po and Kwun Tong, relative to the scenario without additional measures. Therefore the Mong Kok AQMS will remain out of compliance with AQO, even with the additional measures in place. Figure 8.2e presents the predicted changes in peak nitrogen dioxide concentrations on a territory-wide basis. The most significantly impacted areas rare predicted to remain in Chai Wan and Lei Yue Mun, where increases of approximately 30 μgm^{-3} are predicted as was the case for the scenario without the additional measures. However, significant reductions are observed across the New Territories with the additional measures in place (c.f. Figure 5.3e).

Peak ozone concentrations are predicted to decrease at two AQMS. The predicted number of exceedances of the hourly AQO at Sha Tin remains at 3 and hence the AQMS will remain in compliance. Figure 8.2f shows the predicted changes in maximum hourly ozone concentrations. Decreased levels of ozone are predicted along the northern and western shore of Hong Kong Island and increases are anticipated across the New Territories.

Conclusions

As stated in the introduction, the High Growth (High End) scenario is considered to represent the worst case scenario in terms of air quality impacts. The following general conclusions can be drawn from the analysis presented above.

Annual average concentrations of nitrogen dioxide and RSP

- Mong Kok continued to be non-compliant with the AQO even with additional mitigation measures.
- Non-compliances with the AQO for RSP were predicted to reduce from eight to six with the additional measures.

Maximum daily average concentrations of nitrogen dioxide and RSP

- When comparing the scenarios with and without additional measures, the number of exceedances of the twenty four hour average AQO for nitrogen dioxide predicted at Mong Kok is expected to reduce from 6 to 5; from 4 to 2 at Kwun Tong and from 1 to 0 at Kwai Chung. The numbers of exceedances at Sham Shui Po and Tai Po are expected to remain at 3 and 1 respectively.
- Exceedances of the daily average AQO for RSP (180 μgm^{-3}) were predicted to reduce from 3 to 2 at Mong Kok and to remain at one per annum at Sha Tin and Kwun Tong.

Maximum hourly average concentrations of nitrogen dioxide and ozone

- The number of exceedances of the hourly nitrogen dioxide AQO predicted at Mong Kok could decrease from 5 to 4. The numbers of exceedances are expected to remain the same at Sham Shui Po and Kwun Tong, if additional measures are implemented.
- The predicted number of exceedances of the 1-hour AQO for O_3 at Sha Tin was predicted to remain at 3, ie the AQMS remains compliant.

Medium Growth Scenario with Additional Mitigation Measures

This scenario includes policy measures to restrain the vehicle growth rate and an associated reduced level of infrastructure provision. The above stated set of additional measures has been incorporated in the analysis to supplement the committed measures.

Annual Average Concentrations of Nitrogen Dioxide and RSP

Tables 8.2k and 8.2l present the changes in annual average concentrations of nitrogen dioxide and RSP in 2016 under the medium growth scenario.

Table 8.2k
Annual Average Concentrations of Nitrogen Dioxide (μgm^{-3})

AQMS	1997	Increment	Total
Central/Western	58	-1.0	57.0
Mong Kok	85	-1.4	**83.6**
Sha Tin	49	1.0	50.0
Yuen Long	61	4.8	65.8
Tsuen Wan	68	-0.6	67.4
Kwai Chung	49	1.8	50.8
Sham Shui Po	71	-2.1	68.9
Kwun Tong	74	1.1	75.1
Tai Po	50	-2.9	47.1

Reductions of nitrogen dioxide are predicted at five AQMS, only one reduction was predicted without additional measures in place. The Mong Kok AQMS will remain non-compliant with the AQO. The territory-wide changes of nitrogen dioxide concentrations are presented in Figure 8.2g. Increases of over 2.5 μgm^{-3} are predicted in the western half of the New Territories and across the south eastern sector of Hong Kong Island. Significant reductions are predicted in the urban areas, including Kowloon, Central and Wan Chai/Causeway Bay. In these areas, reductions in the order of 15 μgm^{-3} relative to 1997 levels are predicted (c.f. Figure 5.3m). It should also be noted that under this scenario, improved air quality is predicted for much of the western half of Hong Kong Island, in the Tuen Mun/Yuen Long Valley and in Tsing Yi/Kwai Chung.

Predicted changes in annual average RSP concentrations are presented in Table 8.2l for each of the AQMS in the EPD network.

Table 8.2l
Annual Average Concentrations of RSP (μgm^{-3})

AQMS	1997	Increment	Total
Central/Western	51	0.7	51.7
Mong Kok	**60**	2.3	**62.3**
Sha Tin	49	3.1	52.1
Yuen Long	**58**	4.0	**62.0**
Tsuen Wan	54	0.8	**54.8**
Kwai Chung	46	2.0	49.0
Sham Shui Po	**57**	1.5	**58.5**
Kwun Tong	**56**	2.2	**60.2**
Tai Po	**59**	-0.6	**58.4**

Predicted RSP concentrations at the AQMS showed 6 non-compliances with the AQO, a reduction from 8 when compared to the scenario in which no additional measures were assumed.

Territory-wide changes in RSP levels are presented in Figure 8.2h. It is evident that concentrations in the NWNT, West Kowloon and North Point are predicted to increase by a lesser extent than under the scenario without the additional measures (c.f. Figure 5.3n). The majority of the SAR is predicted to have increased levels of RSP, the major exceptions being a central area of Hong Kong Island and Lamma, Kwai Chung and Sha Tin. Increases in excess of 2.5 μgm^{-3} are predicted to occur in Tuen Mun, Tsuen Wan, Mong Kok and in two areas close to the boundary.

Daily Average Concentrations of Nitrogen Dioxide and RSP

Table 8.2m presents the changes in the daily average concentrations of nitrogen dioxide and RSP predicted to occur under conditions typical of photochemical smog. The table also shows the threshold concentration for observations in 1997, beyond which there is a strong probability that the AQMS would exceed the AQO for either nitrogen dioxide or RSP.

Table 8.2m
Changes in Daily Average Concentrations (μgm^{-3})
under Typical Photochemical Smog Conditions

AQMS	Nitrogen dioxide	Threshold	RSP	Threshold
Central/Western	10.0	140.0	3.1	176.9
Mong Kok	-8.7	158.7	3.9	176.1
Sha Tin	-8.4	158.4	2.1	177.9
Yuen Long	-3.5	153.5	0.5	179.5
Tsuen Wan	-7.4	157.4	0.5	179.5
Kwai Chung	-11.0	161.0	1.9	178.1
Sham Shui Po	-8.8	158.8	1.9	178.1
Kwun Tong	-6.4	156.4	3.7	176.3
Tai Po	-6.7	156.7	0.5	179.5

Analysis of the complete set of AQMS data for 1997 indicates that the number of exceedances of the NO_2 standards reported at Mong Kok is expected to drop from six to three per annum, an indication that this station will remain out of compliance with the AQO. At the Sham Shui Po and Kwun Tong AQMS, exceedances of the AQO are anticipated to reduce from three (without additional measures) to two (with additional measures).

Figure 8.2i presents the predicted territory-wide changes in nitrogen dioxide concentrations during a photochemical smog event. Reduced concentrations are predicted for the majority of the SAR and all of the New Territories a greater area than is shown in Figure 5.3o which assumes that the additional measures are not applied. The most marked area of increased concentrations is along the northern and eastern shore of Hong Kong Island and down the East Lamma Channel.

Two exceedances of AQO for RSP are predicted at Mong Kok AQMS without the application of additional measures. When additional measures are assumed, the number of exceedances is reduced to 1, which renders this station compliant. One exceedance at both Sha Tin and Kwun Tong was predicted.

Figure 8.2j presents the predicted changes in RSP levels across the SAR. The extent of increases in RSP concentrations is less than the scenario in which additional measures are not in place. (c.f. Figure 5.3p). However, an increase in RSP levels is predicted for all parts of the SAR. Increases of greater than 2.5 μgm^{-3} are predicted for Kowloon, Kwun Tong and the western half of Hong Kong Island.

Maximum Hourly Average Concentrations of Nitrogen Dioxide and Ozone

Table 8.2n presents the predicted maximum hourly average concentrations of nitrogen dioxide and ozone under typical photochemical smog conditions. In addition to the presentation of predictions at each of the AQMS, the table also shows the threshold concentration and the maximum increase predicted in the model domain.

Table 8.2n
Changes in the Maximum Hourly Average Concentrations (μgm^{-3}) under Typical Photochemical Smog Conditions

AQMS	Nitrogen dioxide	Threshold	Ozone	Threshold
Central/Western	14.7	285.3	-7.4	252.2
Mong Kok	-3.0	303.0	12.3	245.1
Sha Tin	-11.6	311.6	11.2	236.8
Yuen Long	-15.3	315.3	1.7	239.3
Tsuen Wan	-27.9	327.9	3.8	239.8
Kwai Chung	-24.9	324.9	-1.1	240.3
Sham Shui Po	-11.3	311.3	9.1	239.3
Kwun Tong	2.3	297.7	13.9	238.8
Tai Po	-20.5	320.5	1.2	239.4
Maximum	23.3 Junk Island	N/A	6 Junk Island	N/A

The number of exceedances at the Mong Kok AQMS is predicted to reduce from 4 to 3 with the additional measures in place, which will render the station compliant with the AQO. No non-compliant AQMS are predicted, although exceedances are still predicted at Shum Shui Po and Kwun Tong.

Figure 8.2k presents the predicted changes in peak nitrogen dioxide concentrations on a territory-wide basis. It is evident from the figure that significant decreases in concentrations are predicted over quite large areas of the SAR, particularly in the New Territories and Hong Kong Island South. Reductions in NO_2 concentrations in these areas range from 5 μgm^{-3} to in excess of 20 μgm^{-3}. The principal areas of increased concentrations are to the east of Hong Kong Island, in the vicinity of Chai Wan and Tseung Kwan O and in Central/Western.

Three exceedances of hourly O_3 concentrations are predicted at Sha Tin, which is the same as the Medium Growth scenario without additional measures.

Figure 8.2l shows the predicted changes in ozone concentrations across the SAR, most notable are the significant increases in ozone levels relative to 1997 in an area extending from Sha Tin to Tseung Kwan O.

Conclusions

The following general conclusions can be drawn from the analysis presented above.

Annual average concentrations of nitrogen dioxide and RSP

- The Mong Kok AQMS will remain in non-compliant with the annual average AQO for NO_2.
- Non-compliances with the annual average AQO for RSP are predicted to reduce from six to five with additional measures.

Maximum daily average concentrations of nitrogen dioxide and RSP

- The number of exceedances of the daily nitrogen dioxide AQO predicted at Mong Kok is expected to drop from six to three per annum, an indication that this station will probably remain out of compliance with the AQO. At the Sham Shui Po and Kwun Tong AQMS, exceedances of the AQO are anticipated to reduce from three to two, with additional measures in place.
- Two exceedances of the AQO for RSP are predicted at Mong Kok AQMS without additional measures. When additional measures are assumed, the number of exceedances is reduced to 1, which renders this station compliant. One exceedance at both Sha Tin and Kwun Tong continues to be predicted.

Maximum hourly average concentrations of nitrogen dioxide and ozone

- Exceedances at the Mong Kok AQMS will be reduced from 4 to 3, rendering the station compliant with the AQO. No non-compliant AQMS are predicted, although exceedances at still predicted at Sham Shui Po and Kwun Tong.
- Three exceedances of the hourly O_3 AQO are predicted at Sha Tin, which is the same as the Medium Growth scenario without additional measures.

Discussion

Table 8.2o and 8.2p presents the comparison of the predicted numbers of non-compliant AQMS and exceedances for the High and Medium growth scenarios with and without additional measures (ie those listed at the beginning of Section 8.2.5 for testing purposes).

Table 8.2o
Comparison of Predicted Numbers of Non-compliant AQMS in the Year 2016 with and without Additional Measures

	Ozone	RSP		Nitrogen dioxide			Total
Averaging time	1-hr	24-hr	1 year	1-hr	24-hr	1 year	
1997	0	0	5 (KT, MK, SSP, TP, YL)	1 (MK)	3 (KT, MK, SSP)	1 (MK)	10
Medium Growth	0	1 (MK)	6 (MK, SSP, KT, TW, YL, TP)	1 (MK)	3 (MK, SSP, KT)	1 (MK)	12
Medium Growth with additional measures	0	0	6 (MK, SSP, KT, TW, YL, TP)	0	3 (MK, SSP, KT)	0	9
High Growth (High End)	0	1 (MK)	8 (CW, MK, SSP, KT, TW, S, YL, TP)	1 (MK)	3 (MK, SSP, KT)	1 (MK)	14
High Growth (High End) with additional measures	0	1 (MK)	6 (MK, SSP, KT, TW, YL, TP)	1 (MK)	3 (MK, SSP, KT)	0	11

Notes:
(i) CW - Central/Western, MK - Mong Kok, SSP - Sham Shui Po, KT - Kwun Tong, KC - Kwai Chung, TW - Tsuen Wan, S - Sha Tin, YL - Yuen Long, TP - Tai Po
(ii) Hourly concentrations which exceed the AQO more than three times per year will be considered as non-compliant;
(iii) Daily concentrations which exceed the AQO more than once per year will be considered as non-compliant.

Table 8.2p
Comparison of Predicted Numbers of Exceedance at AQMS in the Year 2016 with and without Additional Measures

	Ozone	RSP		Nitrogen dioxide			Total
Averaging time	1-hr	24-hr	1 year	1-hr	24-hr	1 year	
1997	3 (S) 1 (CW)	1 (S) 1 (KT)	5 (MK, SSP, KT, YL, TP)	4 (MK) 2 (KT) 2 (SSP)	6 (MK) 3 (SSP) 2 (KT) 1 (TP)	1 (MK)	32
Medium Growth	3 (S)	2 (MK) 1 (S) 1 (KT)	6 (MK, SSP, KT, TW, YL, TP)	4 (MK) 3 (KT) 2 (SSP)	6 (MK) 3 (SSP) 3 (KT) 1 (TP)	1 (MK)	36
Medium Growth with additional measures	3 (S)	1 (MK) 1 (S) 1 (KT)	5 (MK, SSP, KT, YL, TP)	3 (MK) 2 (KT) 1 (SSP)	3 (MK) 2 (SSP) 2 (KT) 1 (TP)	1 (MK)	26
High Growth (High End)	3 (S)	3 (MK) 1(S) 1(KT)	8 (CW, MK, SSP, KT, TW, S, YL, TP)	5 (MK) 3 (KT) 2 (SSP)	6 (MK) 3 (SSP) 4 (KT)	1 (MK)	42

	Ozone	RSP		Nitrogen dioxide			Total
Averaging time	1-hr	24-hr	1 year	1-hr	24-hr	1 year	
					1 (TP) 1 (KC)		
High Growth (High End) with additional measures	3 (S)	2 (MK) 1 (S) 1 (KT)	6 (MK, SSP, KT, TW, YL, TP)	4 (MK) 3 (KT) 2 (SSP)	5 (MK) 3 (SSP) 2 (KT) 1 (TP)	1 (MK)	34

Notes:

(i) CW - Central/Western, MK - Mong Kok, SSP - Sham Shui Po, KT - Kwun Tong, KC - Kwai Chung, TW - Tsuen Wan, S - Sha Tin, YL - Yuen Long, TP - Tai Po

(ii) Hourly concentrations which exceed the AQO more than three times per year will be considered as non-compliant;

(iii) Daily concentrations which exceed the AQO more than once per year will be considered as non-compliant

The analysis indicates that general improvements can be expected from the implementation of additional mitigation measures (ie those listed at the beginning of Section 8.2.5). This improvement is less significant for RSP than for NO_2. A significant percentage of the RSP emissions are generated from sources other than tailpipe emissions i.e. paved road dust. Such emissions are related to the number of vehicle-kilometre-travelled and cannot be readily reduced, except by traffic management to reduce traffic or physically removing the road dust to reduce the potential for resuspension.

Although improvements in air quality were predicted to arise from the implementation of the additional measures, exceedances of the AQOs are predicted to continue. The current emission control technology is unlikely to deliver major improvements especially for heavy goods vehicles which are significant contributors to NO_x and RSP emissions. It is evident that attaining a territory-wide improvement in air quality would require more than just the application of emission control technologies. Whilst this conclusion is demonstrated for the SAR as a whole, it is nevertheless acknowledged that at street level, emissions reduction techniques would yield significant benefits and should be implemented.

Of the pollutants addressed in the evaluation, RSP continues to be a major concern. It is anticipated that even with additional measures in place, non-compliances with the AQO for annual average concentrations would continue to be reported. This is attributed to the following:

- elevated background levels due to sources outside Hong Kong;
- the direct relationship between vehicle-kilometres-travelled and paved road dust emissions.

Tackling the continuing problems associated with ambient levels of RSP simply by addressing the transport sector in Hong Kong is unlikely to bring the AQMS into full compliance. Therefore, the cost effectiveness of mitigation measures required to produce reduction in traffic needs to be further investigated.

8.3 Noise Mitigation Measures

It is acknowledged that Hong Kong is unique in many ways. The land area that could be profitably used is small while the pressure exerted by a fast growing population is immensely acute. High rise and densely located residential building clusters form the principal feature of the primarily urban landscape. Such unique characteristics have always implied that it would be no easy task to mitigate road traffic noise.

While such unique characteristics are posing great challenges to policy makers and environmental noise professionals, it should be reminded that the abatement of road traffic noise is really an international battlefront that knows no territorial boundaries. Decades of proven overseas experience has already provided much valuable guidance for Hong Kong to develop its own approach to tackle the noise disturbances associated with road traffic in the past 15 or so years. Many of these proven and still advancing measures could point the way to further addressing the road traffic noise issue in the CTS-3 context.

It would be an ideal case if road traffic noise disturbances could be totally eliminated. But the Consultants recognize that because of past oversights (environmental issues were not adequately considered up to the mid 1980s) and unique urban landscape characteristics of Hong Kong, it would be unrealistic to demand total compliance within the CTS-3 context. The pragmatic approach that has been adopted was to strive to meet the relevant established recommended criteria wherever practicable. Opportunities have been explored to innovatively deal with the traffic noise issue with not only technical but other means. One of the aims is to try to ensure that we would, if possible, not experience in future years deteriorations over the year 1997 baseline conditions.

8.3.1 Identification of Mitigation Measures

When one approaches the issue of identifying road traffic noise mitigation measures, it would be helpful to group the potential measures into different categories in accordance with their nature. While there may be certain overlaps in their respective scopes, the following groupings could be considered:

Policy initiatives:
- more extensive network of rail service
- putting new roads underground
- pedestrianisation

Engineering measures:
- more stringent vehicle noise emission standards
- engine encapsulation for heavy vehicles
- trolley buses

Near or at source measures:
- more extensive use of low noise surface
- consideration of retrofitting existing roads

Management possibilities:
- traffic management on noise grounds
- speed regulations

The Consultants recognise that the government is already putting much emphasis to address road traffic noise problems via the planning front. It is now an established practice whereby landuse considerations that are relevant to noise along new roadway corridors will be accounted for while considering new developments. The Consultants appreciate the effectiveness of such an approach and this on-going practice will not be elaborated in this report.

8.3.2 Discussion of Mitigation Measures

Many noise mitigation measures would have cost implications. These may be financial or in other forms. To have a more macro view, it will be helpful to note that not just environmental mitigation measures, but measures with other aims and purposes, have cost and related implications too.

For example, one of the reasons of establishing urban clearway zones (ie to prohibit parking and to restrict loading and unloading during certain hours) is to facilitate vehicle movements. But because the loading and unloading restrictions are in place, people may have to drive extra distances before they could pick up someone or something and this would have cost and time implications. For business located in the vicinity, the restrictions may also have financial implications. As an illustration it is obvious therefore that commonly accepted traffic facilitation measures (and not just environmental mitigation measures) also have social cost implications.

The following discussions on noise mitigation measures generally follow the order and categorisations proposed in the previous section.

8.3.2.1 Policy Initiatives

More extensive network of rail services

Rail services are not noise pollution free. But in the Hong Kong context noise associated with rail operations is much easier to deal with than road traffic noise. This is true not just on the technical side but is also applicable to the institutional and statutory frameworks of control too.

Rail vs. Road - Control Approaches

- Noise from rail services is controlled under objective criteria and assessment methodologies as promulgated in the Technical Memorandum for the Assessment of Noise from Places other than Domestic Premises, Public Places or Construction Sites (IND-TM) issued under the Noise Control Ordinance (NCO, Chapter 400). This is a statutory document and the rail operators have obligations to achieve the relevant emission limits. In case the operators fail to comply with such requirements, the government could resort to legal avenues to address any shortcomings observed during the operations.

On the other hand, road traffic noise is primarily addressed during the design stage of a road under the planning or semi-statutory process. Before the coming into operation of the Environmental Impact Assessment Ordinance (EIAO, Chapter 499) in April 1998, the noise standards published under the Hong Kong Planning Standards and Guidelines provided the basis of planning against road traffic noise. The Technical Memorandum on Environmental Impact Assessment Process (EIAO-TM), promulgated under the EIAO, is now the vehicle whereby road traffic noise is assessed.

There have been discussions in the public arena on whether rail and road traffic noise should be similarly controlled under a single criterion. There are also debates on the appropriateness and adequacy of the current rail and road noise standards. These issues are however outside the scope of this report. It is assumed that the currently adopted criteria could be used as general demarcations on whether excessive exposure situations have been triggered.

In terms of the widespreadness of the impacts, rail noise holds a much less prominent position when compared to that of road traffic noise. It has been estimated by the Environmental Protection Department that committed rail noise mitigation measures on the existing lines would benefit approximately 100,000 people, on a territory wide basis. It is therefore logical to assume that the size of the population affected by rail noise would likely be fewer than this number. This CTS-3 study estimated that there are already some 429,000 people exposed to excessive road traffic noise when only selected key roadway sections are considered. (Such a figure was in conjunction with the roadways scoped and screened under CTS-3, and should be used for scenarios comparison only. It is not to be regarded as an accurate and comprehensive reflection of the territory wide situation.)

The 100,000 number associated with excessive rail noise exposure is fast declining as the rail corporations are on course in implementing a series of abatement measures. It is anticipated that most of the problems associated with the existing rail lines will largely be solved by year 2002/2003.

All new rail lines are now designed to meet the relevant statutory noise emission limits. It is therefore not expected that there will be any rise in the size of population affected by excessive rail noise, even with the extension (both committed and proposed) of the rail network.

On the other hand, the population affected by excessive traffic noise from existing roadways is not expected to see quick relief, if any. While the government's planning process has been successful in limiting exposure from new or upgraded roadways, there is currently no policy to deal with problems arising from the past before the planning mechanism was put into operation.

As for new or upgraded roadways, even with the planning process fully in place, there are also cases whereby mitigation measures are not recommended (or found not able) to provide adequate protection to certain receivers. This may be due to engineering, safety,.topographical or other overriding site-specific constraints.

It could be seen that, in the Hong Kong context, rail noise is much more effectively controlled technically, institutionally and statutorily.

Rail vs. Road - Forward Looking

While Hong Kong would need more new roads to cope with the development pressure of the territory, it is also imperative to develop a stronger preference towards using rail as a means of meeting the associated transport demands. The Consultants are not against building new roads. But rather, because of its generally quieter nature and the relevant local mechanisms of control, we would like to see an extensive rail network as the primary transport service provider wherever applicable. And the traditional view that roads are to hold the leading position should be challenged.

Rail vs. Road - Noise Effectiveness

For the purpose of visualizing the potential noise benefits of adopting rail rather than road, a couple of sensitivity tests have been performed.

The first test is related to the proposed Hong Kong Island South Link running from the Wan Chai/Causeway Bay area to Aberdeen. It has been estimated that the operation of this rail link has the potential of bringing about a 3% improvement to the traffic noise levels of the entire Hong Kong Island.

The second test is on the West Rail running from Kowloon to Tuen Mun via Yuen Long which is now under construction. It has been estimated by the Kowloon Canton Railway Corporation that the West Rail would divert the equivalent of some 2,500 bus loads of passengers from the road to rail mode. This, when transferred to road traffic noise terms, would mean that the West Rail could bring about a 6% improvement to the Tuen Mun corridor.

Putting new roads underground

It is acknowledged that putting new roads underground would generally incur more construction and maintenance costs. These are dis-benefits. But on the other side of the equation are environmental benefits (both noise and air quality) and the making available of additional premium land spaces for other profitable uses.

A sensitivity test has been performed on the likely noise benefits of underground roads. The Central Kowloon Route, which will run from Yau Ma Tei near the West Kowloon Reclamation to the Kai Tak site, has been chosen as it is a primarily underground route. It has been estimated that this proposal of putting a major link underground would bring about a 6% improvement to the traffic noise levels of the related areas.

While the Consultants recognise the impossibility, a sensitivity test has however been performed by putting all new roads underground to gauge the approximately extent of noise benefits. It has been estimated that such a move would provide some 5% improvement to the year 2016 noise climate.

The Consultants recognise that putting roads underground perhaps is an untraditional approach for Hong Kong. However, this measure should be given careful consideration particularly in formulating development plans of new areas if we are to escape the "more-of-the-same" syndrome. For example, parts of New Territories designated for extensive development and some of the reclamation areas would warrant such innovative considerations. This approach of putting new roads underground, apart from abating traffic noise almost totally, would open up entirely new town planning horizons and possibilities.

Pedestrianisation

This is perhaps yet another untraditional and drastic measure. It is noted that roads were built to facilitate vehicle movements in the first place. But because traffic noise in some densely built urban areas has evolved into a situation whereby very little, if any, could be done to alleviate the impact, perhaps it is worth considering "reclaiming" some roadway sections to facilitate people movements. Pedestrianisation is pollution free and substantially quieter than vehicle movements.

It would be difficult to quantify the noise benefits of pedestrainisation in the CTS-3 context as the traffic models do not include non-vehicle modes. It is common understanding, however, that replacing vehicles by pedestrians on roads would have positive noise implications.

The Consultants recognise that pedestrianisation is not a measure that could be applied without discrimination. It would certainly cause a degree of inconvenience to drivers and bus passengers, for example. But this measure could always be applied with flexibility. For example, some roads could be closed to traffic at certain times of the day rather than on a 24-hour basis for every day of the week. This would minimise the impact on drivers, who may find alternative routes, and at the same time provide a much welcome relief to the residents who are continuously affected by traffic noise and would have no alternatives at their disposal.

It is noted that the Government has been deliberating on the setting up of pedestrianisation zones, perhaps for reasons other than environmental noise benefits. It is recommended that the overall effects, including noise, of trial cases like the proposal for Russell Street in Causeway Bay be monitored. This would provide more information to assist the consideration of this noise mitigation measure.

In conjunction with pedestrianisation, the use of moving walkways (travellators) could be considered for appropriate locations to encourage the shift from using vehicles.

8.3.2.2 Engineering Measures

More stringent vehicle noise emission standards

Hong Kong has adopted, via the Noise Control (Motor Vehicles) Regulations, the most current vehicle noise emission standards in force in the European Union and Japan. Individual vehicles have to comply with the relevant noise emission limits before their first registration is granted. It is reasonable and pragmatic to adopt the European and Japanese standards as the local benchmark as these countries supply Hong Kong with most of the local vehicle fleet.

The international trend in the past quarter century has seen a steady tightening of these emission limits (some by more than 10 dB). This is a reflection of both technological advances and the public demand for quieter vehicles.

While there have been much engineering progress on this front, the emission limits are still being scrutinised constantly with a view of seeking rooms for further improvements. For example, Japan will fully implement a revised and more stringent set of vehicle emission limits by year 2001/2002. Relevant noise levels will be tightened by 2 dB generally. But because of corresponding changes to the testing method and associated considerations, it is anticipated that the net benefit would be no more than 1 dB.

The tightening of noise emission limits for individual vehicles will not lower the overall road traffic noise levels overnight. This is because the more stringent limits would usually apply to new cars only and vehicles that have been in operation before the implementation of the revised limits would still be in running conditions for some years. International experience has indicated that the full benefits of tightening noise emission limits would be phased in over a period of 7 to 10 years.

To put this into the local context, if Hong Kong is to adopt the corresponding Japanese emission limits in year 2001/2002, it could be expected that the overall traffic noise levels would drop by up to 1 dB in the early 2010s if traffic volume is to remain constant at turn of the century levels. Further study to its actual benefit and implementation strategy is recommended.

Putting this into the noise score context and accounting for factors like the relationship between noise contributions from road/tyre interaction and maintenance considerations, it has been estimated that the corresponding resultant noise reduction would translate into an improvement of approximately 5%, on a territory wide basis. One will notice that this potential improvement is only theoretical as it has assumed no growth in traffic volume.

While the Hong Kong market may be too small to trigger the vehicle manufacturers' special attention, we would need to follow the international trend very closely. Whenever the major industrialised countries are introducing more stringent standards, we would need to follow suit immediately. The intention is to prevent Hong Kong from turning into a dumping ground of sub-standard vehicles thereby jeopardising our efforts to deal with road traffic noise at source. It is crucial to ensure that we are getting the best products the manufacturers could come up with while they seek to satisfy the ever advancing standards of other jurisdictions.

Engine encapsulation for heavy vehicles

In Hong Kong, perhaps the situation is more acute than in many other major metropolitan areas overseas, the high percentages of heavy vehicles account for the majority of road traffic noise contributions.

There have been pilot tests in Europe to encapsulate the engine compartments of certain types of heavy vehicles in an effort to tackle such worst offenders and to reduce noise at source. While there are limitations to encapsulation (for example, not each and every type of heavy vehicles could be so treated and road/tyre interaction noise would dilute the element of engine noise attenuation from encapsulation if vehicles are travelling at high speeds), results of the pilot tests have been generally encouraging.

It has been observed that engine encapsulation would usually bring noise reduction of about 5 dB. This improvement, however, would need to be looked at with reference to the overall vehicle noise picture. Because engine noise reductions may be offset by road/tyre interaction noise, and this is particularly evident while vehicles are travelling at high speed, further studies in the local context would be necessary to ascertain the overall net noise benefits of this measure.

It has been estimated if 30% of the heavy vehicles fleet in Hong Kong could be encapsulated, it would bring a noise improvement of approximately 10% on a territory wide basis, theoretically. But accounting for factors like maintenance, it is perhaps more reasonable to assume that improvement would be in the region of up to 3%. However, the effect due to stringent noise emission standards may have been overlapped by engine encapsulation.

If Hong Kong is to benefit from this engine encapsulation initiative, it would be necessary to identify the types of locally used heavy vehicles that could accommodate the potential encapsulation arrangements. It is recognised that voluntary implementation by individual vehicle owners and operators, particularly in the local context, of such measures would likely bring less than desirable compliance results. And legislative avenues would need to be taken if this initiative is to see any success.

The Consultants recognise that before legislative means are executed to pave the implementation of the engine encapsulation initiative, a list of issues would need to be examined. Further studies could be commissioned to sort out technical and technological logistics and in ascertaining the net noise benefits in relationship to the adoption of more stringent emission standards across the entire fleet. Considerations like maintenance commitments on the part of the vehicle owners, enforcement approach on the part of the Authority, etc, would also need to be addressed.

Trolley Buses

Closely related to the initiative of dealing with engine noise would be the introduction of trolley buses. Trolley buses do not have on-board internal combustion engines and are low noise pollution alternatives to ordinary diesel powered buses. Modern trolleys have seen widespread applications in many European and North American cities.

It is noted that the introduction of trolley buses would not totally replace the very important role being carried out by ordinary buses. But their appearance would be particular useful in some noise "black spots" (for example, certain urban cores) and some new development areas where the provision of the necessary supporting infrastructure elements is a matter of forward planning rather than retrofitting.

It would not be easy to quantify the benefit on a territory wide basis as the potential and viability of operating trolley buses in different districts are bound to be different and subject to different constraints. The improvements, however, could be estimated on a local level.

Taking the district of Sha Tin as a sensitivity test case, it has been estimated that trolley buses may replace up to 50% of ordinary buses running in the area. Transferring this to traffic noise terms, it would mean that the possible introduction of trolley buses in Sha Tin would bring about an improvement of 7% to the area.

8.3.2.3 Near or At Source Measures

More extensive use of low noise surface

The use of low noise surface (sometimes called open textured friction course) begun in Hong Kong in the late 1980s when a section of the Island Eastern Corridor in North Point was, as a trial, applied with this type of polymer modified asphalt material. The noise reduction results were overwhelmingly favourable (around 5 dB) even with some not so low percentages (around 20%) of heavy vehicle flow on that particular road section.

The Environmental Protection Department (EPD), in conjunction with the Highways Department (HyD), has since then developed objective criteria for assessing if certain existing roadway sections could be retrofitted with low noise surfacing. Some 10 km of roads, primarily with speed limits at 70 km/h or above, have since been resurfaced to provide partial relief to affected residents.

It is also an established policy that new high speed (70 km/h or more) roadways would be surfaced with low noise material generally.

While low noise surfacing is gradually becoming a norm for many new high speed roadways, its application to roads with lower speed limits has been limited. It is generally acknowledged that the noise reduction effectiveness may be not as impressive as in high speed situations. And there are engineering and maintenance considerations because low noise friction course material would deteriorate more rapidly than normal asphalt or concrete pavements. It would require more frequent resurfacing particularly under frequent start-stop traffic conditions.

The HyD in conjunction with EPD have recently (in March 1999) completed a feasibility study of applying low noise surface to low speed (50 km/h or less) roads. While technical limitations are noted, it has been concluded that appreciable noise benefits could be actualized. According to this particular HyD study, roads with a traffic flow of more than 18,500 veh/day may not be suitable for the application of certain types of low noise surfacing. It is apparent therefore that the HyD study results could not be applied to the roadways scoped within the CTS-3 study as we are primarily focussing on those with a flow of 30,000 veh/day or more.

In order to provide noise disturbance relief, considerations should be given to expanding low noise surface treatments to suitable roadway sections other than in the high speed category. International experience has indicated that different asphalt mix, bonding materials, aggregate sizes and application layer depths would have not just varying noise reduction effectiveness but also implications on its resistance to wear induced by traffic. The Hong Kong authorities could undertake more studies in this regard to explore more suitable material for local use.

Consideration of retrofitting existing roads

The Consultants recognise the effectiveness of the government's ongoing policy of incorporating direct mitigation measures within new or upgraded roadway projects whenever these are warranted. The Consultants also recognise the many limitations (be it engineering or otherwise) and implications (be it cost, political or otherwise) of implementing such measures on existing roads.

But there appears to be no or very few practicable remedies to the large number of people now living along busy roadways and are affected by excessive noise on a day-in day-out basis. If our goal is not just to maintain the present situation but really to try to bring about relief to some of those aggrieved residents, we could not escape the responsibility of deliberating further on the appropriateness of not providing direct mitigating measures to existing roads. Sustainability calls for not just upkeeping the status quo but to improve upon past oversights.

Commonly accepted mitigation measures like barriers and enclosures could be considered. And whenever the opportunity arises, for example during redevelopment of particular areas, putting the roads underground could again be examined.

8.3.2.4 Management Possibilities

Traffic management on noise grounds

Traffic management on noise grounds promises to be one measure that has great potentials. It requires virtually no new infrastructures and could be implemented relatively quickly. Potential concerns such as the possibility of shifting the noise problem from one area to another would of course have to be carefully deliberated. This however should not excessively hinder the implementation of this measure which has been in use extensively overseas.

The Road Traffic Ordinance (Chapter 374) empowers the government to regulate traffic on environmental grounds, among others. Section 11(p) states that the Secretary for Transport may make regulations to provide for "generally carrying into effect the provisions of this Ordinance relating to the regulation of traffic, whether generally or for a particular purpose including the protection of the environment."

This particular provision was put into place via an amendment made in 1992. It was the result of the government's explicit intention to broaden the scope of the Ordinance to cover environmental considerations. Before the 1992 amendment, there were arguments that the government could not control traffic with environmental protection as its primary purpose. The amendment was promulgated to reflect the government's decision to take environmental concerns into the realm of traffic management.

The first traffic management proposal deliberated under the blessing of this particular legislative amendment was the Tsing Yi Traffic Management Scheme. The Tsing Yi Scheme was designed to remove nighttime heavy vehicles traffic from the heavily populated northern and eastern portions of Tsing Yi Island and redirecting them to the southern areas, which were primarily industrial in nature. The intention of the scheme was to shift the noise impacts from densely populated areas to relatively non-noise sensitive areas thereby reducing the relevant impacts.

When the Tsing Yi Scheme was first introduced, there were discussions among relevant government departments on the legal basis of traffic management measures in general and this scheme in particular. The related deliberations have subsequently led to the 1992 amendments of the Road Traffic Ordiance.

In the course of evaluating different CTS-3 traffic scenarios, the Consultants noted that traffic management techniques and schemes (even though these are primarily for traffic demand management purposes rather than for addressing environmental concerns) would have a profound effect on the environmental noise picture.

In line with this direction and in order to visualise the likely benefits of managing traffic on environmental grounds, a series of sensitivity tests have been conducted. For illustration purposes, the Consultants have tried to simulate the environmental noise effects of banning heavy vehicles from using the Tolo Highway while directing them to Route 3 and Tuen Mun Highway. On a more local scale, the Consultants have tried banning east-west heavy vehicles movements from Prince Edward Road in the Kowloon City area and re-distribute the flows to Boundary Street and Argyle Street. The Consultants recognised that such banning are arbitrary and there may be economic and other concerns related to these potential traffic management measures. The purpose of the sensitivity tests, however, is to establish whether the environmental noise benefits are significant whereby further studies and considerations would be warrented.

The results of the sensitivity tests indicate that there would be appreciable overall net benefits to the relevant areas. Such net benefits come about after accounting for improvements along Tolo Highway and Prince Edward Road and deteriorations along Route 3, Tuen Mun Highway and Boundary Street and Argyle Street respectively.

- Banning heavy vehicles from using Tolo Highway and re-directing the traffic to Route 3 and Tuen Mun Highway:

  Approximate net noise exposure improvements -

24 hour banning	17%
Peak hours (7am - 10am, 4pm - 7pm) banning	10%

- Banning heavy vehicles from using Prince Edward Road in the Kowloon City area and re-directing the traffic to Boundary Street and Argyle Street:

  Approximate net noise exposure improvements -

24 hour banning	7%
Peak hours (7am - 10am, 4pm - 7pm) banning	3%

It could be seen that traffic management is a useful and effective tool in regulating overall noise exposure and improving the L_{10} situation.

Looking at traffic management from another angle, the Consultants have also tested the case whereby an assumption was made that cross boundary heavy vehicles traffic would be cut by 20%. Such a decrease, when translate into noise terms, would register an improvement of approximately 2% on a territory wide basis.

Speed regulations

Traffic speed is a major influencing factor of traffic noise. In most cases, perhaps with the exception of very low speed (less than 35 km/h) situations, traffic noise increases as vehicles travel at higher speeds. For example, by simply lowering vehicle speed from 80 km/h to 70 km/h, a noise reduction of around 1 dB could be actualised.

It is not unusual to find noise sensitive receivers, the majority of those are high rise in nature, located near or along many of the high speed roadways in Hong Kong. Considerations could be given to regulate the respective speed limits on selected roadway sections, particularly during the more sensitive evening and nighttime hours, by imposing lower allowable speeds. This again would be another low cost quick benefit measure that could contribute to noise reduction.

It is recognised that lower evening and nighttime speed limits are already in place in some countries, primarily implemented on traffic safety grounds. In addition to the safety dividends, this measure carries favourable noise benefits, both in terms of exposure and L_{10} values.

The Consultants realize that the speed limits on certain trunk routes have been relaxed recently. While this may improve traffic flows, the side effects of additional noise should also be noted. Considerations could be given to maintaining lower speed limits during the nighttime hours to curb the creeping up of noise levels associated with faster traffic.

8.3.3 Recommendations of Mitigation Measures

The mitigation measures discussed in the preceding section have various degrees of effectiveness but are all considered relevant to address the Hong Kong road traffic noise situation. Their effectiveness is backed by either international or local experience.

Some of the above measures may be untraditional or drastic for Hong Kong. But our road traffic noise situation is not just certain mild disturbances, it has the potential to further deteriorate into even more drastic proportions. We would require progressive, innovative and at certain times drastic solutions to address our drastic problems.

It is recommended that considerations should be given to adopt these measures fully and immediately.

The Consultants also suggest further studies (see Section 8.3.5 below) be conducted to substantiate the mitigation measures propsed in this section.

With regard to timing of introducing any or all of the recommended measures, the Consultants are of the view that no particular trigger would be required. The recommended mitigation measures, subject to policy clearance and further practicability deliberations (together with results of further studies), could and should be implemented at short notice. Such measures, while derived in the CTS-3 context, are also useful to address the prevailing traffic noise situations and to provide partial relief to the affected population.

The following Table 8.3a summarises the measures proposed in this section, their effectiveness, and the potential agents to bring such into happening.

Table 8.3a
Noise Mitigation Measures

Mitigation Measures		Effectiveness
Type	Item	
Policy	More extensive network of rail service	Substantial
	Putting new roads underground	Substantial
	Pedestrianisation	Medium
Engineering	More stringent vehicle noise emission standards	Medium
	Engine encapsulation for heavy vehicles	Medium
	Trolley Buses	Medium
Near or At Source	More extensive use of low noise surface	Medium
	Consideration of retrofitting existing roads	Medium
Management Possibilities	Traffic management on noise grounds	Substantial
	Speed regulation	Medium

For discussions on relevant strategic level monitoring and audit suggestions (and trigger mechanisms), please refer to Chapter 9.

8.3.4 Adequacy of Measures

The Consultants are aware that each mitigation measure mentioned above could contribute to alleviating part of the problem. However, they may not be adequate to fully address the future situation whereby fleet size keeps expanding and the needs and wants for mobility are continuously surfacing.

Administrative means could be considered to curb such increases. These may be in the form of fiscal, tax, demand management, quota or otherwise. These are however outside the scope of strictly "noise" considerations in this Section. But rather, it could be deliberated in the wider context of balancing transport and environmental needs and objectives.

In an effort to shed more light on a possible way forward, the Consultants have chosen to explore the possibility of capping the year 2016 noise score at 1.0 (ie 1997 baseline level). Using the year 2016 Medium Growth scenarios as a test case (with 8.9 million population), the Consultants have found that the noise score could be maintained at 1.0 if at least 25% of the relevant heavy vehicles traffic could be trimmed from the roads.

The Consultants recognize that such a test may be arbitrary and that the tested measure is drastic and there will certainly be great practical difficulties in implementation, with economic, mobility and other implications. But the aim of the test is to simulate if just by managing the traffic of the worst noise contributors (heavy vehicles) alone, there exists the opportunity of maintaining the noise score at year 1997 level. The result of the test is affirmative.

Managing the traffic of heavy vehicles is just one of the many possible mitigation measures. But this particular measure would warrant careful deliberations as we seek to deal with the ever-increasing traffic noise situation.

8.3.5 Further Studies

Further studies of the following mitigation measures with the aim of producing additional information in the local context to assist policy makers should be considered:

- Pedestrianisation;
- Engine encapsulation;
- Trolley buses;
- More extensive use of low noise surface; and
- Means and implications on controlling the growth of heavy vehicles.

8.3.6 Other Considerations

It is certainly desirable if the potential benefits of the mitigation measues discussed above could all be quantified on a territory wide basis and summarily put into perspective of a particular "noise mitigated" year 2016 scenario. This, however, has not been possible.

Some mitigation measures could not be easily quantified, particularly on a territory wide basis. And the non-cumulative nature of the noise modelling has placed limitations on the related efforts.

The importance of appropriate strategic level environmental monitoring and audit could, therefore, not be over-emphasized. Relevant feedbacks from the monitoring and audit exercise (see Chapter 9) could be used to ascertain the overall combined effectiveness of the implemented mitigation measures. Interim adjustments, if any, could be instituted and additional measures, if required, could be explored to ascertain the measures are adequate to maintain, and hopefully improve upon, the noise sustainability of the Hong Kong ambient.