Report

ECONOMIC POLICY INSTRUMENTS FOR CONTROLLING VEHICULAR AIR POLLUTION

Rita Pandey
Geetesh Bhardwaj

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National Institute of Public Finance and Policy
New Delhi

PREFACE

As the trends in air pollution levels in most Indian cities show deterioration in air quality, there is a growing emphasis on finding and implementing approaches and instruments alternative that are more efficient in controlling the continuing deterioration of the environment than those which have been tried so far in the country. Inevitably this focusses attention on more innovative approaches such as economic instruments. Estimates indicate that health incidences and the corresponding costs of air pollution in India are the highest in Delhi. As the transport sector is the largest contributor to air pollution in Delhi, this study accesses the feasibility of economic measures to prevent and control vehicular air pollution in Delhi.

This study was undertaken at the instance of the Ministry of Environment and Forests, Government of India. The terms of reference required the Institute to: (i) review the existing fiscal provisions relating to vehicular air pollution control and prevention in India; (ii) review the experiences with fiscal measures for controlling pollution in other countries with special reference to Singapore; and (iii) recommend economic instruments that can achieve the goal of reducing vehicular air pollution in Delhi.

While the study suggests a number of economic instruments to effect air pollution from motor vehicles in Delhi, it also emphasises that the laws must be enforced rigorously and persistently.

At the NIPFP, the study was designed and conducted by Dr. Rita Pandey with Mr. Geetesh Bhardwaj. The Governing Body of the Institute does not bear any responsibility for the views expressed in the report. The responsibility lies mainly with the authors of the report.

Ashok Lahiri
Director

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CONTENTS

Preface (i)

Acknowledgement (ii)

Contents (iv)

CHAPTERS

1. **AIR POLLUTION IN DELHI** 1
   - 1.1 Introduction 1
   - 1.2 Objectives and Plan of the Study 1
   - 1.3 Sources of Air Pollution in Delhi 2
   - 1.4 Ambient Air Quality in Delhi 3
   - 1.5 The Transport Sector 5
   - 1.6 Traffic Flow: Implications for Air Pollution 11
2. **POLICY INSTRUMENTS FOR VEHICULAR POLLUTION CONTROL** 13
   - 2.1 The Policy Options 13
   - 2.2 Policies Adopted in Delhi 15
   - 2.3 Economic Instruments: Experience of Other Countries 22
3. **FISCAL INSTRUMENTS FOR CONTROLLING VEHICULAR AIR POLLUTION IN SINGAPORE** 30
   - 3.1 Vehicular Pollution Control: A Background 30
   - 3.2 Vehicular Pollution Control: Approaches and Instruments 32
   - 3.3 Summing Up 44
   - 3.4 Lessons for Delhi 45
4. **ECONOMIC POLICY INSTRUMENTS FOR CONTROLLING AIR POLLUTION IN DELHI** 48
   - 4.1 Vehicular Emission Control: A Theoretical Perspective 48
   - 4.2 Technical Options 52
   - 4.3 Fuel Tax 55
   - 4.4 What are the Options for Delhi 56
   - 4.5 Petrol vs. Diesel Cars 60
   - 4.6 Other Demand Management Options 64
   - 4.7 Non-Fiscal Measures 64

5. ASSESSMENT AND RECOMMENDATIONS — 70
5.1 Recommendations — 70
REFERENCES — 74

AIR POLLUTION IN DELHI 1

1.1 Introduction

Statistics reveal that many Indian cities are faced with the problem of deterioration in air quality due to rising levels of pollutant concentration in the atmosphere. The pollution levels are likely to worsen owing to the growing number of vehicles, energy consumption and industrialisation. The increasing levels of pollution have serious adverse effects on both human health and natural environment. A recent study (Brandon and Homman, 1995) estimates the health costs of urban air pollution in India at about US $ 1.4 billion (Rs. 532 crore) a year. Estimates indicate that health incidences and the corresponding costs of air pollution in India are the highest in Delhi.

Various activities/sectors, such as, industry, including thermal power plants, transport, and household contribute to air pollution in varying proportions depending on the degree/composition of motorisation, density/type of industry present, and the form of energy predominantly used. While a wide range of policies can be and are applied to control the problem of air pollution, in this paper we focus on the fiscal policy options for controlling the vehicular air pollution in Delhi as the transport sector is the largest contributor to air pollution in this city.

1.2 Objectives and Plan of the Study

1.2.1 The study aims to:

- review the existing fiscal provisions to control air pollution from motor vehicles in Delhi;
- review the experiences of other countries in application of fiscal measures;
- study the measures adopted in Singapore for controlling vehicular air pollution; and

- suggest fiscal measures for controlling vehicular air pollution in Delhi.

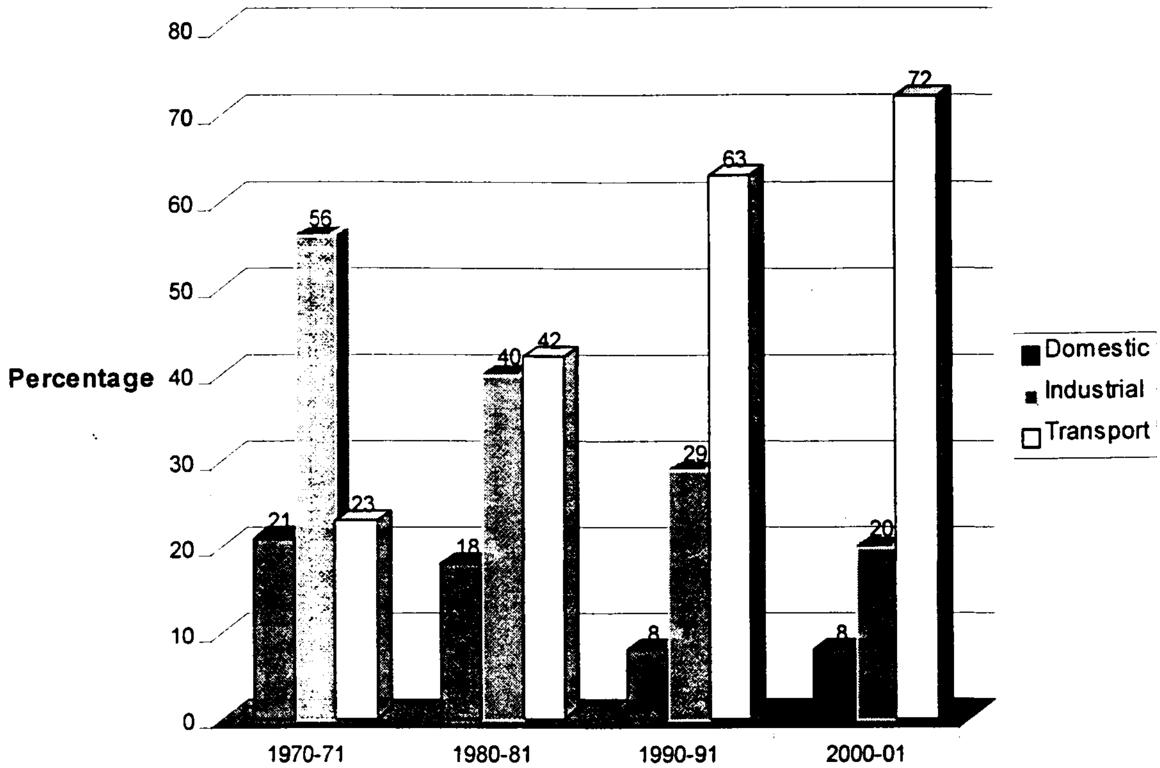
1.2.2 The report is organised as follows:

Chapter 1 identifies the main causes and major sources of vehicular pollution in Delhi. Chapter 2 provides a discussion on various policy options for containing vehicular emissions. It also critically reviews the policies adopted for controlling air pollution from vehicles in Delhi. Finally, a discussion on the actual applications of economic instruments in other countries and their lessons for Delhi is provided. Chapter 3 provides a case study of measures adopted in Singapore and identifies the lessons for Delhi. Chapter 4 suggests the specific fiscal options for containing vehicular air pollution in Delhi. Finally, Chapter 5 presents the constraints of the present system and recommendations from the analysis.

1.3 Sources of Air Pollution in Delhi

The major sources of air pollution in Delhi are: motor vehicles, thermal power plants and the industry. The contributions of different sectors to the daily emissions of the common air pollutants like carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2), suspended particulate matter and particulate matter of diameter 10 microns or smaller (SPM and PM_{10}) and hydrocarbons (HC) were estimated at about 63 percent from vehicles, 29 percent from industry and thermal power generation plants and 8 percent from domestic sources in 1990-91. What is more alarming is the rapid growth in the share of emissions from the transport sector since 1970-71 (Figure 1.1). Projections for the year 2000-2001 suggest a further increase in the share of pollution from transport sector.

Figure 1.1 Trends in air pollution in Delhi



Source: Sengupta, 1999.

1.4 Ambient Air Quality in Delhi

Though WHO has specified guidelines for pollutant concentrations in the ambient air for one hour, eight hour and 24-hour averages, in India only annual mean and 24-hour average standards have been prescribed, except for CO, for which 8-hour and 1-hour standards have been notified. Further, whereas WHO standards are common for all land-use areas, separate standards operate in Indian cities owing to the notification of separate standards for industrial, commercial and residential locations. Indian standards are lax in comparison to WHO norms. The national standard for annual SO_2 emissions and PM_{10} levels in industrial areas respectively is 1.6 times and 3 times higher than WHO norms. National annual SPM standard for residential areas is 2.3 times higher than the 60 μg/cum norm set by WHO (Table

1.1). However, Indian NO_x standards are stricter than WHO norms. While WHO allows 150 μg/cum over 24 hours, Indian residential standards are 80 μg/cum over 24 hours.

Table 1.1. Ambient Air Quality Standards and Compliance Status in Delhi

Pollutants	*Time Weighted Average*	*WHO Guidelines*	*Industrial Area*		*Residential Area*		*Traffic Intersections*
			Indian Air Quality Standards	*Ambient Air Quality in Delhi (1998)*	*Indian Air Quality Standards*	*Ambien Air Quality in Delhi (1998)*	*Ambient Air Quality in Delhi (1998*
Sulphur Dioxide (SO_2)	Annual Mean	50 μg/m³	80 μg/m³	20.2 μg/m³	60 μg/m³	15.8 μg/m³	25 μg/m³
	24 Hours	125 μg/m³	120 μg/m³	-	80 μg/m³	-	-
Nitrogen Dioxide (NO_2)	Annual Mean	-	80 μg/m³	34.7 μg/m³	60 μg/m³	28.6 μg/m³	63 μg/m³
	24 Hours	150μg/m³	120 μg/m³	-	80 μg/m³	-	-
Suspended Particulate Matter (SPM)	Annual Mean	60 μg/m³	360 μg/m³	367 μg/m³	140 μg/m³	341 μg/m³	426 μg/m³
	24 Hours	150 μg/m³	500 μg/m³	-	200 μg/m³	-	-
Respirable Particulate Matter (PM_{10})	Annual Mean	40 μg/m³	120 μg/m³	250 μg/m³	60 μg/m³	230μg/m³	300μg/m³
	24 Hours	70 μg/m³	150 μg/m³	-	100 μg/m³	-	-
Carbon Monoxide (CO)	8 Hours	10mg/m³	5 mg/m³	-	2 mg/m³	-	5.45 mg/m³
	1 Hours	40 mg/m³	10 mg/m³	-	4 mg/m³	-	-
Polly Aromatic Hydrocarbons (PAH)	Annual Mean	-	10 ng/ m³	30 ng/ m³	10 ng/ m³	20 ng/ m³	40 ng/ m³

Source: Parivesh newsletter, June 1999 Vol 6(1),CPCB and Sengupta, 1999.

From Table 1.1 it could be seen that while the annual mean concentrations of SO_x and NO_x and 8-hour mean levels of CO are well within WHO norms, concentration levels of SPM, PM_{10} and Poly aromatic hydrocarbons (PAH) exceed the norms. It is important to note here that the daily maximum levels of these pollutants including SO_x, NO_x and CO are much higher than annual and 24-hour averages. Studies show that NO_x, SO_2 and CO peak with traffic peaks. Further, maximum levels of SPM, PM_{10} and PAH, for which even annual mean concentrations exceed the WHO norms, would be a magnitude higher than the standards. SPM and PM_{10} need special mention as Indian standards for these pollutants are significantly lower (lax standards) than WHO norms. This has been justified by the CPCB on grounds of climatic conditions in Delhi. According to

CPCB, SPM in Delhi comprise a significant amount of dust which comes from natural sources. The SPM also comprise PM_{10} and even smaller size particulates $PM_{2.5}$. The sources of these particulates are mainly diesel exhaust, coal fired power plants, industrial boilers and wood burning stoves. Studies show that automobiles are the major contributors of small particles in Indian cities. According to CPCB officials, 40 per cent of the total SPM that is of size 10 micron or lower, is respirable.

1.5 The Transport Sector

Delhi has witnessed a phenomenal rise in population during the past two decades, from 40.6 lakhs in 1970-71 to 120.34 lakhs in 1998. Consequently, the city has expanded in terms of its geographical limits. As the transport network has been predominantly road-based in Delhi, there has been considerable increase in road length and motor vehicles during the above period. The growth in the number of motor vehicles has, however, been more rapid than the growth of both road length and population (Table 1.2).

Table 1.2. Population, Registered Motor Vehicles and Road Length in Delhi

Year	*Population (lakh)*	*No. of motor vehicles registered (lakh)*	*Road length (Kms)*	*Vehicle density (no./km)*
1971	40.66	1.80	8231.0	21.92
1981	62.20	5.36	14316.0	37.44
1991	94.21	18.13	21564.0	84.07
1996	112.24	27.94	25948.0	107.66
1998	120.34	31.67	-	-
Growth Rates (Percent)				
1971-81	4.34	11.50	5.69	5.50
1981-91	4.24	12.96	4.18	8.43
1971-91	4.29	12.23	4.93	6.95
1991-96	3.56	9.03	3.77	5.07

Source. Delhi Statistical Hand Book (1997); Motor Transport Statistics of India (1996), Ministry of Surface Transport, Government of India; and Transport Department, Government of Delhi.

High growth in the number of motor vehicles has contributed to increase in air pollution in two ways: (i) rapid growth in number of vehicles has resulted in increased fuel consumption leading to increase in emissions; and (ii) growth in vehicle density (number of vehicles per km road length) has caused road congestion leading to increased fuel consumption and pollutant emissions.

1.5.1 Major vehicular emissions and their effects

The major pollutants emitted by motor vehicles include CO, NO_x, SO_x, HC, lead (Pb), SPM, PM_{10} and volatile organic compounds. These pollutants have damaging effects on both human health and ecology. Table 1.3 lists the hazards effected by motor vehicle emissions. The effects of air pollution on human health vary in degree of severity, covering a range of minor effects to serious illnesses, as well as premature deaths in certain cases. Most of the conventional air pollutants are believed to directly affect the respiratory and cardio-vascular systems. In particular, high levels of SO_2 and SPM are associated with increased mortality, morbidity and impaired pulmonary function. Lead prevents haemoglobin synthesis in red blood cells in the bone marrow, impairs liver and kidney function and causes neurological damage. Pollutants like SO_2, NO_2 and PM_{10} may be the cause of an increase in the incidence and severity of allergies in children and aggravating asthma.

Table 1.3. Health and Ecological Effects of Air Pollution

Pollutants	*Effects on human health*	*Effects on the natural environment*
Carbon monoxide (CO)	Can affect the cardiovascular system, exacerbating cardiovascular disease symptoms, particularly angina: may also particularly affect foetuses, sickle cell anaemics and young children; can affect the central nervous system, impairing physical coordination, vision and judgement, creating nausea and headaches, reducing worker productivity and increasing personal discomfort.	
Nitrogen oxides (NO_x)	Nitrogen dioxide (NO_2) can affect the respiratory system: Nitrogen monoxide (NO) and nitrogen dioxide (NO_2), where they play a part in photochemical smog formation, may indirectly increase susceptibility to infections, pulmonary diseases, impairment of lung function and eye, nose and throat irritations.	NO and NO_2 can contribute significantly to acid deposition, damaging aquatic ecosystems and other ecosystems such as forests; NO_x can also have a fertilizing effect on forests.
Sulphur oxides (SO_x)	Sulphur dioxide (SO_2) can affect lung function	Sulphur oxides can contribute significantly to acid deposition impairing aquatic and forest ecosystems. Sulphates can affect the perception of the environment by reducing visibility even at low concentrations.

Pollutants	*Effects on human health*	*Effects on the natural environment*
Particulate matter (SPM and PM_{10})	Fine particulate matter may be toxic in itself or may carry toxic (including carcinogenic) trace substances, and can alter the immune system. Fine particulates can penetrate deep into the respiratory system thus irritating lung tissues and causing long-term disorders.	Fine particulates can significantly reduce visibility. High dust and soot levels are associated with a general perception of dirtiness of the environment.
Lead	Can cause brain damage, encephalopathy in children resulting in lower IQ, death, hyperactivity and reduced ability to concentrate.	

Source: Houghton & Hunter (1994) and Prabhu (1997).

The magnitude of emission of various pollutants from the transport sector has a direct relationship with the number and composition of vehicle fleet, technology of vehicles, type of fuel used, usage and maintenance of vehicles, traffic flow, road conditions, terrain, etc. In order to identify the right approaches and instruments to control vehicular emissions, it is important to understand this relationship. This is illustrated in the following sections.

1.5.2 Growth in registered motor vehicles in Delhi

During 1971-98 there has been more than 18 fold rise in the total number of vehicles. As of 1998, there were more than 31 lakh motor vehicles in Delhi (Table 1.4).

If we look at the growth rates we find that the growth in private passenger vehicles has been higher than the growth in public vehicles. A large number of private vehicles are two-wheelers (about two-third of the total number of vehicles) followed by cars and jeeps (about 25 percent of total vehicles). Further, the average annual growth in passenger vehicles is higher at 11.32 percent *vis-a-vis* growth in goods vehicles (9.26 percent), during the period 1971 to 1998 (Table 1.5). Among the petrol driven vehicles, growth in number of two-wheelers is the highest (12.18 percent) followed by cars and jeeps (10.34 percent). Among diesel driven vehicles, buses have grown at a higher rate *vis-a-vis* other vehicles. In addition, a large number of vehicles come and/or pass through the city of Delhi every day adding to air pollution.

Table 1.4. Registered Motor Vehicles in Delhi (in lakhs)

Category	*1971*	*1985*	*1990*	*1995*	*1998*	*1999**
Car/Jeep/St. Wagon (petrol driven)	0.56	1.58	3.45	5.76	8.05	8.37
Scooter/Motorcycle (petrol driven)	0.93	5.79	11.13	16.18	20.77	21.31
3-Wheeler (petrol driven)	0.10	0.30	0.59	0.75	0.86	0.87
Taxi (mostly diesel)	0.04	0.09	0.10	0.13	0.17	0.17
Buses (diesel driven)	0.03	0.14	0.18	0.26	0.35	0.36
Goods vehicles (diesel driven)	0.14	0.52	0.93	1.25	1.49	1.52
Total	1.80	8.41	16.38	24.32	31.67	32.61

* as on July 1999.

Source: Motor Transport Statistics of India 1996, Ministry of Surface Transport, Government of India; and Transport Department, Government of Delhi.

1.5.3 Environmental characteristics of vehicle fleet: Implications for air pollution

Information on environmental characteristics can be a good guide in designing appropriate instruments for pollution control as well as in making a choice of sectors for greater focus. It was noted earlier, that emission characteristics of transport vehicles depend on the technology, type of fuel, usage and maintenance of vehicles, operating conditions (speed, congestion), etc. Emission rates observed for motor vehicle fleet in India have been used as reasonable approximation to examine the emissions of vehicle fleet in Delhi.

Table 1.5. Vehicular Population in Delhi: Profile of Growth Rates

Category	*1971-85*	*1971-95*	*1971-98*	*1985-90*	*1990-95*	*1995-98*
Car/Jeep/St. Wagon (petrol driven)	7.62	10.16	10.34	16.95	10.78	11.81
Scooter/Motorcycle (petrol driven)	13.93	12.62	12.18	13.96	7.76	8.68
3-Wheeler (petrol driven)	8.00	8.66	8.19	14.45	4.93	4.48
Taxi (mostly diesel)	5.85	5.05	5.65	2.50	5.42	10.50
Buses (diesel driven)	11.25	9.39	9.42	5.70	7.99	9.68
Total Vehicles	11.62	11.45	11.20	14.25	8.23	9.20
Petrol-driven Vehicles (Total)	11.85	11.68	11.42	14.62	8.38	9.36
Diesel-driven Vehicles (Total)	9.65	9.05	8.81	10.08	6.38	6.91
Passenger Vehicles (Total)	11.74	11.57	11.32	14.39	8.35	9.37
Goods Vehicles (Total)	10.10	9.68	9.26	12.12	6.16	5.93

Source: Motor Transport Statistics of India (1996), Government of India; and Transport Department, Government of Delhi.

1.5.4 *Emission rates per vehicle kilometre*

Table 1.6 presents emission rate per vehicle-kilometre for different types of vehicles. From the data presented in Table 1.6 the following observations can be made:

Table 1.6. Emission Rates from Different Types of Vehicles(per km.)

Type of Vehicle	*Emission in grams*			
	PM_{10}	*HC*	*CO*	NO_x
Cars	0.25	1.5	9.5	1.9
Taxi	0.33	6.2	28.9	2.7
3-wheeler	0.5	7.65	12.25	0.1
2-wheeler	0.5	5.18	8.3	0.1
Diesel bus	2	2.1	12.7	7.96
Diesel truck	2	2.1	12.7	7.96

Source: Xie.J. *et. al.* (1998).

- Taxies have substantially higher emission rates *vis-a-vis* other vehicles in respect of CO.

- Emission rates of NO_x and PM are significantly higher in the case of diesel driven vehicles *vis-a-vis* petrol vehicles.

- HC is emitted more by the two-stroke engine petrol driven two and three wheelers followed by taxies, diesel buses and trucks.

- In terms of total emissions, taxies, buses and trucks are most polluting followed by two-stroke engine vehicles and cars.

Based on the above observations and the data presented in Table 1.4, it can be inferred that about 68 percent of the total vehicles in Delhi are of the most polluting kind, that is, two stroke engine two-and three-wheelers, in terms of emissions of HC. Over 70 percent of total vehicles (including the two-stroke engine vehicles) are the most polluting kind in terms of CO emissions. Diesel vehicles which constituted 7 percent of total vehicles in 1998 are mainly responsible for emissions of SO_x, NO_x and particulate matter. However, if we look at the total emissions per vehicle, we find that buses and taxies are the biggest polluters followed by diesel trucks and three wheelers. This is supported by the statistics for Delhi given in Table 1.7.

Table 1.7. Vehicle Emission Inventory for Delhi

Vehicle Type	*Pollutant (hundred tonnes/year)*					
	PM_{10}	*HC*	*CO*	NO_X	*Total Emissions*	*Emissions per Vehicle (tonnes)**
Cars	20.12	120.72	764.57	152.91	1058.33	0.13
Taxi	1.73	32.53	151.65	14.16	200.08	1.18
3-wheeler	17.96	274.77	439.99	3.59	736.31	0.86
2-wheeler	51.91	537.83	861.77	10.38	1461.89	0.07
Diesel bus	44.94	47.18	285.35	178.85	556.32	1.61
Diesel truck	104.07	109.27	660.84	414.19	1288.37	0.87
Total	240.73	1122.31	3164.17	774.10	5301.30	0.17

* Computed by dividing total emissions with the number of vehicles as on December 1998.

1.5.5 Emission rates per passenger kilometre

Since the number of petrol vehicles is higher *vis-a-vis* diesel vehicles, contribution of petrol vehicles to atmospheric pollution is higher. Among all types of vehicles, the contribution of two-wheelers to air pollution is highest owing to their high number in the vehicle fleet in Delhi. If we look at the emission characteristics of passenger vehicles per passenger km. (Table 1.8), the ranking of passenger vehicles in terms of emissions is changed with taxies as the highest polluting, followed by two and three wheelers, cars and buses.

Table 1.8. Emissions from Different Types of Vehicles (per passenger-km)

Vehicle type	*Emission/ vehicle/year*	*Occupancy*	*Emission/ passenger/km*	*Occupancy*	*Emission/ Passenger/km*
Cars	131500	4	3.3	2.5	5.3
Taxi	1182030	3	12.7	2	19.1
3-wheeler	861000	3	6.8	2	10.2
2-wheeler	70400	2	7.0	1.5	9.4
Diesel bus	1609400	40	0.6	60	0.4

Notes. Emission values are in grams and are based on emission factors in Table 1.6.

1.6 Traffic Flow: Implications for Air Pollution

Congestion, poor quality roads and too many traffic lights affect the traffic flow adversely. Poor traffic flow causes frequent speed cycle changes which increase the average emission rates significantly. According to an estimate by the Central Road Research Institute (CRRI), vehicles consume as much as 20 percent extra fuel owing to constraints in traffic movement. It has been estimated that during idling, cruising and deceleration, the weight of particulates per cubic metre of exhaust gases is 25 to 50 times higher in the case of diesel vehicles. However, during acceleration this increases by 500 to 800 percent above the average value for petrol engines (CSE 1996). The magnitude of pollutants emitted from automobiles (petrol driven) and heavy vehicles under different driving modes in the US is presented in Tables 1.9 and 1.10 respectively. The main points that emerge from these tables are discussed below.

Table 1.9. Magnitude of Pollutants Generated by Automobiles Under Different Driving Modes in US (in parts per million)

Driving mode	*Hydrocarbons (HC)*	*Carbon monoxide (CO)*	*Carbon dioxide (CO_2)*	*Oxides of nitrogen (NOx)*
Idling	1.34	16.19	68.35	0.11
Accelerating				
0-15 mph	536.00	2,997.00	10,928.00	62.00
0-30 mph	757.00	3,773.00	19,118.00	212.00
Cruising				
15 mph	5.11	67.36	374.23	0.75
30 mph	2.99	30.02	323.03	2.00
45 mph	2.90	27.79	355.55	4.21
60 mph	2.85	28.50	401.60	6.35
Decelerating				
15-0 mph	344.00	1,902.00	5,241.00	21.00
30-0 mph	353.00	1,390.00	6,111.00	41.00

Source: Bellomo and Liff (1984).

Table 1.10. Representative Composition of Exhaust Gases from Heavy Vehicles (in ppm by volume)

Pollutant	*Idling*	*Accelerating*	*Cruising*	*Decelerating*
Gasoline Engine				
Carbon monoxide	69,000	29,000	27,000	39,000
Hydrocarbons	5,300	1,600	1,000	10,000
Nitrogen oxides	30	1,020	650	20
Aldehydes	30	20	10	290
Diesel Engine				
Carbon monoxide	Trace	1,000	Trace	Trace
Hydrocarbons	400	200	100	300
Nitrogen oxides	60	350	240	30
Aldehydes	10	20	10	30

Source: Holdgate *et. al.* (1982).

- emissions of CO and HC decrease by about 50 percent with increase in cruise speed from 15 mph to 60 mph;

- emissions of CO_2 and NO_x increase by 7.3 percent and 747 percent respectively with increase in cruise speed from 15 mph to 60 mph;

- emissions of HC, CO_2 and NO_x increase while those of CO decrease with deceleration;

- emissions of HC, CO_2, CO and NO_x increase mani fold with acceleration; and

- amount of emissions from heavy vehicles also changes with the driving mode.

Clearly, poor traffic flow contributes significantly to the problem of air pollution and no discussion on controlling vehicular pollution can afford to ignore this. It has been estimated that the improvement in vehicular speed from an average of 20 km/hr to 40 km/hr will reduce emissions of TSP, SO_2, NO_x, CO, HC and Pb by 43, 38, 35, 16.5, 17, and 15 percent respectively. This points towards the need for policies to improve traffic flow by controlling the demand for private vehicles and improved traffic management.

POLICY INSTRUMENTS FOR VEHICULAR POLLUTION CONTROL 2

This chapter discusses the various policy options for containing vehicular pollution and critically reviews the policies adopted in Delhi. Finally, a discussion of the actual applications of economic instruments in other countries and their lessons for India is provided.

2.1 The Policy Options

The policies adopted for controlling vehicular pollution can be broadly divided into economic approaches[1] and command and control (CAC) strategies. These policies can be directed at three broad aspects of vehicular pollution problem, namely, vehicle (technology), fuel and traffic (Table 2.1).

Table 2.1. Policy Instruments to Control Environmental Impacts of Motor Vehicles

	Economic approaches		***Command-and-control regulations***	
	Direct	***Indirect***	***Direct***	***Indirect***
Vehicle	·Emission fees	·Tradable permits ·Differential vehicle taxation ·Tax allowances for new vehicles	·Emissions standards	·Compulsory inspection and maintenance of emission control systems ·Mandatory use of low polluting vehicles ·Compulsory scrapping of old vehicles
Fuel		·Differential fuel taxation ·High fuel taxes	·Fuel composition ·Phasing out of highly polluting fuels	·Fuel economy standards ·Speed limits
Traffic		·Congestion charges ·Parking charges ·Subsidies for less polluting modes	·Physical restraint of traffic ·Designated routes	·Restraints on vehicle use ·Bus lanes and other priorities

Source: Cabajo (1991).

It can be seen from Table 2.1 that economic instruments comprise a wide range of instruments such as pollution taxes, tradeable permits, input taxes, product charges, and differential tax rates. Economic instruments work through the market

[1] It may be noted that while distinction can be made between "economic instruments" and "fiscal instruments", with the latter being a subset of the former, the two terms are used interchangeably.

and alter the behaviour of economic agents by changing the nature of the incentives and disincentives these agents face. In India, so far there has been an overwhelming reliance on the CAC measures listed in columns 4 and 5 of the above mentioned table. These are discussed in the Section 2.2.

Within economic instruments one can differentiate between direct and indirect instruments. The former make the economic agents, let us say vehicle owners/users generating pollution, internalise the cost of pollution by increasing the cost of using the environmental resource – air. For example, a fee levied on the vehicle owner for its emissions is in effect a price for the use of air which is a free resource. Faced with a levy on its emissions, the vehicle owner will reduce the emissions/use of free resource – air. Indirect instruments say a tax, on the other hand increases the price of inputs and outputs that are complementary to the polluting activity. For example, a tax on fuel would be an indirect instrument to address vehicular air pollution.

- **Emission fees:** Such fees are levied on polluters based on the quantity and/or quality of emissions released to the atmosphere. Theoretically, the emission fee should be set such that the marginal gains from the pollution reduced equal the marginal cost of reducing it. In other words, a rate of fee equal to the marginal pollution abatement cost at the socially optimum level of pollution will induce the polluter to reduce his/her vehicular discharges to the socially efficient level.

- **Tradeable permits:** These are based on the concept of creating property rights for the use of environmental resources. These rights can be transacted among the polluters. Under this approach the pollution control agency determines the total amount of emissions that can be discharged on the basis of a target pollution level and translates it into permits. These permits can be assigned and/or sold/auctioned to the polluters. Since the target level of pollution is usually less than the current aggregate level of pollution, there is a scarcity value of the permits and this puts an initial price on them.

- **Differential taxation:** This is used to promote use of products that are less polluting. For example, tax differentiation between leaded and unleaded petrol or between 'not so clean' and 'cleaner' vehicles.

- **Congestion charges:** These are used to discourage traffic at specific locations at specific times.

- **Parking charges:** These are used to discourage congestion in busy business centres.

- **Subsidies for less polluting modes:** The most common example is a subsidy on public transport. A subsidy on public transport (a substitute of private transport which is less efficient in terms of fuel and road space used per passenger) reduces its price thereby encouraging its use.

2.2 Policies Adopted in Delhi

In order to reduce vehicular pollution in Delhi several measures have been taken[2]. These can be divided into CAC measures, enforcement measures and fiscal measures.

(i) Command and Control (CAC) measures

- *The Motor Vehicles Act*

Although legislations to deal with the problem of air pollution were introduced in early 80's in India, regulations to deal with vehicular air pollution came into force only in 1990. The two legislations, the Air (Prevention and Control of Pollution) Act and the Environment Protection Act (EPA) introduced in 1981 and 1986 respectively, focussed on stationary sources of pollution like industries and thermal power plants - and did not adequately address the fast growing problem of emissions from vehicular sources excepting that it provided for the prescription of

2 For a lucid discussion see Pandey (1998).

automobile emission standards by the CPCB/MoEF. Enforcement of these standards rested with the Ministry of Surface Transport (MoST). The Central Motor Vehicles Act of 1939 was amended in 1989 to regulate vehicular emissions.

- *Mass Emission Standards*

Following the amendment of the Motor Vehicles Act of 1939 the exhaust emission rules for the owners of the vehicle were notified in April 1990, and the mass emission standards for vehicle manufacturers were enforced in 1991. Mass emission standards refer to gm/km of pollutants emitted by the vehicles during mass emission tests conducted under specified driving conditions. Mass emission standards for vehicles have been further revised upwards for 1996 and subsequently for 2000 since they were first introduced in 1991 (Table 2.2). The main criticism of the emission standards is that in the year 2000 India will meet Euro I standards which Europe had enforced in 1992-93 – excepting in Delhi where Euro II standards will come into force from April 2000 for the non-commercial motor vehicles. For commercial vehicles, however, Euro I emission standards will be applicable.

Table 2.2. Delhi and Euro Mass Emission Norms for Vehicles

S.No	*Type of vehicles and pollutants*	*1991*		*1996*		*2000*	
		Delhi	*Euro*	*Delhi*	*Euro*	*Delhi*	*Euro*
1.	Petrol Cars						
	CO (g/km)	14.3-27.1	2.72	8.68-12.4	2.2	2.2	2.3
	HC (g/km)	2.0-2.9	-	-	-	-	0.20
	NO_x (g/km)	-	-	-	-	-	0.15
	HC + NO_x (g/km)	-	0.97	3.4-4.36	0.57	0.57	-
2.	Diesel Cars						
	CO	14.0 g/kwh	2.72	5.0-9.0	1.00	1.00	0.6
	HC (g/km)	3.5 g/kwh	-	-	-	-	-
	NO_x (g/km)	18.0 g/kwh	-	-	-	-	0.50
	HC + NO_x (g/km)	-	0.97 (IDI)	2.0-4.0	0.7	0.7	0.56
	PM (g/km)	-	0.14 (IDI) 0.19 (DI)	-	0.08	0.08	0.05
3.	Light duty diesel vehicles<3.5 tons						
	CO (g/km)	14.0 g/kwh	2.72-6.92*	11.2 g/km	1.0-1.5*	2.72-6.92 g/km	
	HC (g/km)	3.5 g/kwh	-	2.4 g/kwh	-	-	-
	NO_x (g/km)	18.0 g/kwh	-	14.4 g/kwh	-	-	-
	HC + NO_x (g/km)	-	0.97-1.7*	2.0-4.0 g/km	0.7-1.3*	0.97-1.7 g/km	-
	PM (g/km)	-	0.14-0.7	-	-	0.18-0.29 g/km	-
4.	Heavy duty diesel vehicles>3.5 tons						

S.No	Type of vehicles and pollutants	1991		1996		2000	
		Delhi	Euro	Delhi	Euro	Delhi	Euro
	CO (g/kwh)	14.0	4.5	11.2	4.0	4.5	2.1
	HC (g/kwh)	3.5	1.10	2.4	1.10	1.1	0.66
	NO_x (g/kwh)	18.0	8.0	14.4	7.0	8.0	5.0
	PM>85 kw/g/kwh	-	0.36	-	0.15	0.36	0.1
	PM<85 kw/g/kwh	-	0.61	-	0.15	0.61	0.1

Notes: * European Driving Cycle

IDI – Indian driving cycle.

Source: Parivesh, Vol. 6(1), June 1999, CPCB, New Delhi.

The other main developments in the mass emission standards notified for the year 2000 are:

(i) Standards have been set for the durability of catalytic convertors (CAT).

(ii) Standards have been set for particulate emissions from diesel vehicles.

(iii) Cold start emission measurement has been adopted for emission tests.

- *Fuel standards*

MoEF has notified binding fuel standards under the EPA for the first time in 1997. Prior to that, standards of the Bureau of Indian Standards governed fuel quality in the country. Present fuel quality standards are poor compared to world standards. A comparison of fuel standards for the year 2000 for Delhi and European standards is given in Tables 2.3 and 2.4. The major developments in the fuel standards for Delhi are:

Table 2.3. Petrol quality specifications in India and Europe

S.No.	Property	2000	
		India	Europe
1.	Octane Number, AKI	84	95
2.	Oxygen Content	Oxygenates Allowed	-
3.	Benzene, % v/v max	5% (3% in NCR)	1.0
4.	Aromatics, % v/v max	No standard	42
5.	Olefins, % v/v max	No standard	18
6.	Sulphur, % m/m max	0.1 (0.05 in NCR)	.015
7.	Lead Content gm/ltr	0.013	.005

Source: Bhatnagar and Raje, 1999.

Table 2.4. Diesel quality specifications in India and Europe

S.No.	*Property*	*2000*	
		India	*Europe*
1.	Cetane Number	48	51
2.	Sulphur, % m/m max	0.2 (0.05 in NCR)	0.035
3.	T 95, deg C (Distillation)	370	340
4.	Polyaromatics, % v/v	No standard	11

Source: Bhatnagar and Raje, 1999.

(i) low sulphur diesel (0.05 per cent);

(ii) leaded petrol phase-out;

(iii) ban on supply of loose 2T oils at petrol stations and service garages;

(iv) pre-mix oil dispensors made compulsory.

- *Other measures implemented/proposed*

1. Private vehicles not fitted with CAT cannot be registered.
2. All existing government vehicles to be fitted either with CAT or to be converted to CNG.
3. All commercial vehicles above 15 years to be banned from plying in Delhi.
4. From June 1999 only vehicles confirming to Euro I norms to be registered.
5. Expansion of CNG supply network from 9 to 80 stations by the year 2000.
6. All DTC buses to be converted to CNG by April 1, 2001.
7. No 8 year old bus to ply except on CNG or other clean fuel from March 31, 2000.

- *Certificate of Pollution Under Control*

Poor maintenance of vehicles adversely affects their emission efficiency. The role of maintenance in combating vehicular pollution was reflected in government policy for the first time in 1989 which made the certificate of fitness mandatory for registration of public vehicles, commercial vehicles and personal vehicles older than 15 years. The 1990 vehicular emission rules required all motor vehicles to comply with the laid down exhaust emission standards. It is mandatory for every motor vehicle to obtain a certificate of pollution under control (PUC). Validity of this certificate has now been reduced from six months to three months. Only a sub-inspector of police or an inspector of motor vehicles is empowered to measure emission levels.

Though it is mandatory for all vehicles to have a valid PUC at all times, according to statistics maintained by transport department, percentage of vehicles with valid PUC was highest at 23 per cent in 1997 since the introduction of this legislation (Table 2.5). This, it appears, was the result of the special PUC enforcement drive launched by the transport department in 1996-97.

Table 2.5. PUC Compliance Status

Year	*Total Vehicles*	*Vehicles with Valid PUC %*	*Vehicles without PUC %*	*Vehicles fined as a % of vehicles without valid PUC*
1991	1923787	9	91	0.17
1992	2064682	11	89	0.76
1993	2198908	11	89	0.71
1994	2372990	13	87	0.39
1995	2575731	12	88	0.48
1996	2793605	10	90	0.37
1997	3033045	23	77	1.07
1998	3167044	13	87	0.59

Source: Transport Department, Government of Delhi.

There is a provision to levy a monetary fine of Rs. 1000 on motorists who fail to abide by the law. However, enforcement of the law is poor. For instance, since the introduction of the law in 1991, vehicles fined as a per cent of those without valid PUC was highest at 1.07 in 1997. Statistics maintained by Automobile Association of Upper India (AAUI) reveals that more than 50 percent of vehicles in Delhi in May 1995, failed to comply with the prescribed standards. What is more alarming is that nearly 44 percent of the new vehicles checked were found to be not in compliance with the standards. This shows that PUC despite being a potentially powerful instrument in controlling pollution from vehicles has failed to make an impact on vehicular pollution.

The law also provided for cancellation of PUC of vehicles which were found in violation of the norms during the random on-road inspection. The vehicles were given one week time for tuning and obtaining a new PUC. PUC cancellation was discontinued in 1997 under public pressure. This, in our opinion, was a very powerful tool to induce better maintenance of vehicles and discourage the practice of obtaining a fake PUC certificate or reverse tuning the vehicles after obtaining a PUC.

(ii) Enforcement measures

- Monetary fines are charged from vehicles that are not carrying a valid PUC. Under section 190(2) of Motor Vehicle Act, 1988, a sub-inspector of police or an inspector of motor vehicles is empowered to charge a fine of Rs. 1000 for first challan and Rs. 2000 for subsequent challans. Fines are fixed charges rather than related to the extent of violation. Though the law provides for a fine of Rs. 2000 for second and subsequent offences, it remains on paper due to lack of information required for implementing it.

(iii) Fiscal measures

- An interest subsidy is given on purchase of a new commercial vehicle, provided a 15 year old (or older) commercial vehicle is scrapped.

- CNG kits and parts required for the conversion of petrol or diesel vehicles to CNG vehicles are charged customs duty at a low rate of 5 per cent.

- CAT and parts of CAT are charged customs duty at 5 per cent.

From the above discussion it can be clearly seen that with the exception of penalty for non-compliance with the vehicle emission standards and custom and excise duty concessions on CAT and interest subsidy on loan for purchase of a new commercial vehicle subject to certain conditions, economic instruments to either directly encourage the use of more efficient modes of transport, more efficient vehicle technology, better quality fuel or to encourage the reduction in vehicle utilisation rate are lacking in the policies adopted for vehicular pollution control in India. At the same time, however, the economic instruments have been implemented in both the developed and developing countries and their use has been on the increase. Section 2.3 presents a review of the various economic instruments used in other countries.

(iv) Revenue implications of existing economic measures

As noted earlier, the economic measures implemented to encourage the control of vehicular pollution are:

(i) concessional rate of customs duty (5 per cent) on CNG kits;

(ii) concessional rate of customs duty (5 per cent) on catalytic convertors;

(iii) interest subsidy on purchase of a new commercial vehicle, provided a 15 year old commercial vehicle is scrapped; and

(iv) monetary fines for violating exhaust emission standards.

The MoEF does not keep any record of the extent of utilisation of these fiscal incentives. Interest subsidies are granted on a case-by-case basis by various departments of the Delhi Government. There has been no attempt to collate this data. Thus, there is no way to discern what their budgetary implications are. Similarly, data on duty concessions availed is not available. However, statistics on revenue collected from fines for violating exhaust emission standards is maintained by the transport department, Government of Delhi. According to this statistics, highest number of motorists were fined in 1997 which yielded Rs. 250.7 lakh (Table 2.6). In subsequent years this has declined due to poor enforcement of the law.

Table 2.6. Revenue Collected from Fines

Year	*Challans*	*Fine (Rs. Lakh)*
1990	1830	18.3
1991	2969	29.7
1992	14126	141.3
1993	13883	138.8
1994	8033	80.3
1995	10988	109.9
1996	9142	91.4
1997	25070	250.7
1998	16290	162.9
1999*	13639	136.4

* Upto July.

Source: Transport Department, Government of Delhi.

2.3 Economic Instruments: Experience of Other Countries

The role of fiscal instruments in both developed and developing countries has been gaining importance since 1980s. As can be seen from the overview of recent policy trends below, besides introducing new fiscal instruments there is a great deal of interest in developing the use of existing taxes/charges/fee on polluting goods such as fuel and vehicles to take account of environmental considerations.

Table 2.7 provides an overview of the application of economic instruments in developed and developing countries. The following main points emerge from this table.

(i) The strategies resorted to by other countries to control vehicular pollution mainly comprised of policies to:

- induce shifts to more efficient transportation modes. As part of the efforts to promote this policy, disincentives such as introduction of environmental tax, increased excise and sales tax, and registration and parking fee, have been introduced;
- encourage use of new technology and phasing out of old vehicles: differential vehicle taxation. tax allowances on purchase of new vehicles provided old vehicles are scrapped. environmental taxes on vehicles not meeting the prescribed standards (differentiated on the basis of whether or not they are

equipped with catalytic convertors), and penalty for violation of air pollution standards; and

- induce production and use of cleaner fuels: lower taxes on cleaner fuels and tax incentives for producers of cleaner fuel.

(ii) Until late eighties, taxation policies of motor vehicles and motor fuels had focused primarily on raising revenue. Since early nineties many countries have implemented coordinated fiscal and environmental policies, aimed at reducing motor vehicle related pollution.

(iii) Vehicular pollution control, in almost all countries, started with a CAC strategy, and over time was supplemented with economic instruments.

(iv) In general, indirect instruments have been used more extensively than direct instruments.

(v) Within indirect instruments, policies directed at vehicle technology and fuel have found extensive application.

(vi) The use of economic instruments has generally been successful in controlling vehicular air pollution. In particular, user fee to address the problem of congestion and air pollution in Norway and Singapore, use of differential pricing in favour of unleaded petrol in Taiwan, Thailand, Denmark etc, and a tax on polluting vehicles in Sweden have been successful.

A review of actual application of economic instruments based on published information, reveals that they have been extensively used in a number of countries including many developing countries such as Korea, Chile, Taiwan, Thailand and Brazil. Use of these instruments has helped in containing environmental pollution. The critical state of atmospheric pollution in Delhi is a clear indication that policies currently in use have failed to make the desired impact and it is important to implement economic instruments for controlling emissions from motor vehicles.

Table 2.7. Application of Economic Instruments in Various Countries

Country	*VEHICLE*	
	Direct	*Indirect*
Australia		Tax on sale or initial registration of vehicles. Rate of tax varies on the basis of value of vehicles. Higher annual registration fee on commercial vehicles compared to private vehicles.
Austria		Environmental tax on car registration was introduced in 1992. While the base is the selling price of cars the tax rate depends on the standard petrol consumption. Since May 1, 1993, the annual vehicle tax on passenger cars is assessed on the basis of engine power and no longer on cylinder volume. From January 1, 1995, cars without catalytic converters are imposed a surtax of 20 percent. At the same time VAT on new vehicles was reduced from 32 percent to 20 percent and the VAT rate on electric cars was cut by half to 10 percent. Tax is based on net weight for buses and on loading capacity for trucks.
Belgium		An annual tax on registration was introduced for new motor cars on June 1, 1992, and it has been extended to in-use cars since June 1, 1993. This tax is based on the engine power of the car.
Brazil		Penalty system for violation of air pollution standards since 1981. Fines are arbitrary as the level of emission from trucks is generally visually assessed. Fines are related to frequency of violation rather than intensity or toxicity of pollution.

Country	***VEHICLE***	
	Direct	***Indirect***
Britain		Sales tax on new cars (17.5 percent) and annual vehicle excise duty. Higher taxes on commercial vehicle sales, ownership (excise duty based on axles and weight) and use than on private cars.
Canada	British Columbia introduced permit fees on pollutant emissions in 1992. The fees are reduced if the actual emissions are less than the permitted emissions.	A tax on purchase of fuel inefficient passenger and sport utility vehicles. A subsidy of $100 is provided to cars with a highway fuel efficiency rating of less than 6 litres per 100 km.
Finland		Annual tax on diesel vehicles and passenger cars of 150 FIM/100 kg of weight, and on delivery vans of 27 FIM/1000 kg of weight. Environmental taxes on cars, differentiated on the basis of whether or not these are equipped with catalytic converters.
France		Accelerated depreciations allowed for electrical vehicles.
Germany		Annual tax on motor vehicle not meeting the EU emission standards to accelerate the introduction of cleaner vehicles. Rates are differentiated by age of the car. A higher tax has been imposed on diesel cars as compared to petrol cars since 1994.
Greece		Since 1990 exemption from the road surtax and initial lumpsum tax for a period of 5 years for new cars fitted with a catalytic convertor, subject to scrapping of old car by the buyers of new car. About 3 lakh old cars were scrapped.
Hungary		New cars with catalytic convertors get a discount of Forint 50000 from consumption tax.

Country	*VEHICLE*	
	Direct	***Indirect***
Iceland	Excise duty based on cylinder capacity of vehicles.	IKr 330 is charged for a mandatory annual emission test. Inspection fee charged for annual inspection of vehicles over 2 years old. Rate of charge is on the basis of weight of vehicles.
Ireland		Sales tax on retail price of private vehicles based on cylinder capacity.
Italy		One-off Registration tax on purchase of new and used vehicles depending on type and size of vehicles.
Japan		Tax deductions for cars with low emissions, electric cars and cars on alternative fuels. One-off consumption tax on new or old car registration at 3 percent. Annual tax in relation to power and load of vehicles.
Korea		Introduced environmental quality improvement charges, in 1991. Besides other economic activities it covered vehicles (buses and trucks using diesel). The charge is computed by the price of catalytic converter.
Netherlands		Lower sales tax on cars that complied with future EU standards. Consequently, share of future EU standard cars rose from 37% to 70%, faster than expected by the government.
Norway		Differentiated taxes on car prices, with a tax advantage given to cars fitted with catalytic converters and cars powered by electricity or gas.
Singapore		Additional registration charge at 150 percent, since 1983, of the cost of the car to discourage ownership. A rebate on tax is given if an old vehicle is scrapped simultaneously.
Sweden		Vehicle taxes based on weight and environmental characteristics. Subsidy on cars with catalytic converters, special tax on cars without catalytic converters.

Country	*VEHICLE*	
	Direct	***Indirect***
United States		Higher excise tax (12 percent) on trucks, annual use tax on "heavy vehicles", excise tax on tyres weighing over 40 pounds, a "Gas Guzzler" tax on automobiles with unsatisfactory fuel economy ratings. The Gas Guzzler excise tax is imposed on the sale of autos whose fuel efficiency is less than 22.5 miles per gallon. The tax varies from $ 1000 to $ 7700 depending on the fuel efficiency. Non-conformance charge on heavy vehicles and engines are based on the degree of non-compliance.

Country	*FUEL*	
	Direct	***Indirect***
Australia		Petrol taxes were increased. Differential pricing for leaded and unleaded petrol was introduced in favour of the latter.
Belgium		Higher excise duty on leaded petrol.
Britain		Tax Differential has been gradually increased and now stands at 4.8 pence per litre. The proportion of unleaded in total petrol sales rose to 50% in 1993 from a negligible share in 1986.
Denmark		Fuel tax based on CO_2 content at combustion was introduced in 1992. Since the mid-1980s, differential tax on leaded and unleaded gasoline. In 1994 the market share of unleaded petrol rose to nearly 100%.

Country	*FUEL*	
	Direct	***Indirect***
Finland		Lower tax on lead free petrol than on leaded petrol since 1986. Lower excise duty on sulphur free diesel since 1993. Carbon tax on fuel since 1994.
Germany		Duty differential between leaded and unleaded petrol at the rate of DM 0.10 per litre.
Hungary		In 1992, at tax at the rate of 0.7% of the price was introduced on motor vehicle fuels. The revenue is earmarked for environmental expenditure relating to vehicular traffic.
Ireland		Higher excise duty on leaded petrol than on the unleaded petrol.
Luxembourg		Higher excise duty and VAT rates on leaded petrol by 2-3% than on unleaded petrol.
Mexico		Higher excise tax on leaded petrol than on unleaded variety.
Netherlands		Environmental charges on fuel since 1988. These charges were revised in 1990 to include CO_2 emissions. Unleaded petrol was cheaper than leaded petrol.
New Zealand		Tax treatment in favour of unleaded petrol vis-a-vis leaded petrol. A fee of NZ$ 0.066 i.e. US$ 0.039 per gram was levied on lead added to gasoline.
Norway	Since 1995 gasoline tax difference was introduced for leaded petrol based on emissions of lead per litre.	Fuel tax based on sulphur, carbon and lead content. CO_2 tax since 1991.
Sweden		High gasoline taxes. Differential tax in favour of unleaded petrol. A carbon tax was imposed on motor and other fossil fuels since 1991. The part of the tax levied on motor fuels amounted to SKr 0.58 per litre for petrol and 0.92 for diesel. System of tax rebate for producers of cleaner diesel fuel since 1991.

Country	*FUEL*	
	Direct	*Indirect*
Switzerland		The market share of unleaded petrol increased to 655 in 1992 due to a tax differentiation of ECU 0.04/l in favour of unleaded petrol.
Taiwan		Differential price in favour of unleaded petrol. This led to an increase in the market share of unleaded petrol from 18.7 per cent in 1990 to 51.84 per cent in 1993.
Thailand		Differential price in favour of unleaded petrol.
Thailand		A surtax on leaded gasoline to finance the subsidy on unleaded gasoline.
US		Trade in lead credits, to phase out lead in gasoline in 1982-87.

Country	*TRAFFIC*	
	Direct	*Indirect*
Chile		In 1990 the city allocated bus transit rights and auctioned routes based on fares and types of buses.
Norway		In 1986 to control congestion the city of Bergen introduced toll for motorists entering the city between 6 a.m. to 10 p.m. on weekdays. The rate is differentiated on the basis of loading capacity of vehicles. The revenue so collected is used to finance the construction of by-passes.
Singapore		Implemented a licence ticket scheme for entering some identified zones during peak hours. Fine for non-compliance was 10 times the licence price. It helped reduce the traffic flow and thus pollution. These zones also have higher parking fee.

Sources: Bergman 1994; Bernstein 1993; Buchan 1994; Guha 1997; Hahn 1989; Henry 1990; Margulis 1994; McKay *et al.* 1990; Oates 1994; O'Connor 1994; OECD 1994; OECD 1995; Rhee 1994; Smith 1995; Tietenberg 1991; World.

FISCAL INSTRUMENTS FOR CONTROLLING VEHICULAR AIR POLLUTION IN SINGAPORE 3

This chapter examines various measures including the fiscal measures adopted for controlling vehicular air pollution in Singapore and identifies which instruments have worked and why. In examining the effectiveness of various instruments the focus is on the basic objectives such as target ambient air quality levels and traffic congestion/speed. Finally, we identify lessons for Delhi from the experience of Singapore.

3.1 Vehicular Pollution Control: A Background

The key feature of air pollution control system in Singapore, as far as air pollution from land transport is concerned, is the integration of air pollution control policies with the land transport policies. The coordinated and concerted efforts between the Ministry of Communication and Information Technology (CIT) – responsible for land transport policy – and the Ministry of Environment (ENV) have successfully made Singapore roads one of the safest in the world and maintained the ambient air quality levels in Singapore well within the internationally accepted standards (Table 3.1).

Table 3.1. Ambient Air Quality in Singapore

Pollutant	*Averaging time*	*Singapore air quality, 1997*	*USEPA primary air quality standards*
Sulphur Dioxide	Annual mean	20 $\mu g/m^3$	80 $\mu g/m^3$
Carbon Monoxide	8 hours	0.9 mg/m^3	10 mg/m^3
Nitrogen Dioxide	Annual	32 $\mu g/m^3$	100 $\mu g/m^3$
PM_{10}	Annual mean	51 $\mu g/m^3$	50 $\mu g/m^3$

USEA: United States Environment Protection Agency

Source: Annual Report, 1997, ENV, Government of Singapore.

Singapore faced an explosive demand for transport during the late seventies and eighties. During this period, while the road network grew by 27 per cent, the car population alone grew at 10 per cent per annum. Further, the number of vehicular trips grew annually by more than 10 per cent, from 2.7

million trips in 1981 to about 7 million trips a day in 1995. 23 per cent of the total trips were made during the short two hour period comprising of morning and evening peaks. This trend was not surprising given the rising levels of income, changes in lifestyle and other demographic and social developments in Singapore. Rising number of vehicles as well as vehicular trips not only put tremendous pressure on the available road network but also contributed to air pollution. The government soon realised that given the limited land area of Singapore, it is not feasible to rely on road expansion alone to solve the growing transport needs and the problem of air pollution resulting from high growth in vehicle population. In this scenario, the environmental policy and land transport policy were seen as two sides of a coin which needed perfect coordination in their design and implementation for achieving the objectives of clean air and congestion free roads.

Keeping this in view, the following key areas were identified for action:

(i) Integrating transport and land use planning;
(ii) expanding the road network and maximising its capacity;
(iii) controlling demand for vehicles through ownership and usage restraints;
(iv) providing efficient public transport;
(v) discouraging the use of old vehicles;
(vi) strict vehicular and fuel quality standards; and
(vii) periodic inspection of in-use vehicles.

While (i) seeks to ensure: (a) easy accessibility to public transport for commuters to key nodes of employment, housing and other social activities; and (b) reduction in miles travelled per person for accessing these activities, the primary objective of (ii), (iii) and (iv) is to ensure smooth and speedy traffic flows which has positive spin offs for the ambient air quality. These measures however are under the sole jurisdiction of the Ministry of CIT. The last three measures (v – vii) intend to target vehicular pollution directly and are under the jurisdiction of ENV. Clearly, road transport policies are complementary to the measures taken by the ENV for vehicular air pollution control.

It is well recognised in Singapore that a high standard of transport is a must for economic growth. To ensure due attention to the design and implementation of land transport policies, Minister for CIT launched the Land Transport Authority (LTA) on 15th September, 1995. The LTA's main missions are to: (i) provide people with a wide spectrum of transport choices, while ensuring that they are effectively integrated; and (ii) ensure that the roads are free from congestion. The LTA is responsible for land use planning, providing public transport, controlling vehicle population and usage, and expansion of road networks. Some of ENV's legislations are also enforced by the LTA.

ENV is the main body responsible for air pollution control in Singapore. Two major Acts, the Clean Air Act 1971 and Clean Air (Standards) Regulations 1972, form the foundation of the air pollution control system. The control of vehicular emissions is under the Road Traffic Act and its subsidiary legislation, the Road Traffic (Motor Vehicles, Construction and Use) Rules.

The main principle of vehicular pollution control is – minimising emissions at source. The key strategies in managing the air quality encompass three elements viz. prevention, monitoring and enforcement. ENV is responsible for enacting the legislation, stipulating vehicle technology, fuel and emission standards, and monitoring and enforcing emission standards. These standards are reviewed regularly and tightened where necessary.

3.2 Vehicular Pollution Control: Approaches and Instruments

The ENV and LTA work together to achieve the targeted air quality levels. The approach to tackle air pollution in Singapore can be categorised as below.

1. Control on the number of vehicles.
2. Control on use of vehicles, and discouragement to use old vehicles.
3. Efficient and user friendly public transport system.
4. Strict vehicular and fuel quality standards.
5. Periodic inspection of in-use vehicles.

3.2.1 Controlling the Number of Vehicles

Keeping a check on the growth of vehicle population comes under the purview of LTA. During the period 1971 to 1983 vehicle population grew at an average annual rate of more than 13 per cent (Table 3.2).

Table 3.2. Vehicular Population in Singapore

Type of Vehicle	*Number of Vehicles*			*Growth rates (average annual)*		
	1971	*1983*	*1991*	*1971-83*	*1971-91*	*1991-98*
Motorcycles & scooters	80,720	140,267	122,410	6.15	2.58	1.28
Cars	97,910	204,370	287,411	9.06	9.68	4.47
Taxies	3,800	10,673	12,705	15.07	11.72	5.83
Buses	2,298	7,840	9,478	20.10	15.62	2.94
Goods & others	NA	113,138	127,300	NA	NA	1.54
Total	184,728	476,288	559,304	13.15	10.14	3.11

Source: Thong, Ho Siew. 1999.

The trend increase was excessive in the absence of commensurate increase in the road network. The policy response came in the form of higher registration fee and import duty on vehicles. Though these measures were effective in moderating the demand for vehicles, they were not effective enough. In 1991, a Vehicle Quota System (VQS) was introduced to regulate the growth of the vehicle population. VQS is now one of the principal tools to control the demand for vehicles. To maintain the predetermined vehicular growth rate, in the beginning of any year the Ministry of CIT announces the number of new vehicles by vehicle types, that can be registered in that year in Singapore. Accordingly, an equal number of certificates of entitlement (COE) are printed. Those who aspire to own a vehicle, participate in a bidding process to compete for a given number of COE which is a must for vehicle registration and thus for vehicle ownership. COE prices are determined by the supply and demand[1]. The 'single strike price' method is followed in bidding wherein a bidder can quote a price only once. VQS attempts to address the equity objective by incorporating an element of progressivity in having different COE categories for different vehicle types as well as within a vehicle type (such as car) by its engine capacity (Table 3.3).

[1] For Mercedes E 200 (A), 1998 CC, the price of COE in August 1999 was 94.8 per cent of its open market value (OMV), whereas for Toyota Corona, 1587CC, the price of COE was 202.1 per cent of its OMV (Table 3.4).

From November 1, 1995, an electronic bidding system replaced the manual bidding procedure for COEs. The new system delivers the bidding results very fast and returns the deposits of unsuccessful bidders within two working days. However, the method used in bidding remains unchanged, viz., the 'single strike price' method. It is felt that the current method of bidding needs to be refined and made more transparent. It is believed that an open bidding method such as 'pay-as-you-bid' method will be fairer than the current method and will moderate COE prices.

Table 3.3. Vehicle Quota Premium and COE by Vehicle Category

Year		Vehicle Category							
		A		B		C	D	E	Total
		Cat 1	Cat 2	Cat 3	Cat 4	Cat 5	Cat 6	Cat 7	
1995	COE	3,102	17,756	3,875	1,158	7,702	7,526	6,856	47,975
	QP	S$ 27,550	S$ 46,046	S$ 71,510	S$ 75,002	S$ 31,996	S$ 4,006	S$ 78,098	
1996	COE	3,013	14,626	3,392	1,233	7,878	7,422	5,624	43,188
	QP	S$ 41,008	S$ 62,208	S$ 74,600	S$ 75,500	S$ 36,050	S$ 3,506	S$ 75,002	
1998	COE	2,097	14,131	4,015	1,630	9,636	9,747	6,361	47,617
	QP	S$ 36,426	S$ 43,088	S$ 44,700	S$ 50,998	S$ 30,088	S$ 1,160	S$ 40,502	
Jan. 99-Apr.99	COE	655	4,801	1,302	569	3,135	3,431	2,338	16,231
	QP	S$ 29,494	S$ 35,403	S$ 35,808	S$ 39,998	S$ 18,548	S$ 855	S$ 37,010	
May 99-July 99**	COE	6,553		1,680		3,418	2,638	6,031	20,320
	QP	S$ 43,600		S$ 53,502		S$ 26,001	S$ 589	S$ 53,001	

Source: Personal interaction with LTA officials.

QP: Quota premium. As bidding is done on a monthly basis, the highest QP in a year is reported for respective vehicle categories.

* COE is certificate of entitlement. COE here represents the maximum number of COEs that can be issued in a year.

** From May 1999, Cat 1 and Cat 2 were merged into CAT A, and Cat 3 and Cat 4 into CAT B

Vehicle Categories:

- A Cars (1600cc and below) and Taxis
- B Cars (1601cc and above)
- C Goods vehicles and buses
- D Motor cycles
- E Open (for any kind of vehicle).

3.2.1 Measures to Restrain the Use of Vehicles

While VQS has helped in controlling the number of vehicles, it has resulted in increasing the fixed cost of purchasing a vehicle and thus in reducing the variable cost of running the vehicle relative to the fixed cost. According to an estimate, the mileage clocked by a car in Singapore averaged 18,600 km per year in 1994 – very high by international standards. Clearly, there was a need to tighten controls on excessive use of vehicle acquired. One way of controlling the usage is to make trips more costly. Traditionally this has been done either by making fuel more expensive, or the use of roads more expensive, or with an optimal mix of the two. One of the main objectives of controlling usage of vehicles is to contain congestion. Since the problem of congestion is more severe at specific locations at specific times, it is important that the measures intended to control congestion are location and time specific. Realising this, the following innovative schemes were introduced in Singapore:

a) Electronic Road Pricing (ERP)
b) Off-Peak Car Scheme (OPC)
c) Vehicle Entry Permit Scheme (VEP)

Table 3.4. Net Price of Cars (S$)

	Subaru Vivio 685cc	***Toyota Corona 1587cc***	***Mercedes E200(A) 1998cc***
Average OMV (June 99)	9,387	22,700	52,136
Import duty (31%)	2,910	7,037	16,162
Sales tax	369	892	2,049
Additional registration fee (140%)	13,142	31,780	72,990
Registration fee	140	140	140
COE – Aug. 99	45,876	45,876	49,400
Road Tax	516	1,188	1,918
Total selling price July 99	75,900	136,388	223,000
Less: 80% PARF*	4,610	11,149	25,605
Net Price	71,290	125,239	197,395

Source: Personal interaction with LTA officials.

* Preferential Additional Registration Fee (PARF) benefits in the form of rebate on registration fee are given if a vehicle is deregistered in 5-10 years of age. It is assumed that the previous vehicle was deregistered in the age group 9-10 years.

a) Electronic Road Pricing

ERP was introduced in 1998. It is an automated version of the earlier road pricing scheme called Area Licensing Scheme (ALS) introduced in 1976 to reduce traffic congestion in the busy areas of the city that existed until 1998 when ERP was introduced. Areas covered under the ALS were called restricted zones. All vehicles (except exempted ones) entering the restricted zone during the restricted hours were required to display valid license coupons (daily or monthly) on their wind screens. ALS was enforced by policing the entry points of the restricted zones. ALS was very successful in reducing the traffic volume during rush hours in Central Business District (CBD) by spreading traffic to other times and alternative routes.

Under the ERP system, electronic sensors and devices are implanted on roads and an In-Vehicle Unit (IU) is fitted on vehicles. ERP covers certain express ways and arterial roads of CBD. All vehicles including the foreign registered vehicles using ERP roads during certain hours need an IU and a cash card to pay for the ERP charges. The electronic sensors implanted on roads are able to track vehicles that pass through sensors and deduct the ERP charges from cash cards in the IU (for ERP charges see Table 3.5). In case of a violation, the sensors which are also fitted with cameras take the photograph of the rear number-plate of the vehicle. A maximum fine of S$500 can be charged for violation. The traffic speed targets to be achieved through ERP are 30-40 km/hr on major arterial roads and 60 km/hr on express ways. It is claimed that ERP has been successful in controlling congestion on roads. To cushion the impact of ERP on road users, offsets are provided in road tax which is a one-off cost paid annually by the vehicle owners. ERP is more efficient than ALS as in this system each trip is charged unlike in ALS which charged a fixed fee for any number of trips in a day/month.

Table 3.5. ERP Rates

		ERP Rates for Motorcycles		
Time	***ECP****	***CTC*****	***PIE******	***Restricted Zone*******
	Monday-Friday	***Monday-Friday***	***Monday-Friday***	***Monday-Friday***
7.30 - 8.00 a.m.	S$ 0.50	S$ 0.50	S$ 0.75	S$ 0.50
8.00 – 8.30 a.m.	S$ 0.75	S$ 1.25	S$ 0.75	S$ 1.00 S$ 1.25 Nicoll Highway
8.30 – 9.00 a.m.	S$ 1.00	S$ 1.25	S$ 0.50	S$ 1.25
9.00 – 9.30 a.m.	S$ 0.25	S$ 0.50	S$ 0.50	S$ 1.00
9.30 am-5.30 pm		-		S$ 0.50
5.30 – 6.00 p.m.				S$ 0.75
6.00 – 6.30 p.m.				S$ 1.00
6.30 – 7.00 p.m.				S$ 0.50
		ERP Rates for Passenger Cars		
7.30 - 8.00 a.m.	S$ 1.00	S$ 1.00	S$ 1.50	S$ 1.00
8.00 – 8.30 a.m.	S$ 1.50	S$ 2.50	S$ 1.50	S$ 2.00 S$ 2.50 Nicoll Highway
8.30 – 9.00 a.m.	S$ 2.00	S$ 2.50	S$ 1.00	S$ 2.50
9.00 – 9.30 a.m.	S$ 0.50	S$ 1.00	S$ 1.00	S$ 2.00
9.30 am-5.30 pm		-		S$ 1.00
5.30 – 6.00 p.m.				S$ 1.50
6.00 – 6.30 p.m.				S$ 2.00
6.30 – 7.00 p.m.				S$ 1.00
		ERP Rates for Goods Vehicles/Small Buses		
7.30 - 8.00 a.m.	S$ 0.40	S$ 0.80	S$ 0.60	S$ 0.40
8.00 – 8.30 a.m.	S$ 0.60	S$ 1.90	S$ 0.60	S$ 0.80 S$ 1.00 Nicoll Highway
8.30 – 9.00 a.m.	S$ 0.80	S$ 1.90	S$ 0.40	S$ 1.00
9.00 – 9.30 a.m.	S$ 0.20	S$ 0.80	S$ 0.40	S$ 0.80
9.30 am-5.30 pm		-		S$ 0.40
5.30 – 6.00 p.m.				S$ 0.60
6.00 – 6.30 p.m.				S$ 0.80
6.30 – 7.00 p.m.				S$ 0.40
		ERP Rates for Heavy Goods Vehicles/Big Buses		
7.30 - 8.00 a.m.	S$ 0.50	S$ 1.00	S$ 0.75	S$ 0.50
8.00 – 8.30 a.m.	S$ 0.75	S$ 2.50	S$ 0.75	S$ 1.00 S$ 1.25 Nicoll Highway
8.30 – 9.00 a.m.	S$ 1.00	S$ 2.50	S$ 0.50	S$ 1.25
9.00 – 9.30 a.m.	S$ 0.25	S$ 1.00	S$ 0.50	S$ 1.00
9.30 am-5.30 pm		-		S$ 0.50
5.30 – 6.00 p.m.				S$ 0.75
6.00 – 6.30 p.m.				S$ 1.00
6.30 – 7.00 p.m.				S$ 0.50

Source: LTA, 1999.

* East Coast Parkway

** Central Expressway

*** Pan-Island Expressway

**** Central Business District

b) *Off-Peak Car Scheme*

OPC Scheme which replaced the weekend car scheme was introduced in October, 1994. Vehicles which opt for OPC scheme are allowed to ply on Sundays, public holidays and Saturdays between 3:00 p.m. to 7:00 a.m. and on weekdays between 7.00 p.m. to 7.00 a.m. For running an OPC scheme vehicle during restricted hours, one can get a license for a fee of S$20 per day. Cars registered as OPC are given various tax concessions, like S$17,000 upfront rebate on additional registration fee (ARF), rebate on customs duty and COE, and a flat discount of S$800 on annual road tax subject to a minimum payment of S$50 a year. Number-plates of OPC vehicles are in red for better identification.

c) *Vehicle Entry Permit Scheme*

Each car registered in Malaysia is allowed free entry for five days in a calendar year. For rest of the days (except public holidays, Sundays and Saturdays after 3.00 p.m.), such cars, or motorcycles, are required to have valid VEPs during their stay in Singapore. Daily VEP costs S$30 for cars and S$4 for motor cycles, while monthly VEP costs S$600 for cars and S$80 for motor cycles.

Success of these measures is assessed on the basis of pre-determined targets of traffic speed at specific locations and time which are continuously monitored. It is claimed that in Singapore average traffic speed is 35-45 km per hour on major arterial roads and 60-80 km per hour on expressways (during the morning and evening peak hours) which is satisfactory in view of the target traffic speed. In fact, on central expressways (CTE), the average speed during the morning peak hours has more than doubled from 25 km/h to 65 km/h since the introduction of electronic road pricing scheme.

3.2.3 Measures to Encourage Early Scrapping of Vehicles

Emission intensity of older vehicles, other things being equal, is likely to be more. In Singapore, measures have been employed to discourage the use of old vehicles. The life of certain category of vehicles is fixed, at the end of which the vehicles must be scrapped. While taxies must retire at the end of 7 years of age, buses and goods vehicles are not allowed on roads beyond 15 years of age.

Though there are no statutory limits on the life of other categories of vehicles, various economic incentives are provided for early scrapping of vehicles. Preferential additional Registration Fee (PARF) benefits are given if a vehicle is deregistered between 5-10 years of age. If a vehicle is scrapped before CEO expiry (CEO is valid for 10 years), Quota Premium (QP) paid for CEO is refunded on a pro-rata basis for the remaining period. Vehicles over 10 years of age are charged road tax surcharge at an increasing rate (see Table 3.6).

Table 3.6. Measures to Discourage the Use of Older Vehicles

PARF Benefits*

Age of Vehicle at De-registration	*PARF Benefit*
Less than 5 years	130% of OMV
Less than 6 years	120% of OMV
Less than 7 years	110% of OMV
Less than 8 years	100% of OMV
Less than 9 years	90% of OMV
Less than 10 years	80% of OMV

* PARF benefits are transferable and one can get the rebate at the purchase of a new vehicle.

Road tax Surcharge

Age of Vehicle	*Annual Road Tax Surcharge*
More than 10 years	10%
More than 11 years	20%
More than 12 years	30%
More than 13 years	40%
More than 14 years	50%

Source: Personal interactions with LTA officials.

Certificate of Entitlement:

Certificate of entitlement is valid for a period of 10 years, after that it has to be revalidated either for 5 or for 10 years. If revalidation is done for 10 years one has to pay full Prevailing Quota Premium (PQP). PQP is calculated on the basis of current 3-month moving average of quota premium in the respective vehicle category. If revalidation is done for 5 years one has to pay 50 per cent of PQP but the vehicle has to be scrapped at the end of the 5-year period.

If the vehicle is deregistered before COE expiry, Quota Premium paid for remaining period is refunded.

3.2.4 Public Transport System

The success of demand management measures for private vehicles is highly dependent on the quality of public transport. At present the trips by public transport account for 51% of total trips in a day, the objective of Singapore government is to make it 75%. In order to achieve this target, a good quality public transport system which can induce people to switch to public transport in a scenario of increasing incomes, is a must.

Buses and taxies run by private operators and government operated Mass Rapid Transport (MRT) network constitute the public transport in Singapore. The bus industry structure is completely regulated by the government. There are only two bus operators. The bus companies are required to ply all routes, even unprofitable ones, at prescribed frequencies and regulated fares. Given the small domestic market, this industry structure has benefited the bus companies in terms of profitability, and commuters in terms of service levels and affordability. Buses in Singapore have been provided preferential treatment in ARF and customs duty (Table 3.7).

Table 3.7. Various Taxes and Fees on Vehicles

Type of Vehicle		*Registration Fee*	*Additional Registration Fee*	*Diesel Tax*	*Customs duty**
Cars	New	S$ 140	140% of OMV**	-	31% of OMV
	Old***	S$ 1000	150% of OMV		
Taxies	New	S$ 140	140% of OMV	S$ 5100	17% of OMV
	Old	S$ 15	S$2000 - S$5000		
Motor Cycles	New	S$ 140	15% of OMV	-	12% of OMV
	Old	S$ 5	15% of OMV		
Buses	New	S$ 140	5% of OMV	-	41% of OMV****
	Old	S$ 15	55% of OMV		
Goods Vehicles	New	S$ 140	140% of OMV	-	Exempted
	Old	S$ 7000 for LGV's S$ 14000 for HGV's S$ 15 for others	150% of OMV		

Source: Personal interactions with LTA officials.

* Only vehicles less than 3 years of age can be imported. A surcharge of S$ 1000 is payable for such vehicles.

** OMV: Open Market Value.

*** Old vehicles refer to second-hand imported vehicles.

**** For seating capacity of 8 seats or less, while for seating capacity of 9 seats or more no customs duty is charged.

In addition to buses, Singapore has 87 km of MRT network which was started in 1987. It is proposed to expand the MRT network to 160 km. An extensive LRT (Light Rail Transport) network is also proposed to provide a linking network with MRT at a maximum distance of 100 meters from any work place and residential area.

3.2.5 Vehicle and fuel quality standards

The vehicular emission standards prescribed by the ENV require that all new vehicles must conform to Euro I emission standards. All vehicles are inspected before they are registered. Only unleaded petrol and diesel with sulphur content of 0.05 per cent (by weight) can be imported. Euro II emission standards have been implemented from April 1, 1999.

3.2.6 Inspection of In-use Vehicles

(i) Periodic Inspection

All vehicles are required to undergo detailed inspection at prescribed intervals at the LTA authorised inspection centres. Periodicity of inspection for different vehicle types is determined by the LTA. Each vehicle must pass the specified tests before it can pay the annual road tax. Inspection centres give the test report to the vehicle owner, a copy of which is sent to the LTA. According to the officials in LTA approximately 20 per cent of vehicles fail the tests in the first instance. These vehicles are sent for repair and called again for inspection until they can pass all the tests. The frequency of inspection and prescribed emission limits for different vehicles vary according to vehicle type and age (Tables 3.8 and 3.9). There is no fine on vehicles which fail the tests. However, an inspection fee is charged for each inspection.

Table 3.8. Schedule of Compulsory Motor Vehicle Inspection

Type of Vehicle	*Frequency*			*Inspection Fee*	
	For age below 3 years	*For age 3 to 10 years*	*For age 10 years and above*	*First Inspection*	*Subsequent Inspection*
Two Wheelers	Nil	Annually	Annually	S$ 15	S$ 8
Cars	Nil	Once in two years	Annually	S$ 50	S$ 25
Taxies	6-monthly	6-monthly	Nil	S$ 50	S$ 25
Buses	Annually	Annually	6-monthly	S$ 60	S$ 30
Light goods vehicles	Annually	Annually	6-monthly	S$ 50	S$ 25
Heavy goods vehicles (=2 Axels)	Annually	Annually	6-monthly	S$ 60	S$ 30
Heavy goods Vehicles/buses (>2 Axels)	Annually	Annually	6-monthly	S$ 65	S$ 35
Trailers	Annually	Annually	Annually	S$ 50	S$ 25

Source: Thong, Ho Siew. 1999.

Table 3.9. Exhaust Emission Standards

(a)	Petrol driven vehicles	CO < 6% by volume for vehicles registered before October 1, 1986. < 4.5% by volume for motorcycles registered on or after October 1, 1986. < 4.5% by volume for vehicles other than motorcycles registered on or after October 1, 1986 but before July 1, 1992. < 3.5% by volume for vehicles other than motorcycles registered on or after July 1, 1992.
(b)	Diesel driven vehicles	< 50 Hartridge Smoke unit (HSU)

Source: Thong, Ho Siew. 1999.

(ii) Random Inspection

To ensure that vehicles are maintained well such that these meet the emission standards at all times, random inspections are carried out by the ENV. Inspections are carried out by mobile inspection vans. Violators are punished with monetary fines. The fine varies from between S$150 to S$300 for first offence and S$500 for subsequent offences depending on smoke level. The amount of fine for first offence is differentiated according to the smoke level i.e. the extent of violation of the prescribed standards (Table 3.10). Two wheelers emitting white smoke based on visual observation of enforcement officers, can also be prosecuted.

Table 3.10. Penalty Structure for Violation of Exhaust Emission Standards

S.No.	*Smoke Level*	*Penalty*	*Subsequent Action*
1.	51 – 70 HSU	Ist offence S$ 150 on owner S$ 150 on driver Subsequent offences S$ 500 on owner S$ 500 on driver	Vehicle must be repaired and sent for inspection within one month
2.	71 – 85 HSU	Ist offence S$ 150 on owner S$ 150 on driver Subsequent offences S$ 500 on owner S$ 500 on driver	Vehicle prohibited from road until rectified.
3.	86 HSU and above	Ist offence S$ 300 on owner S$ 300 on driver Subsequent offences S$ 500 on owner S$ 500 on driver	Vehicle prohibited from road until rectified.

Source: Thong, Ho Siew. 1999.

3.3 Summing Up

Annexure 3.1 provides an overview of the existing fiscal instruments and command and control measures in controlling vehicular air pollution in Singapore. The main points emerging from this annexure can be summarised as follows.

(i) The strategies adopted to control vehicular pollution mainly comprises policies to:

- induce shifts to more efficient transportation modes which result in reducing energy consumption as well as space needed per person thus reducing environmental pollution. As part of the efforts to promote this policy, measures such as requirement of COE, ERP, OPC and ARF have been used.
- encourage the use of new technology, incentives are given for early scrapage and disincentives in the form of higher road tax on older vehicles and heavy fines for violation of emission standards.

- ensure smooth and speedy traffic flows, a number of measures which are location and time specific such as ERP, OPC, VEP and higher parking fees for parking in restricted zones have been implemented.

(ii) Vehicular pollution control system in Singapore is a mix of CAC measures and economic instruments.

(iii) Various economic measures adopted in Singapore have helped in controlling the growth in number of vehicles, reducing the use of vehicles on busy routes during peak hours, and inducing better maintenance of vehicles, thus reducing air pollution from vehicles.

3.4 Lessons for Delhi

Delhi being the fourth most polluted city in the world can draw many lessons from the experience of Singapore.

- Develop capacity to come up with bold and innovative solutions and muster political and people's support to carry them out.
- Environmental policies can at best be partially successful in controlling vehicular pollution if not integrated with the road transport policies.
- With growing economic affluence, high taxes and other charges cease to act as a disincentive for people to own vehicles, hence some command and control mechanism must be adopted to control vehicular population.
- A judicious mix of measures to contain use of vehicles is a must.
- Any measure to control vehicular population and restrict their use should be complemented by an effective and reliable public transport system.
- There are limits to which buses can provide an effective public transport, ultimately a rail network has to be developed.
- There is a need to have an effective inspection and maintenance programme for in-use vehicles as they are the major contributors to air pollution.
- There is a need to develop a range of incentives/disincentives for scrapage of old vehicles. The running of vehicles of old vintage should be made

uneconomical. Though age limits can be set for use of commercial vehicles, in case of private vehicles use of economic instruments is more desirable.

- Any measure to combat vehicular air pollution would affect the life style of the population and hence there is a need to inform the public about such measures and get its support for effective implementation. This works better than *bans and other authoritarian measures.*
- Effective enforcement of legal provisions is essential for implementing any policy, including environmental policies. Even when CAC measures are substituted by market-based instruments, such instruments will have to be applied by the government. For example, a PARF scheme and surcharge on road tax for vehicles over 10 year old for encouraging the scrapping of old vehicles will have to be accompanied by actual verification of cars for detecting those that are old and collecting fines from the violator. Similarly, the violators under off-peak car scheme who ply their vehicles in peak hours without the necessary authorisation will have to be booked and punished. Singapore has been singularly successful in implementing its laws. Delhi, on the other hand, could not even implement its PUC scheme. The most important lesson for Delhi from the Singapore experiment is that laws will have to be enforced, rigorously and persistently.

Annexure 3.1. Policy Instruments to Control Environmental Impact of Motor Vehicles

	Market-based incentives		*Command-and-control regulations*	
	Direct	***Indirect***	***Direct***	***Indirect***
Vehicle	♦ Monetary fines: For vehicles violating emission standards fines are charged depending on smoke level.	♦ COE Quota Premium: Price of a COE, which is a compulsory requirement for purchasing a vehicle, is determined by bidding, thus making buying of the vehicle very costly. ♦ Differential Vehicle Taxation: Public transport is given various tax concessions for example buses are exempted from paying customs duty. ♦ Restricting Use of Old Vehicles: Early scrapage benefits (PARF benefits for vehicles deregistered between 5-10 years of age). Disincentives for running old vehicles (annual road tax surcharge for vehicles over 10 years of age).	♦ Emissions Standards: All new vehicles are required to conform to Euro I emission standards. ♦ Inspection and Maintenance: All vehicles are periodically required to undergo detailed inspection. Valid inspection certificates are required for annual road tax payment.	♦ Vehicle Quota Scheme: The number of vehicles by vehicle type, that can be registered in a year is determined in advance by the government. ♦ Compulsory scrapage of Old Vehicles: For taxies (7 years), goods vehicle and buses (15 years).
Fuel			♦ Fuel Standards: Only unleaded petrol and diesel with sulphur content of 0.05% (by weight) is used.	
Traffic	♦ Public Transport System: A world class public transport system through a network of taxies, buses, MRT and LRT to induce people to shift from private transport.	♦ Measures to Control Congestion: Every time one enters restricted areas (decided on the basis of congestion) he has to pay ERP charge. Various tax concessions are provided under off-peak car scheme (OPC), entry of Malaysian vehicles is restricted through vehicle Entry Permit Scheme (VEP).		♦ Bus lanes and other priorities for public transport, like special traffic lights for buses ('B' lights).

ECONOMIC POLICY INSTRUMENTS FOR CONTROLLING AIR POLLUTION IN DELHI — 4

Environmental pollution problems typically arise when common property resources like air and water are considered free goods for discharging wastes. The need for public intervention[1] to control environmental pollution arises because of the external costs of pollution – the costs that the polluting individuals or firms impose on other members of society (since the negative costs of pollution are distributed across society). Without intervention, polluters may have no incentive to take these external costs into account in making decisions about the level of production, the choice of technology, the use of pollution abatement measures and the disposal of wastes. This would result in more pollution than is desirable from the society's point of view[2].

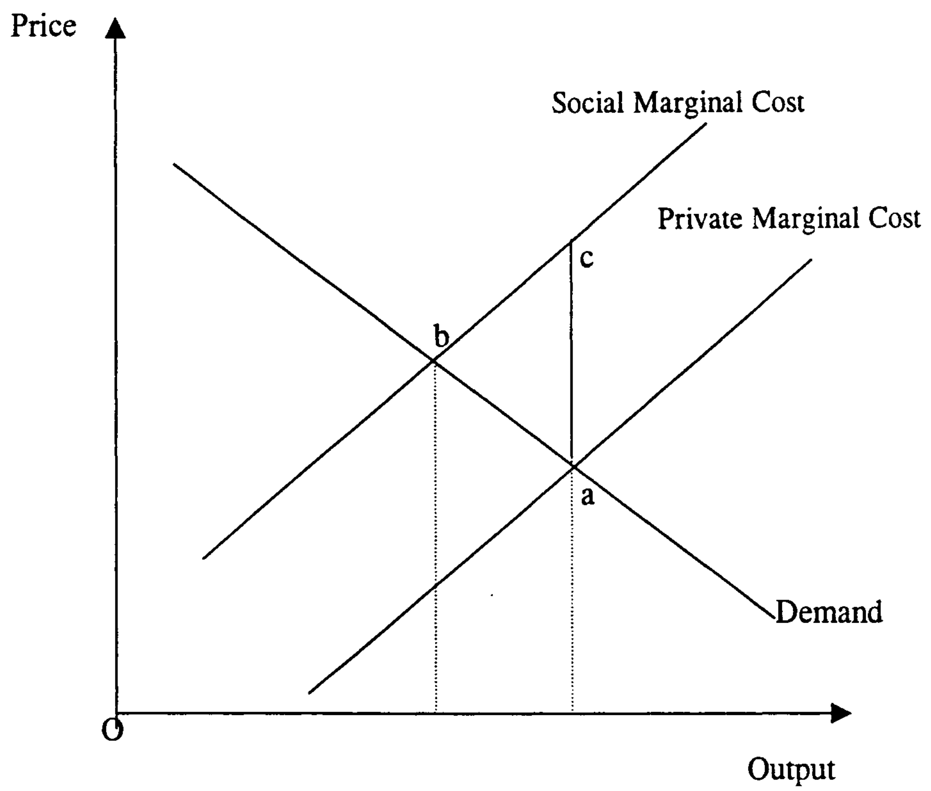
4.1 Vehicular Emission Control: A Theoretical Perspective

Air pollution from transport is a typical case of negative externality. A vehicle can be seen as a production unit whose output is passenger kilometres and the by-product is emission of pollutants released in the atmosphere. To the vehicle owner, the marginal benefits of emitting pollutants into the atmosphere, a free common property resource, outweigh the marginal costs that he has to bear because of air pollution (as negative costs of air pollution are distributed across all the users of polluted air). In the absence of any intervention to correct the failure of the existing market system an equilibrium like 'a' would occur causing the society a welfare burden measured by area abc (Figure 4.1).

[1] The position, propounded by Pigou (1920), that public (regulator) intervention, for instance through taxation of pollution (emission/discharge), is necessary for efficiency when there are external effects, was later challenged by Coase (1960). Coase argued that voluntary negotiations between the polluters and those affected by pollution could provide for efficiency. Later literature has emphasised that negotiations may be costly and inefficient.

[2] Optimal level of pollution is that at which the social benefits from a pollution causing activity and the social cost of pollution are equalised at the margin.

Figure 4.1



Text book solution to this problem would be to impose a tax on emissions equal to the difference between the marginal private cost and marginal social cost. This would make the motorists aware of their social costs and induce them to treat emission tax t as a relevant decision making parameter. Polluters exposed to such a tax would self-select the most effective measures from society's point of view, such as modified travel plans, technical modifications in vehicles and/or fuel, better maintenance of vehicles. However, to levy such a tax, the regulator would need to know how much pollution each vehicle is causing during a day/year. Since continuous monitoring of emissions from this mobile source of pollution – which is also very large in number – is not feasible, the regulator needs to look for alternative instruments/programmes aimed at achieving the least cost solution to the externality problem that an emission tax would have induced.

It has been argued that while an emission tax equal to the cost of damages caused by emissions would generally be the first-best policy instrument, taxes can also be levied on polluting goods such as fuels in presumption of emissions associated with their use. Higher fuel prices would, in principle, have three main effects of relevance to environmental policy objectives: (i) reduction in vehicle use; (ii) reduction in vehicle ownership; and (iii) encouragement to design and purchase more fuel efficient cars. The actual impact of these changes on fuel consumption and thus on emissions from transport sector would depend on 'own price' relationship between the price of fuel and fuel demand. However, there are two limitations of the presumptive tax on the polluting good, say fuel. One is related to the failure of a tax on fuel to effectively stimulate other initiatives that may be more cost effective, for example technological options. The other limitation of the presumptive tax on fuel is that it discourages the use of the polluting good equally for all polluters who may have different marginal emission rates.

As noted earlier, levy of an emission tax would provide incentives to vehicles owners to reduce emissions. Reduction in emissions can be achieved in two ways: one, by making the polluting activity cleaner by either switching to cleaner vehicles or technical modifications in in-use cars – whether in the form of tune-ups or retrofitting of existing equipments or in the form of new configurations of machinery (e.g. catalytic converters), fuels etc. – and two, by reducing its scale i.e. reduced vehicle trips. For any given emission tax, the vehicle owner will choose the socially optimum mix of these two ways of reducing emissions such that emission reductions, at the margin, cost the same from each. Eskeland (1995) has shown that in the absence of continuous monitoring of emissions, a cost effective programme aimed at controlling vehicular pollution would seek emission reductions from a combination of instruments which induce better technology (i.e. make the polluting activity cleaner) and reduced vehicular trips (reduced scale of polluting activity). Such a cost effective programme is characterised by the equilibrium where marginal costs of technological changes and the tax on fuel are equalised. This can be represented as

$$\frac{t_x}{e_x} = -\frac{P_a}{e_a} \qquad (1)$$

where

t_x: tax levied on fuel

e_x: emissions (say gm/lt)

P_a: cost of technological change

e_a: emission reduction through technological change

The main argument is as follows. If the pollution control programme did not follow a combination of these instruments, for instance did not tax the fuel and pursued policies to stimulate adoption of only the technical modifications, to achieve a given level of pollution reduction, motorists may be faced with technical modification requirements which are quite costly at the margin compared to the cost of foregoing some less essential vehicle trips. Similarly, in the absence of technical changes as a policy instrument, motorists may be burdened with a very high cost at the margin owing to many essential trips sacrificed, compared to the cost of technical changes in the vehicle.

What combination of instruments will be used depends on the elasticity of demand for the polluting good and the relative costs of options. In the context of motor transport, the reduction in emissions will be provided mostly by technical changes if the vehicle fleet is old and poorly maintained and fuel quality is inferior. These circumstances will provide good scope for switching to environmentally superior fuel and vehicle technology and retrofitment options for reducing emissions cheaply, thus minimising the role of a fuel tax. Conversely, if the vehicle fleet is relatively modern and fuel is of better quality, fuel tax will have a relatively greater role in effecting vehicular emission reduction.

Following this framework, this study examines various technical options for controlling emissions from various types of vehicles in Delhi along with their benefits in terms of emission reduction and provides a cost effective ranking of the technical options. Whether and how these technical options can be combined with an uniform fuel tax is also examined. Based on the analysis of results, policy recommendations are drawn.

4.2 Technical Options

A number of technological options can be considered for controlling air pollution in Delhi. These options include conversion of petrol and diesel driven vehicles to CNG or switching to new CNG driven vehicles; switching to four-stroke 2 and 3-wheelers; vehicle retrofitting (electronic iginition system, leaner carburettor, continuously regenerating trap (CRT) and catalytic converter); and periodic inspection and maintenance. These technological options have been analysed and ranked according to their net cost of emission reduction (Table 4.1).

Table 4.1. Technical Options, Fuel Tax and Emission Reduction

S.No	*Technical Options*[i]	*Cost: Thousand Rs. Per Weighted ton of abatement*[ii]	*Emission reduction (weighted tons)*	*Emissions reduced as % of total vehicular emissions*	*Fuel tax (Rs./lt.)*
1.	Convert taxies to CNG vehicles[iii]	-27.7	27348.4	2.5	-13.8
2.	Convert cars to CNG vehicles[iv]	-22.3	121007.6	11.1	-12.2
3.	Convert buses to CNG vehicles (50% of the fleet)[v]	-20.3	15343.0	1.4	-10.9
4.	Convert 3-wheelers to CNG vehicle (40% of 3-wheeler fleet)[vi]	-20.1	49129.6	4.5	-10.4
5.	Modern carburetor (20% of 3-wheeler fleet)[vii]	-10.6	2531.7	0.2	-5.5
6.	Fuel/oil premix (10% of 3-wheeler fleet)[viii]	-6.5	1278.5	0.1	-3.3
7.	Electronic ignition (10% of 3-wheeler fleet)[ix]	-2.5	3004.1	0.3	-1.3
8.	Periodic I & M (10% of 3-wheeler fleet)[x]	1.2	4720.1	0.4	0.6
9.	Catalytic converter (10% of 3-wheeler fleet)[xi]	5.9	7499.6	0.7	2.9
10.	Catalytic converter retrofitment (10% of 2-wheeler fleet)[xii]	9.6	14654.8	1.3	4.7
11.	CRT retrofitment in buses (50% of fleet)[xiii]	32.3	35317.4	3.2	15.0
12.	4-stroke 2-wheelers (30% of fleet)[xiv]	55.2	45970.0	4.2	24.2

Notes:

(i) Computations are based on vehicular population as on 31st December, 1998.

(ii) The cost of technical changes is paid up-front. It is also assumed that this is financed by a loan obtained at 10 per cent interest to be repaid in equal installments over a period of five years. The net cost is: annual fixed cost of technical changes minus the difference between the operating cost of vehicle before and after the technical changes.

(iii) Reduction in emissions of CO and HC is 98 and 82 per cent respectively from the base line emissions from a petrol driven Ambassador car. Cost of CNG conversion is taken to be Rs. 30,000. Source: Gas Authority of India Limited (GAIL, 1999).

(iv) Emission reduction of CO and HC is 97 and 11 per cent from the base line emissions from a Maruti 800 model car. Source: GAIL, 1999.

(v) Reduction in emissions of CO, HC, NO_x and PM_{10} is 19, 17, 42 and 83 per cent respectively. Source: GAIL, 1999. The operating cost is taken to be Rs. 3.37/km, on CNG and Rs. 5.08/km on diesel mode. Source: Sharma, 1999. The cost difference between a new CNG bus or CNG retrofitment in a diesel bus and diesel bus is Rs. 3.5 lakh. Source: Chima, 1999.

(vi) Emission reduction of CO, HC, NO_x and PM_{10} is 71, 63, 20 and 80 per cent respectively. Source: GAIL, 1999 and Xie et. al, 1998. The cost of conversion to CNG fuel is taken to be Rs. 18,000. Source: AIAM, 1999.

(vii)-(xi) Source: Xie, et. al, 1998.

(xii) Emission reduction of CO and HC is 45 and 40 per cent respectively. Cost of CAT retrofitment is taken to be Rs. 1000 and refuel cost of catalyst is Rs. 500 once in two years. Source: AIAM, 1998.

(xiii) Emission reduction of CO, HC, NO_x and PM_{10} is 76, 96, 34 and 90 per cent respectively from the base line emissions from a diesel bus. The cost of CRT is taken to be Rs. 2.5 lakh and it requires ultra low sulphur diesel (50 parts per million). Source: Adie, 1999.

(xiv) Emission reduction of PM_{10} and HC is 86 and 76 per cent respectively. Emissions of CO and NO_x increased by 18 and 100 per cent respectively. Source: ARAI, 1998. The cost of a four-stroke 2-wheeler is taken to be higher by Rs. 8000 than a two-stroke 2-wheeler. Four-stroke engine is 40 per cent more fuel efficient vis-à-vis a two-stroke 2-wheeler. The average resale value of an in-use two-stroke 2-wheeler is taken to be Rs. 12000. Source: Personal interaction with AIAM officials.

Vehicular emissions constitute a number of pollutants with varying health and other impacts (see Chapter 1). A prioritisation of pollutants is necessary in any programme attempting to control vehicular air pollution. Prioritisation of pollutants can be done in two ways: one, which reflects the health and other impacts of pollutants; and two, that reflects the desirability to reduce pollutants in a city/air shed so as to achieve the legislated ambient air quality standards for that city/air shed (i.e., divergence between existing ambient air quality and the legislated ambient air quality). Because of both paucity of reliable data on health impact of pollutants and the fact that the relationship between threshold concentrations of pollutants in the atmosphere and their health effect is taken into account in setting the ambient air quality standards, the latter approach has been used in assigning weights to various pollutants. Further, owing to the criticism of Indian ambient air quality standards that these are lax in comparison to WHO norms, in calculation of weights for various pollutants WHO norms are used instead of Indian ambient air quality standards[3].

[3] Following weights have been applied: NO_x 0.9/gm: CO 1.56/gm: HC 4/gm; and PM_{10} 3.33/gm.

It can be seen from Table 4.1 that out of 12 options listed as many as 7 could be win-win solutions as these result in negative costs (or savings) largely on account of fuel economy and lower price of CNG[4]. These measures are estimated to achieve a cumulative weighted emission reduction of more than 20 per cent[5] of total weighted vehicular emissions. Conversion of taxies to CNG is the most attractive (cost effective) option for Delhi. Estimates reveal that the conversion of entire fleet of taxies in Delhi would result in 2.5 per cent reduction in total vehicular emissions. Our analysis shows that the second best option is conversion of existing fleet of cars to CNG which would reduce emissions upto 11.1 per cent[6] of total vehicular pollution with a net annual saving of Rs. 22.3 thousand per weighted ton of pollution reduction. For three wheelers, the most cost effective option is conversion to CNG which would lead to 11.2 per cent reduction in total emissions[7]. For buses, two options are considered: CNG retrofitment and CRT retrofitment. Our estimates show that while the former is more cost effective than the latter, emission reduction with the former option is only about 44 per cent of what could be achieved with the latter option. However, the costs of per weighted ton of emission reduction with the latter option is 60 times higher than the cost with the former. In view of the fact that the CRT device can be very effective in reducing particulate matter from all types of vehicles including trucks – in which CNG retrofitment does not seem feasible until CNG is made available across the country – there is a strong case for encouragement to further research on this technology in making it commercially viable. In the interim, however, CNG option appears most viable.

So far as emission control from 2-wheelers is concerned, there are two technical options: (i) retrofitment of catalytic converter in existing 2-stroke vehicles; and (ii) substitution of 2-stroke vehicles with 4-stroke vehicles. Since the former option is significantly more cost effective vis-à-vis the latter and can bring about a 13.4 per cent reduction in total vehicular emissions which is

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4 Current market price of CNG has been used. It is assumed that the cost of necessary infrastructure for supplying CNG is fully reflected in current market price of CNG.

5 Considering the most cost effective measure for 3-wheelers.

6 Calculation is done for cars registered in Delhi.

7 If entire fleet is converted to CNG. Further, this option is said to cause increase in greenhouse gas (GHG) emissions – a global pollutant which contributes to global warming. As the focus of this study is on local pollutants, GHG emissions are not considered.

marginally lower (0.6 per cent) than that can be achieved with the latter option, there appears to be a strong justification in favour of catalytic retrofitment in in-use two stroke vehicles until emission standards for two wheelers are tightened further. Thus only very old 2-stroke two-wheelers, 10 years old and above, should be phased out.

Given the existing emission standards for 2-wheelers and the current market prices of 2-stroke two-wheelers with catalytic converters and 4-stroke two-wheelers, purchasers of new vehicles are more likely to choose the latter over former. The main factor which would induce this decision would be fuel efficiency and relatively better pick-up of 4-stroke vehicle which would recover the price differential between these vehicles in less than five years assuming a vehicle utilisation rate of 5000 km per year. For two-wheelers used more intensively, cost recovery would be faster.

4.3 Fuel Tax

The rates of fuel tax corresponding to various technical options are calculated using equation (1). In equation (1) while P_a and e_a are known (Table 4.1), e_x is average emission rate per litre for the vehicular fleet resulting from adoption of a given technical measure. The fuel tax would thus be equal to the value of P_a/e_a multiplied by the value of e_x. For example, if technical changes 1-8 were applied in a programme with a cost of Rs. 1.2 thousand per weighted ton of abatement then Rs. 0.6 per litre is the rate of fuel tax[8] which should be levied to affect the demand for vehicular trips.

It can be noted from Table 4.1 that there is a lot of scope for using technical measures to effect emission control from the existing fleet of vehicles in Delhi. This is mainly attributed to old technology and poor maintenance of vehicular fleet. However, once cheaper technical options are exhausted, further

[8] It would be seen that the tax rate per litre of fuel in Table 4.1 increases less than proportionally with the costs of technical measures. This is due to the fact that as successive technical control measures are taken, the vehicles become cleaner so the base (e_x) for fuel tax declines.

reductions in emissions can be achieved with costly technical options, that is where a tax on fuel begins to play a role.

The advantages of combining fuel tax with technical controls can be highlighted as follows. If the target level of emission reduction is 23 per cent from the base line and technical change is the only available instrument, the cost to society of achieving the targeted emission reduction would be upto Rs. 9600/weighted ton. By combining the two instruments, the targeted emission reduction can be attained with lower technical control costs at Rs. 1200 and a fuel tax of Rs. 4 per litre. Thus, the resulting cost saving is Rs. 8400 per ton of pollutant abatement[9]. Furthermore, the fuel tax would generate an estimated Rs. 109.5 crores in additional revenue.

4.4 What are the Options for Delhi

A. In-Use Vehicles

The following options may be considered for in-use vehicles.

For cars, taxies, three wheelers and buses, CNG retrofitment appears most cost effective among the available options (see section 4.2). The entire fleet of cars, taxies and three wheelers may be converted to CNG. Retrofitment of CNG kit entails a cost to be paid up-front, while emission reductions and savings from using CNG will come as a flow through subsequent periods, proportional to the utilisation rate and equipment life time. Our estimates show that under certain assumptions about vehicle utilisation rates etc. (see footnotes (iii) to (vi) to Table 4.1), the cost of CNG kits in a taxi, car, 3-wheeler and bus can be recovered in 6, 28, 5.7 and 37.8 months, respectively. When retrofitment is financed by a loan, to be repaid over 5 years (see footnotes to Table 4.1), flow of savings is as in column 2, Table 4.2. The amount of savings will increase from the 6th year as

9 Emission reductions which would result from a given tax on fuel would depend on the price elasticity of fuel. Using the results of a cross country study (Imran and Quan, 1992) of price elasticity of petrol consumption in India, the additional emission reductions resulting from fuel tax are estimated. The above study found that the short-run elasticity of petrol consumption is –0.52 in India.

loan will be repaid by the end of the 5th year. CNG retrofitment will be more cost effective in vehicles with higher utilisation rates.

Table 4.2. Abatement Options, Cost and Pollution Reduction

Abatement options	*Cost: Thousand Rs. Per Weighted ton of Abatement*	*Emission reduction (Wt. Tons)*	*Emission reduced as % of total vehicular emissions*
Convert taxies to CNG vehicles	-30.5	27348.4	2.5
Convert cars to CNG vehicles	-28.6	121007.0	11.1
Convert 3-wheelers to CNG vehicles	-22.0	122824.0	11.2
Convert buses to CNG vehicles	-21.4	30686.0	2.8
Catalytic converter retrofitment (2-wheelers Entire fleet)	9.8	146548.2	13.4

It can be seen from Table 4.2 that conversion to CNG leads to positive gains. Potential savings from switching to CNG will induce owners of cars, taxies and three wheelers to self-select for conversion. Owing to low utilisation rate of school buses (buses owned by schools) CNG retrofitment is a costly option for them. Faster CNG retrofits in school buses may be induced by providing a subsidy. Further, as mentioned earlier CRT device is not only more effective in containing emissions of PM from diesel buses, its application in goods vehicles is also feasible, there is merit in encouraging application of CRT in diesel vehicles. In the case of 2-stroke two-wheelers retrofitment of CAT would be more cost effective.

The following measures are proposed for controlling emissions from in-use vehicles.

a. Periodic check of vehicles is essential for two reasons: (i) for building an information base which is required in both, designing appropriate policies for pollution control and their evaluation; and (ii) to assess the extent of compliance with regulations.

We recommend an annual inspection for all vehicles and imposition of a differentiated annual emission tax according to emission intensities of vehicles. Relatively low rate of charge be imposed on relatively cleaner, low-use vehicles vis-à-vis not so clean high-use vehicles. This is likely to encourage charges at the margin both in the type of vehicles purchased in scrapping of other vehicles. The following rates of annual emission tax on vehicles are proposed. For computation of the rate of tax for diesel cars see Section 4.5.

S.No.	*Vehicle Type**	*Rate of tax (Rs.)*
1.	Cars (i) with CAT (ii) Without CAT	 200 400
2.	Taxies (i) petrol (ii) diesel	 1700 2200
3.	Three Wheelers (i) petrol (ii) diesel	 1500 1800
4.	2-stroke two-wheelers (i) with CAT (ii) without CAT	 - 200
5.	4-stroke two-wheelers	-
6.	Buses	2200
7.	Trucks (i) <3.5 ton (ii) >3.5 ton	 - -
8.	Diesel cars	750

* Cars, taxies, buses and three wheelers running on CNG are proposed to be exempt from the annual emission tax.

b. To induce faster conversion of school buses to CNG fuel, a loan upto 50 per cent of the CNG retrofit cost may be provided at an interest rate of 10 per cent per annum for a period of 5 years. Alternatively, a lump sum subsidy equivalent to the present value of interest paid (present value of the difference between the amount of interest to be paid at the market lending rate of banks and the amount that would be paid if the rate of interest was 10 per cent) on a five year loan equivalent to 50 per cent of the cost of CNG retrofitment.

c. Current system of on-road inspection of vehicles to continue along with the existing structure of fines.

d. Emission intensity of older vehicles, other things being equal, is likely to be more. To discourage the use of old vehicles, the life of high-use commercial vehicles should be fixed at the end of which they must be scrapped. To encourage phasing out of old non-commercial vehicles, an annual emission tax surcharge should be levied on vehicles over ten years of age. The following rates of surcharge are proposed.

Age of vehicle	*Rate of surcharge (as % of emission tax)*
More than 10 years	25%
More than 11 years	35%
More than 12 years	45%
More than 13 years	55%
More than 14 years	65%
More than 15 years	75%

B. New Vehicles

(i) Mass emission standards should be revised periodically keeping in view the number and environmental characteristics of vehicles. Emission standards should be notified well in advance to facilitate timely adoption of appropriate vehicle technology. To encourage the industry to meet tighter emission norms before the specified time, excise duty concession of 10 to 15 per cent should be given.

(ii) Identified institutions should be entrusted with the responsibility of further research on CRT device in making it commercially viable. State funding should be provided for the same. Funding should be provided in appropriate instalments. Release of funds should be based on the progress/performance milestones.

(iii) Fuel quality standards should be revised periodically and notified well in advance. To encourage the industry to meet tighter norms before the specified time, excise duty concession of 5-10 per cent should be given.

C. Toll Tax for Vehicles Entering Delhi

A toll tax has recently been imposed on commercial vehicles entering the geographic limits of Delhi. Rates of toll tax appear to be based on the weight of vehicles. Since emissions from vehicles are not necessarily directly proportional to the weight of the vehicle, toll tax does not seem to possess features of an emission tax. Since these vehicles contribute to air pollution in Delhi, there is justification in sending signals to them to encourage changes at the margin in scrapping of older vehicles. The rates of proposed toll tax can be modified to reflect environmental characteristics of vehicles. Further, tax should also be imposed on non-commercial vehicles. The following rates of toll tax for vehicles are proposed.

S.No.	*Type of Vehicle*	*Per entry (Rs.)*	
		<10 years old	***>10 years old***
A.	**Commercial Vehicles**		
1.	Tempos/Taxies	25*	35
2.	Buses/Mini trucks (Nissan and other vehicles having identical size)	50*	70
3.	Six-wheeler trucks	100*	140
4.	Ten-wheeler trucks/trawlers	200*	280
5.	Sixteen-wheeler trawlers	500*	650
B	**Non-Commercial Vehicles**		
1.	Car/Jeep	10	20
2.	Two-wheelers	10	20

* Rates of toll tax currently in force.

4.5 Petrol vs. Diesel Cars

Statistics on passenger vehicles show that in recent years new models of diesel cars have been introduced in the market and that there is a significant rise in the growth of sale of diesel cars. This trend which is attributed to the significant difference in petrol and diesel prices – a result of the governments fuel pricing policy – has evoked considerable discussion on the desirability of diesel versions of passenger cars in India. The main concern is the greater pollution potential of diesel vehicles vis-à-vis petrol vehicles. Focussing on Delhi, this section analyses the issues involved in the light of the concentration levels of pollutants in the ambient air in Delhi and the likely costs of emissions of diesel cars to the citizens, and suggests the necessary policy interventions.

The relative environmental damage caused by petrol and diesel engine vehicles is complex; emissions of some pollutants, especially those affecting the local air quality, tend to be higher from diesel vehicles than from catalyst fitted petrol cars (and in some cases, even higher than petrol cars without catalysts) whilst emissions of green house gases may be lower. Whether diesel should be preferred to petrol on environmental grounds or vice versa, thus depends partly on the relative weight given to various different environmental problems. Emissions of CO and hydrocarbons are substantially lower from diesel engines than from conventional petrol engines.

Emission rates of SO_x, NO_x and PM are higher in diesel vehicles vis-à-vis petrol vehicles fitted with catalytic converters. While the problem of SO_x emissions can be largely addressed by reducing the sulphur content in diesel, for which technology is available, the problem due to PM which is a serious health hazard, remain. Emissions of PM is also the main issue for those who demand a ban on non-commercial diesel vehicles.

Relatively lower emissions of CO and HC vis-à-vis petrol vehicles, fuel efficiency, longer engine life are some of the other advantages of diesel vehicles. These are, however, not the main reasons for the spurt in supply and demand for diesel vehicles in India. The key factor responsible for this is the price difference between diesel and petrol. In other countries, where diesel does not enjoy a significant price advantage vis-à-vis petrol, growth in demand for diesel vehicles is mainly driven due to two factors; (i) given the vehicular engine technology, diesel engines provide more cost effective options for advancements in technology than petrol engines, and (ii) diesel engines are more fuel efficient. Experts say that the problem of PM emissions has to a large extent been solved with the development of a device called CRT for diesel vehicles and there is a lot of scope for improvement in this technology to further reduce the harmful emissions of diesel vehicles.

In this scenario, it may not be prudent to put a ban on non-commercial diesel vehicles. Instead, the government should end the price discrimination in favour of diesel and against petrol to discourage excessive use of diesel vehicles because of the artificial fuel price advantage. The dismantling of the administrative price mechanism in hydrocarbons by 2001 is going to solve part of the price distortion. But, the duty structure even after the introduction of market determined pricing needs a careful scrutiny. At the same time, the government should encourage adoption of environmentally cleaner diesel engines by enforcing strict mass emission norms and fuel (diesel) quality standards.

In case the artificial price difference between petrol and diesel is removed only in a phased manner then to discourage the use of relatively greater environmental damage causing diesel vehicles in the interim, theoretically, the regulator should levy a charge on diesel vehicles which would induce motorists to take measures to internalise the negative external costs. Such a tax should be based on the cost which emissions from diesel vehicles inflict on the society. It may be noted, that petrol driven vehicles also emit pollutants in the atmosphere which impose a cost on the society. Since emissions from petrol vehicles are not currently taxed in India, the base for a tax on diesel vehicles should be the difference in cost of emissions from a typical diesel vehicle and that from a typical petrol vehicle. Information on the cost of emissions is however not available for all the pollutants. In the context of India, some estimates of health costs of PM_{10} are available (World Bank, 1996). We thus take the emission of PM_{10} as the additional negative externality from diesel vehicles vis-à-vis a petrol driven vehicle. This seems justified on two grounds; first, emission of PM_{10} is the main issue against diesel vehicles; and second, particulate matter is the only pollutant, concentration levels of which in the ambient air in Delhi exceed the WHO norms for PM_{10}, which suggests that this pollutant needs to be given special attention.

Following the World Bank (1996), the present value of cost of pollution (income loss and medical costs) due to emissions by a diesel car over a period of ten years[10] is estimated to be Rs. 10,648[11]. This works out to Rs. 1109 per year. An annual tax of Rs. 752 (an average of lower and upper bound estimates of annual costs due to PM_{10}) should be levied on diesel cars.

It must be noted that this measure would not have the desirable impact as long as difference between diesel and petrol prices is significant. An analysis of estimates in Table 4.3 highlights this point. Table 4.3 provides estimates of

10 Life of car is assumed to be 10 years.

11 This is upper bound estimate. Lower bound estimate of present value is Rs. 3797.3.

present value of savings from diesel driven Tata Indica vis-à-vis petrol driven Tata Indica over a period of ten years. Seating capacity and engine capacity of petrol and diesel version of Tata Indica are the same. After adjusting for the price difference (higher price of diesel version) in these cars, the present value of net savings from diesel version of Tata Indica over a period of 10 years is estimated to be Rs. 67,725 which is 23.76 per cent of the ex-showroom price of the diesel version of Indica. That is, given the existing pricing of petrol and diesel, a tax of equivalent amount should be levied on diesel cars to neutralise the price advantage in favour of diesel.

Table 4.3. Costs of Diesel and Petrol Versions of Tata Indica

Items	*Standard Petrol*	*Standard Diesel*
Ex-showroom Price	2,59,000	2,85,000
Piston Displacement	1405cc	1405cc
Capacity	5	5
Weight (unladen)	980 Kg.	980 Kg.
Road Tax	Rs. 3815 (one time tax)	Rs. 3815 (one time tax)
Excise Duty	40%	40%
Sales tax	8%	8%
Mileage	12 km/lt	18 km/lt
Annual utilisation (Km/yr)	10000	10000
Annual fuel use, lt.	834	556
Fuel price Rs./lt.	26	14.04
Annual fuel cost	Rs. 21667	Rs. 7800

One may argue that international prices of diesel are relatively lower than international prices of petrol, therefore it may not be fair to take away the full price advantage in favour of diesel in the Indian market. Taking this into account the present value of savings from diesel Indica have been re-computed. The present value of net savings over a period of ten years works out to Rs. 60,968 which is 21.39 per cent of ex-showroom price of diesel version of Tata Indica. In addition to this, an annual charge of Rs. 752 may be levied on diesel cars.

4.6 Other Demand Management Options

In India, it is not just the inferior fuel, poor technology and poor maintenance of vehicles that is responsible for pollution. Congestion, poor quality roads and too many traffic lights affect the traffic flow adversely. Poor traffic flow causes frequent speed cycle changes which increase the average emission rates significantly. According to an estimate by CRRI, vehicles consume as much as 20 per cent extra fuel owing to constraints in traffic movement. One way to target the road congestion would be to restrict the growth of vehicles. However, since problem of congestion is more severe at specific locations at specific times, measures than can affect traffic volume at busy locations at specific times would be more effective. To design such measures it is important to identify the specific locations since the design of these measures would depend on the area in question. Two types of instruments can be used: (i) vehicle entry permit system and (ii) higher parking fee. The Singapore experience offers good practical evidence of the implementation and effects of these measures.

4.7 Non-Fiscal Measures

Whilst fiscal measures can be used to ensure that vehicle ownership and use decisions reflect the environmental costs involved, it must be noted that no single fiscal instrument can fully reflect the complexity of the environmental problems involved in the transport sector and that there remains an important role for non-fiscal measures in controlling environmental pollution. In particular, reliable public transport has an important role in containing the growth in vehicle ownership as well as vehicle use. This has been successfully used in Singapore and other countries. The city of Freeburg in Illinois, US, provides subsidised rail passes to discourage car use during morning and evening peak hours.

An analysis of data on hourly average concentration of CO, SO_2 and NO_x in ambient air in Delhi shows significant rise in levels of these pollutants in the morning and evening hours. Also, pollutant concentrations during evening peaks are higher than during morning peaks[12]. From Figure 4.2 it can be seen that concentrations of CO show a rising trend between 7 and 8 a.m. (relatively greater in winter months), remain either steady or show marginal declines during the day and show a rising trend again at around 4 p.m. in winter months and between 5 and 6 p.m. in summer and monsoon months. Peak occurs between 8 and 9 p.m.

[12] Source of data is CPCB's automatic air quality monitoring station located at Sirifort in South Delhi area. Data for particulate matter is not available from this source.

With respect to SO_2, (Figure 4.3) the morning peak is between 8 and 9 a.m., its concentration declines sharply during the day except in the months of June and August. SO_2 concentration in the air increases again between 5 and 6 p.m., except in December (when it starts rising at 3 p.m.), and reaches its peak at around 8 p.m. except in April when the peak occurs later at around 10 p.m. Concentration levels of NO_x (Figure 4.4) show different trends in summer (lower levels) and winter months (higher levels). The reason being that NO_2 reacts with hydrocarbons in the presence of sunlight and produces ozone. Since more ozone is produced during summer months, NO_x concentrations are low during these months. Hourly annual average of NO_x shows higher concentrations around 8 a.m. which declines during the day and shows an increase again at 5 p.m. and is at the highest level between 9 and 10 p.m. In winter months also, a similar trend is observed though concentration levels are a magnitude higher.

Two observations on the trends in levels of these pollutants need special mention: (i) highest morning concentration levels are significantly lower than highest evening concentration levels; and (ii) towards noon, concentration of pollutants shows significant declines from morning peak levels. This is due to both lower traffic volume and the presence of sunlight which serves as a natural cleaner. This suggests that high concentration levels of these pollutants (especially in the evening) can be affected by altering the travel times. In this context, advancing the office timings by an hour may be considered.

Of the total 8.54 lakh employees in Delhi, in 1995, 6.31 lakh were in the public sector (Table 4.4). 52 per cent of those in public sector were Union and State government employees and the remaining were employed with the local and quasi government bodies. Change in office timings of these employees from 9 a.m. to 5:30 p.m. at present, to 8 a.m. to 4:30 p.m. would help significantly in reducing traffic congestion and air pollution problem in Delhi.

Table 4.4. Employment in Public and Private Sector in Delhi (as on 31st March)

(No. in Lakhs)

Year		*1991*	*1992*	*1993*	*1994*	*1995*
Public Sector	Central Government	2.15	2.14	2.14	2.13	2.15
	Government of NCT of Delhi	1.04	1.05	1.07	1.10	1.11
	Quasi Government bodies	2.14	2.16	2.17	2.12	2.10
	Local Bodies	0.83	0.97	0.97	0.97	0.95
	Total	**6.16**	**6.32**	**6.35**	**6.32**	**6.31**
Private Sector	25 or more persons	1.61	1.69	1.69	1.60	1.64
	10 to 24 persons	0.55	0.57	0.58	0.58	0.59
	Total	**2.16**	**2.26**	**2.27**	**2.18**	**2.23**
Grand Total		**8.32**	**8.58**	**8.62**	**8.50**	**8.54**

Source: Delhi statistical handbook, 1997.

Figure 4.2 Trends in Ambient concentration of CO (hourly averages)

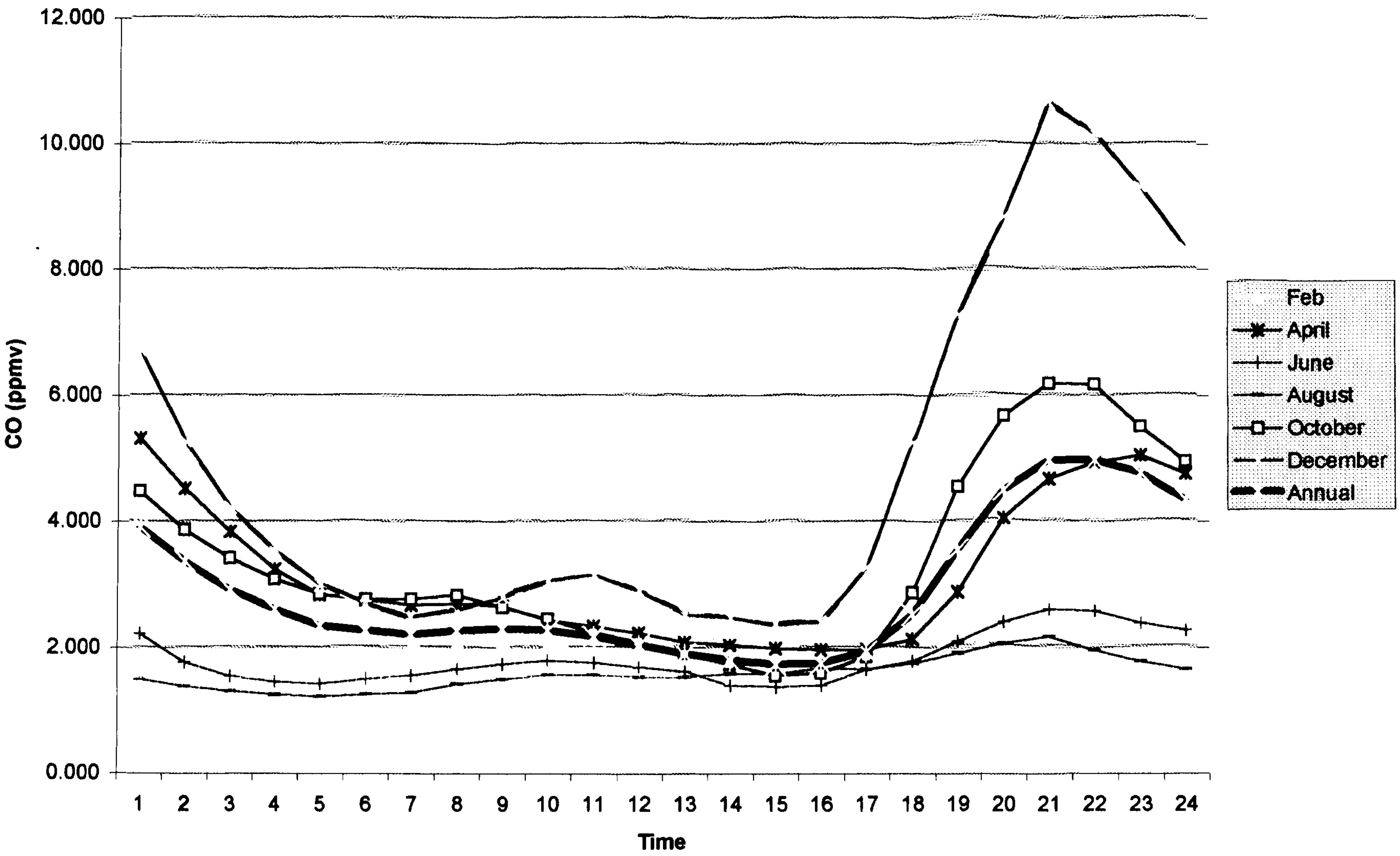


Figure 4.3 Trends in Ambient concentration of SO_2 (hourly averages)

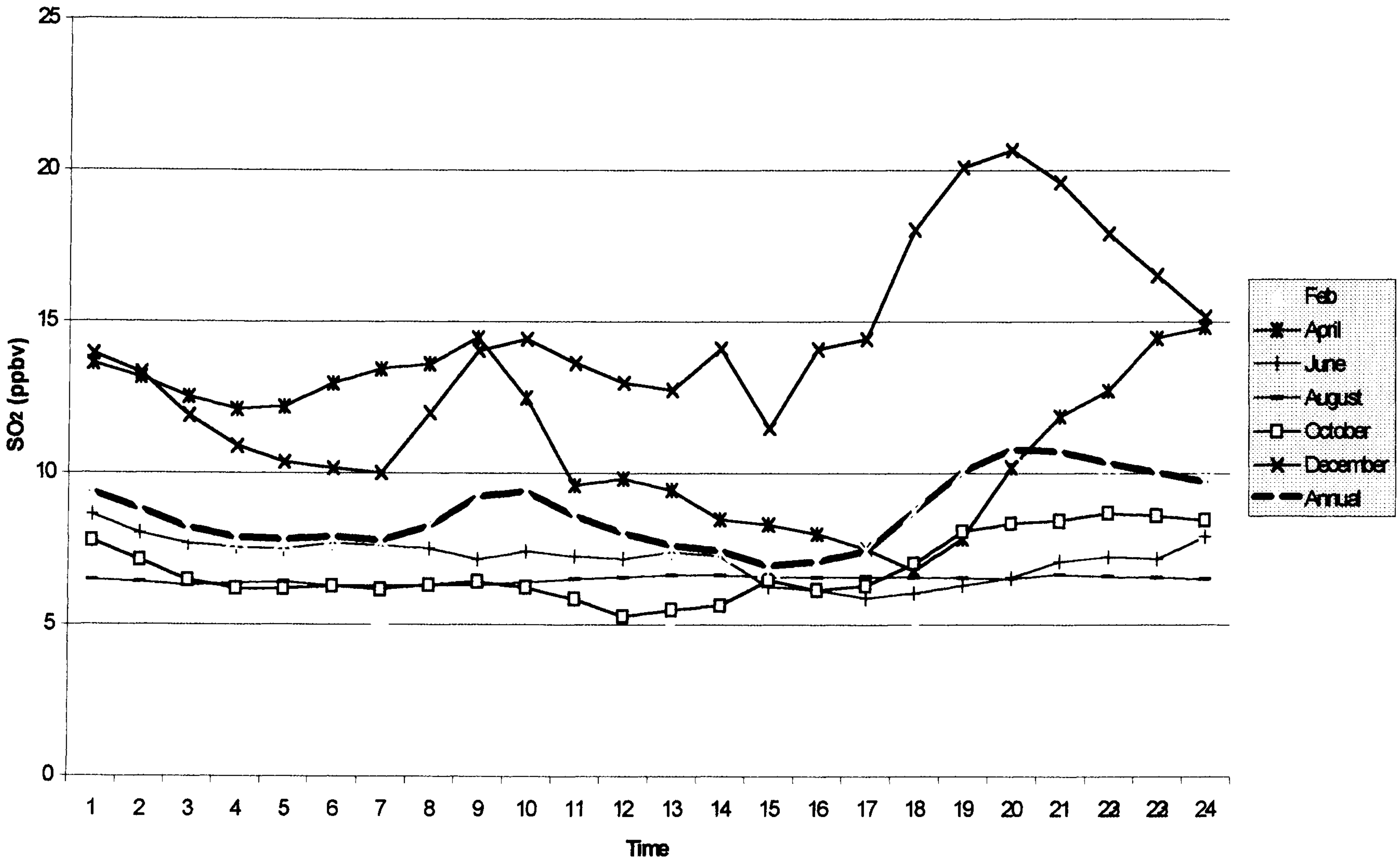
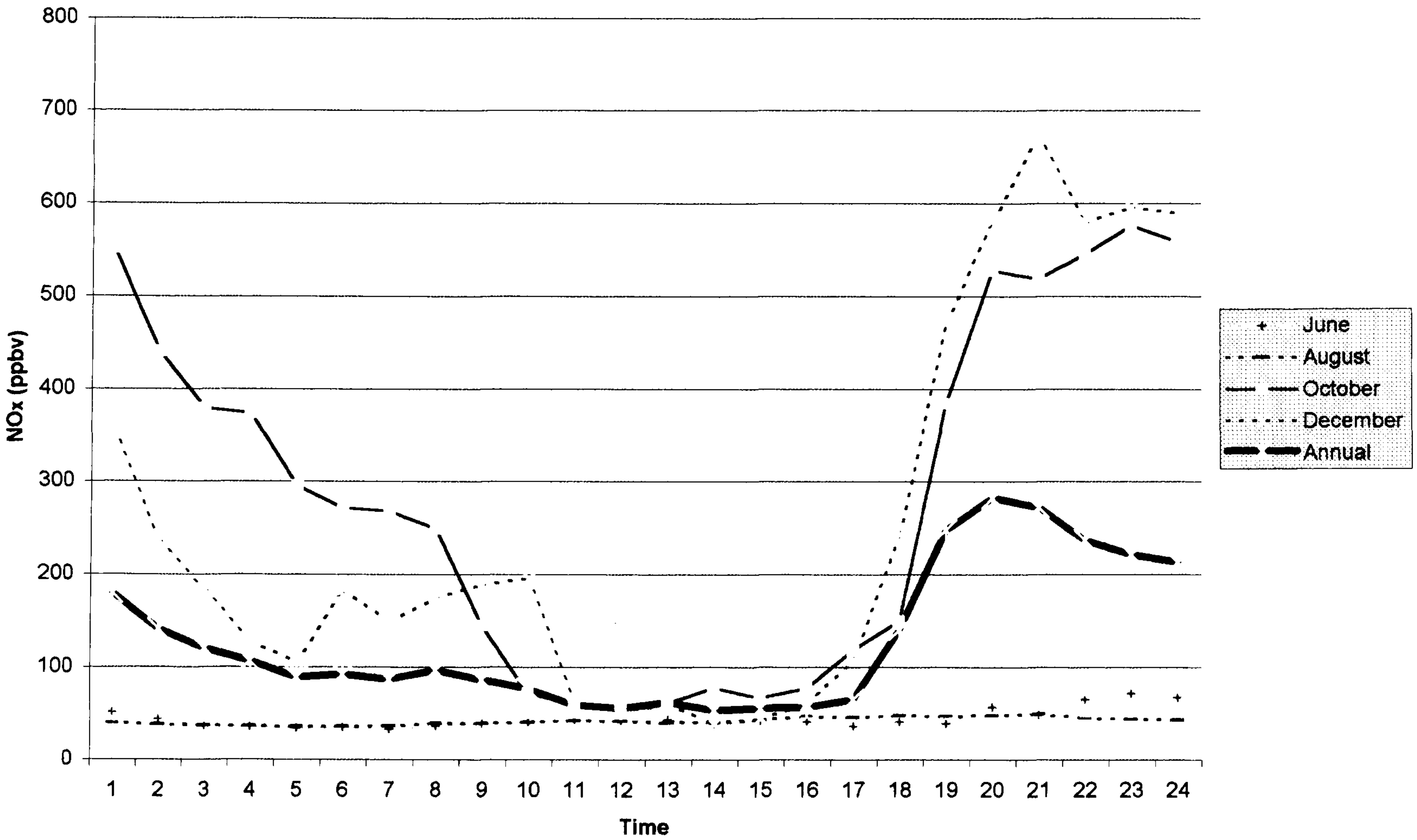


Figure 4.4 Trends in Ambient concentration of NOx (hourly averages)



ASSESSMENT AND RECOMMENDATIONS 5

The critical state of atmospheric pollution in Delhi is a clear indication that policies currently in use have failed to make the desired impact and it is important to implement economic instruments and improve enforcement of regulations.

Effective enforcement of legislation whether it is of CAC type or economic instruments, is essential to achieve the desired results. Implementation of environmental legislation has been poor in India including Delhi. In this context, PUC needs a special mention which despite being a potentially powerful instrument in controlling pollution from vehicles has failed to make an impact on vehicular pollution primarily due to lack of effective enforcement. The most important lesson for Delhi from the experience of other countries particularly Singapore is that laws must be enforced rigorously and persistently.

Since the problem of vehicular pollution is caused by poor vehicular technology, poor maintenance of vehicles, poor road and traffic conditions and inferior fuel, a mix of instruments focussing directly on the quantity and quality of vehicles, quality of fuel and traffic management is necessary.

5.1 Recommendations

1. An annual emission tax differentiated by the emission intensities [Section 4.4 (A.a)] of different types of vehicles should be levied. Cars, taxies, three-wheelers and buses running on CNG fuel should be exempt from the annual emission tax.
2. All vehicles should be required to undergo detailed inspection focussed primarily on environmental performance of vehicles, at authorised inspection centres. Each vehicle must pass the specified tests and obtain a certificate to this effect. Activities of inspection centres such as testing procedures, certification etc. should be monitored by a vigilance authority.

3. Random on-road inspection should continue to ensure that vehicles are maintained well and meet the emission standards at all times. Once the mandatory annual inspection is phased in, and the random on-road checks are intensified, the requirement of obtaining PUC certificate should be abolished.

4. Owing to low utilisation rate of school buses (buses owned by schools), CNG retrofitment does not appear to be a cost effective option for them. For environmental reasons, a subsidy to induce conversion of school buses (diesel) to CNG fuel, seems justified. A loan upto 50 per cent of the CNG retrofitment cost should be provided at an interest rate of 10 per cent for a period of five years. Alternatively, a lump sum subsidy equivalent to the present value of interest paid (present value of the difference between the amount to be paid at the market lending rate of banks and the amount that would be paid if the rate of interest was 10 per cent) on a five year loan equivalent to 50 per cent of the cost of CNG retrofitment (Rs. 1.75 lakh) can be given. The present value of subsidy would amount to Rs. 36,150. This is 10.33 per cent of the cost of CNG retrofitment.

5. The substantial price differential in favour of diesel fuel vis-à-vis petrol in India has contributed to the growth of the market for diesel-powered passenger cars. A fiscally-induced development having some clear disadvantages from the point of view of air pollution. While there are good reasons for motor fuels used in the course of business activity to be taxed less heavily than motor fuels used in final consumption, the distinction between diesel and petrol-engined vehicles no longer coincides exactly with the distinction between intermediate and final consumption. Thus, excise duty on diesel cars should be increased by 24 per cent.

6. Toll tax should be modified to reflect the environmental characteristics of vehicles [Section 4.4 (c)]. Private vehicles should be brought under the scope of toll tax.

7. Mass emission standards should be revised periodically keeping in view the number and environmental characteristics of vehicles. Emission standards should be notified well in advance to facilitate timely adoption of appropriate vehicle technology. To encourage the industry to meet

tighter emission norms before the specified time, excise duty concession of 10 to 15 per cent should be given.

8. Institutions should be identified and entrusted with the responsibility of further research on CRT device in making it commercially viable. Government funding should be provided for the same. Funding should be provided in appropriate instalments. Release of funds should be based on the progress/performance milestones.

9. Emission intensity of older vehicles, other things being equal, is likely to be more. To discourage the use of old vehicles, the life of high-use commercial vehicles should be fixed at the end of which they must be scrapped. To encourage early scrapage of old non-commercial vehicles, an emission tax surcharge [Section 4.4 (A.d)] should be levied on vehicles over ten years of age.

10. Fuel quality standards should be revised periodically, and notified well in advance to facilitate long-term planning by the industry. To encourage the industry to meet tighter fuel quality norms before the specified time, excise duty concession of 5-10 per cent should be given.

11. To reduce traffic flow in particularly congested zones, a scheme of permits should be introduced. Rates of parking charges in these zones should be doubled. Enforcement of penalties for violation of traffic rules and unauthorised parking should be stricter.

12. The success of demand management measures for private vehicles is highly dependent on the quality of public transport. In order to affect demand for private vehicles (demand for both, ownership and use of vehicles), good quality public transport system which can induce people to switch to public transport is a must.

13. To reduce congestion and thus vehicular pollution, staggered office timings should be enforced. Altering the office timings of government offices from 9 a.m. to 5:30 p.m. to 8 a.m. to 4:30 p.m. is likely to result in reduction in traffic congestion and thus air pollution.

14. Awareness of motorists about emission from their vehicles, its causes and effects and their role in minimising emission is crucial for the success of an emission control programme. Through well-designed awareness campaigns it should be ensured that the motorists understand the benefits

derived from compliance as well as the wider implications of non-compliance on environment and health.

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