REFINERY UPGRADATION ENVIRONMENTAL SUSTAINABILITY AND COST SHARING

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Preface

The study was undertaken by the National Institute of Public Finance and Policy. The study team consists of Prof Ramprasad Sengupta of Jawaharlal Nehru University, New Delhi and Dr.Subrata K Mandal. Opinions expressed here are those of the authors. The members of the Governing Body of National Institute of Public Finance and Policy are in no way responsible for these.

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Introduction

1.1 Introduction

The issue of controlling of vehicular pollution for improving the air quality has come into sharp focus with various Supreme Court directives on auto fuel and emission regulation. The vehicle manufacturers, refiners, transporters, Governments, citizens and the media have intensely debated the best way to ensure clean air for citizens. Such debates would often remain inconclusive due to lack of precise information on vital aspects like cost of providing clean fuel, the extent of deterioration in ambient air quality due to vehicular pollution, the benefits of upgrading fuel in terms of savings in health cost and intensity and nature of air pollution due to vehicular emission across locations. The debate on such issues would get further complicated if aspects like the responsibility of sharing of costs for providing clean air to the citizens, prices of petroleum products in a regime of market determined prices, engine technology, competitiveness of refineries of wide-ranging vintages, strategic nature of petroleum product and highly volatile prices of petroleum products in the international market are also taken into consideration. These issues are indeed the starting point of what is to follow in the sections of various chapters of this report.

It may be acknowledged that these issues are very common and debated all around the world. The answer to such vexed issues in the developed countries are sought through well designed studies and experiments like the Auto Oil Program or epidemiological studies conducted over a number of years. But in India, given the lack of such studies or experiments the answer is often difficult to gauge. This explains the time overrun of this study and the necessity to fall back on results obtained for other countries.

The next section of this chapter begins with a discussion on the emission regulations. The emission regulations are presented in a chronological order to emphasize that the concern for air quality and the enactment of law to combat air pollution was quite early and it was at the initiative of the legal authorities that various norms have been put in place to control vehicular pollution. There has never been a comprehensive auto fuel policy to address the problem of air pollution. The section on emission regulations is followed by a discussion on emission norms and fuel quality, the discussion here is on the permissible level of pollutants in fuel associated with various emission norms.

In the second chapter the issue of upgradation of refineries is addressed. The chapter begins by outlining the steps taken by IOC refineries to meet the fuel quality norms in the future. This is followed by a discussion on the vintage of existing refineries of IOC in terms of various existing processing facilities and the possible options to upgrade these refineries by adding additional facilities so that they can be able to meet the fuel quality norms. Investment on additional facilities would depend on the vintage of the refinery and thus influence the cost of upgradation to a large extent besides issues of economies of scale and management. A simple model has been framed to derive the cost of upgradation of fuel in each of the refineries of IOC. The model is based on present value of life period cost of operation of additional facilities distributed over the present value of the tonnage of output during the same time horizon. The cost of upgradation added to the existing cost would indicate the price that needs to be realized by a refinery to remain competitive.

The third chapter estimates the savings in health cost due to upgradation of fuel and vehicle engine to Euro III / Euro IV levels. The health cost for 35 urban agglomerates with million plus population has been estimated. It takes into account vehicle population, distances traveled by each vehicle type, emission coefficients of vehicles to derive the pollution load in these urban agglomerates. The model of health cost of pollutant has been based on an epidemiological study in The US. The health cost in the US model has been suitably adjusted to local condition by taking into account purchasing power parity of currencies, variation in population density and income between India and the US. The savings in health cost estimates have been obtained for two scenarios of high and low cost. The savings in health cost would determine the rate of return on investment in refineries and whether the investment is beneficial and desirable from the society's point of view.

An important aspect of debate on vehicular pollution is the impact of vehicular pollution on ambient air quality across locations. The aspect of supplying uniform quality of environmentally upgraded fuel across location assumes significance since a large amount of investment needs to be made at one go in all refineries. A ranking of the acuteness of the problem in terms of cost benefit ratio across such locations may serve as a benchmark for a map to supply upgraded products in the future time horizon. In chapter four the attempt is to construct a cost benefit ratio in terms of savings in health cost from a liter of upgraded fuel compared to the cost of upgradation of the fuel. The estimation has been done for 35 urban agglomerates across the country with million plus population. The exercise has been done for two scenarios of low and high health cost estimates.

In a resource scarce country like that of India the least cost or the most efficient way of attaining a target assumes importance. A query in the context of upgradation of fuel may be the aspect of engine design of vehicles – whether it is enough to clean the fuel or is it required to upgrade the engine technology along with the fuel. In the fifth chapter this issue has been addressed by taking into account the pollution load emitted due to using superior (Euro III) fuel in non upgraded (pre Euro) vehicle engines. The chapter concludes by deriving the percentage of savings in health cost foregone due to use of engine design of older vintage.

The final chapter addresses the problem of cost sharing for providing clean air to citizens by undertaking investment in refineries to decrease the content of pollutant in the fuel as well as making it more efficient. The recommendation on cost sharing among the stake holders - public, government and the industry, takes into account the issue of support to refineries as well as the nature of strategic importance of petroleum products and the volatility of petroleum prices which are very sensitive to demand supply situations.

1.2 Emission Norms

The deterioration in air quality in most Indian cities has led to an intense search for ways of controlling pollution. Tentative estimates of health costs of urban air pollution in India is US $ 1.4 billion (Brandon and Hommann, 1995).[1] Vehicular emission is a major source of air pollution. For example, in Delhi, where the health incidences and the cost of air pollution is the highest in India, contribution of vehicles to the daily emission level is the highest.

Control of air pollution has to factor in the growth in the number of vehicles, congestion, poor quality of roads and quality of fuel used in vehicles. Though the history of legislation for maintenance of air quality starts with the Air (Prevention and Control of Pollution) Act, 1981, it was the Environmental (Protection) Act, 1986 that prescribed emission standards for vehicles for the first time. The prescribed standards pertained to the emission of carbon monoxide and hydrocarbons. The Act proposed to implement the standards in 1992. The responsibility of enforcing these standards was vested in the Ministry of Surface Transport (MoST).

In 1989, the Motor Vehicles Act of 1939 was amended and the Idle Emission Regulation was enacted. In April 1990, these rules were notified to vehicle owners. The rules made it mandatory to obtain a certificate of fitness for registration of public, commercial and private vehicles older than 15 years. The rules also required all motor vehicles to comply with the laid down emission standards and obtain a certificate of 'pollution under control' (PUC).

In 1991, Mass Emission Regulation was introduced. The legislation laid down emission standards of pollutants under specified driving conditions for vehicle manufacturers as well as for in-use vehicles. The emission rates of vehicles were checked during mass emission tests. In 1995, fitment of catalytic convertors (CAT) for cars in the four metros was made compulsory. The mass emission standards were tightened in 1996 to improve the effectiveness in producing the desired result. Evaporative Emission and Crank Case Emission Regulation was introduced and emission limits of CO, HC and NO_x were lowered.

In May 1999, the Supreme Court of India directed that Euro-I emission norms would be effective for the National Capital Region (NCR) for registration of all private (non-commercial) vehicles with effect from June 1, 1999 and Euro-II norms with effect from April 1, 2000. The apex court passed these directives after detailed consideration of various options recommended by the Environmental Pollution Authority (EPA). Following the Supreme Court directives, India 2000 norms were formulated in the year 2000. These norms are significantly tighter than the mass emission standards of 1996. India 2000 norms are at least Euro-I equivalent for all four-wheelers, Euro-II equivalent for non-commercial four-wheelers in the NCR (also referred to as Bharat Stage II) and are the tightest norms in the world for two-wheelers.

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[1] Brandon, Carter and Hpmmann, Kristen, 1995 *The Cost of Inaction: Valuing the Economy-wide Cost of Environmental Degradation in India*, Asia Environment Division, The World Bank, Washington, D.C.

It has been proposed by an Inter Ministerial Task Force Committee to review the feasibility of Euro III emission norms for the mega cities after 2005. A CPCB Committee comprising of representatives from IOC, research institutes like IIP, ARAI, ministries of Industry and Petroleum recommended a road map for the implementation of emission norms covering the major cities and the whole country, which stipulates deadlines for implementing the various Euro norms in the different regions.

1.3 Fuel Quality Norms

The emission norms essentially induce upgradation of motor engines and the exhaust system of vehicles to reduce the load of pollutants emitted. Upgradation of motor engines and improvement in fuel quality are concomitantly linked. Better engines require better quality of fuel. Besides, some of the pollutants emitted are contained in the fuel itself. This section briefly outlines the changing fuel quality requirements designed to suit the emission norms discussed in the previous sections.

Fuel quality improvement norms were notified in 1994 with the requirement of low lead petrol (0.15 gm/litre) in the metros by December 1994, in the Taj Trapezium by September 1995 and in the entire country by December 1996. Subsequently, more stringent measures were adopted with respect to lead. Only unleaded petrol (0.013 gm/litre) was required to be supplied to the four metros by April 1995, in the State capitals and Union Territories by December 1998, and in the entire country by April, 2000.

Fuel quality in India is governed by the Bureau of Indian Standards (BIS) specifications. The BIS specifications were introduced in 1995, referred to as BIS 1995. These specifications were subsequently amended with target specifications for the year 2000, and are referred to as BIS 2000. The two norms of specifications with respect to motor spirit (MS) are summarised in Table 1.1. With respect to high speed diesel (HSD) the BIS 2000 norms include the minimum permissible limit for Cetane Number, maximum permissible limit of sulphur and temperature for distillation. The BIS 2000 specifications for HSD are given in Table 1.2.

Table 1.1. BIS Specifications for MS

S.No.	Characteristics	BIS 1995	BIS 2000
1.	AKI	82	84
2.	Lead Content gm/lit	0.15	0.013
3.	Sulphur, %wt.	0.2	0.1
4.	Benzene, % vol	-	• 5% by vol. For the entire country • 3% by vol in metro cities

Table 1.2. BIS Specifications for HSD

Sl.No.	Attributes	Max./Min	BIS 2000
1.	Cetane No.	Min.	48
2.	Sulphur Content, ppmw	Max.	2500
3.	Distillation 85% vol. 95% vol.	Max. °C	 350 370
4.	Polycyclic aromatics	% wt. Max.	-

The Supreme Court directive of May 1999 making Euro-I emission norms effective in NCR for registration of all private vehicles with effect from June 1, 1999 and Euro-II norms with effect from April 1, 2000 do not make reference to the quality of fuel.

However, a subsequent gazette notification of October 1999 issued by the Ministry of Surface Transport (MoST) specified that sulphur content for commercial fuel for meeting emission standards both in gasoline and diesel engines shall be upto a maximum weight of 0.05 percent. Further, directive has also been issued for limiting benzene content to a maximum volume of 1 percent for supply of MS to NCT by October 2000 and to NCR by April 2001. The implementation of these standards for the rest of the country will be notified by the Central Government. The present benzene limit for MS is a maximum volume of 5 percent for the entire country and a maximum volume of 3 percent for metro cities. The notifications essentially imply that only fuel quality of Euro-IV specifications with respect to benzene and sulphur can be sold in the NCR. There have been some

Public Interest Litigations in Mumbai and Kolkata, in response to which court–appointed Committees have specified limits for sulphur in diesel (0.05%max.) and benzene in petrol (1% max.), for fuel supplied to these metros as well as to the entire country. The Inter Ministerial Task Force comprised of experts, representatives of Auto Industry, Oil Industry, concerned ministries and BIS, gave a set of recommendations on vehicle emission as well as auto fuel standards. These recommend the implementation of Bharat Stage II for the entire country by April 2005 and by 2003/4 for the mega cities. Bharat Stage III may be considered for the severely affected cities from April 2005.

Chapter II

Cost Computation for Refinery Upgradation

2.1 IOC Refineries Upgradation for Meeting Fuel Quality Norms

The Indian Oil Corporation (IOC) refineries have upgraded their production facilities from time to time to keep pace with the emission and fuel quality norms.[1] The supply of low lead petrol and unleaded petrol for the entire country has been complied with by 1996 and 1999, respectively. With respect to benzene content in MS, the requirement of 5 percent by volume for the entire country and 3 percent by volume in metro cities have been complied with by 1999. With respect to sulphur, entire MS supply to NCR is of 0.05 percent content for Euro-II compliant motor vehicles. All IOC refineries meet the BIS 2000 specifications for MS and HSD at present.

Subsequent to the Supreme Court order of May 1999, the IOC refineries are drawing up plans to further upgrade the quality of MS and HSD that they produce. The Association of Indian Automobile Manufacturers has filed an application requesting the Supreme Court to pass orders directing the Union of India to arrange for MS and HSD with improved quality as per the fuel charter made by them in all towns in the NCR. The IOC, based on its past experience on introduction of unleaded petrol in the metros, anticipates that the requirement for MS and HSD with improved quality would become obligatory for supply to other metros, state capitals and subsequently throughout the country within a very short span of time.

IOC refineries at Mathura, Panipat and Gujarat have drawn plans to supply superior grade MS and HSD to NCT and NCR in line with Supreme Court directives. Supply of MS of 0.05 percent sulphur and 1 percent benzene content to NCT has already commenced from July 2000. Supply of HSD with 0.05 percent sulphur content to NCT have begun from the end of year 2000 from Gujarat, Mathura, Panipat and Haldia by modifying the existing diesel hydro-desulferisation (DHDS) unit. Plans have been drawn for all IOC refineries to upgrade the entire amount of MS and HSD produced by 2004.

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[1] The IOC has seven refineries with a total installed capacity of 38.15 million tons. These refineries are located in Barauni, Gujrat, Haldia, Panipat, Mathura, Digboi and Guwahati.

The upgradation will target MS quality (Table 2.1) that will be compatible with Euro-IV (with the exception of RON/AKI for which the lower bound is set at to 91/86). With respect to HSD, the target quality will be compatible with Euro-III norms as can be seen from Table 2.2 (with the exception of Cetane No. limited to 48 for Digboi and Guwahati refineries).

Euro norms, emerging as the reference for MS and HSD quality upgradation in India, are issued by the European Economic Community (EEC) council from time to time, and serve as a useful reference for setting of quality targets of fuel. These norms basically provide limiting values of emissions coming out of the new vehicles under standard driving conditions. Euro-I and Euro-II norms make no reference to quality of fuel. Euro-III and Euro-IV notifies specification of fuel along with emission norms. The attributes of quality specification of the Euro norms for MS and HSD are given in Table 2.1 and Table 2.2, respectively. Table 2.3 outlines the implementation schedule of the Euro norms. The implementation schedule of Euro norms would probably serve as reference points for the implementation schedule for these norms in India.

Table 2.1. Euro Norms and Target Quality for MS in IOC Refineries

Sl. No.	Attributes	Max./Min	BIS 2000	EURO II	EURO III	EUROI V	Target Quality for MS
1.	RON AKI	Min. Min.	88 84	91 82.5	95	95	91 86
2.	SULPHUR CONTENT Ppm wt	Max.	1000	200	150	50	50
3.	BENZENE Vol %	Max.	5*	5	1	1	1
4.	AROMATIC CONTENT Vol%	Max.	-	-	42	35	35
5.	OLEFIN CONTENT Vol%	Max.	-	-	18	18	18

* As per CPCB 3% by vol max for metro cities with effect from 2000.

Table 2.2. Euro Norms and Target Quality for HSD in IOC Refineries

Sl. No.	Attributes	Max./ Min	BIS 2000	Euro II	Euro III	Euro IV	Target Spec. for upgraded HSD
1.	Cetane No.	Min.	48	49	51	53	51
2.	Sulphur Content, ppmv	Max.	2500	500	350	50	350
3.	Distillation 85% vol. 95% vol.	Max °C	 350 370	 - -	 - 360	 - 340	 - 360
4.	Polycyclic aromatics	% wt. Max.	-	-	11	11	11

Table 2.3. Implementation Schedule of Euro Norms

Attributes	Notification Date	Implementation Date
Euro I		1992/93
Euro II	March 93	1996/97
Euro III	October 1998	2000
Euro IV	October 1998	2005

From Table 2.1 it can be seen that to attain the target quality of MS, benzene, sulphur and olefin content of the fuel has to be reduced while the AKI will have to be improved. The facilities required for each of these are in Table 2.4. The investment requirement for these facilities in each of the refineries is tabulated in Table 2.5.

To attain the target quality of HSD that are equivalent to the Euro III norms additional Diesel Hydrotreatment Units (DHDT) will be required. Additional investments have to be made for this purpose; refinery-wise investment requirements have been tabulated in Table 2.6.

Table 2.4 Facilities Required for Upgradation.

QUALITY REQUIREMENT	FACILITIES REQUIRED	REMARKS
Benzene Control	- Splitter for Reformate, HCU Naphtha & fluid catalytic cracking (FCC) unit gasoline - Benzene Saturation Unit	• Reduction in AKI
Sulphur reduction	- Extractive Merox for light FCC gasoline - Hydro-treatment of light straight-run (LSR) naphtha and heart-cut form FCC gasoline splitter - Post-hydro-treatment for heavy cut of fluid catalytic cracking unit (FCC) gasoline.	• Disulphide oil to be routed to DHDT.
Olefins reduction	- Hydro-treatment of light FCC gasoline as well as post-treatment of heavy cut of FCC gasoline shall reduce olefin content	• Possible loss of RON
Aromatics reduction	- Controlling aromatic rich reformate stream in the overall MS pool.	• Blend dilution with Isomerate stream.
RON/AKI improvement	- Generation of high RON/MON streams by isomerization of light naphtha hydro-treated streams.	• Compensates for loss of RON during hydro-treatments as above.

The third section of this chapter attempts to derive the cost of upgradation per unit of MS/HSD by calculating the unit cost with up-gradation and without up-gradation. Detailed Feasibility Reports (DFR), available for MS and HSD up-gradation, have been used to calculate the cost of upgradation for these seven refineries.

Table 2.5. Investment Requirement for MS Quality Improvement

(Rs. Crores)

Refinery	Investment Requirement	Expected Date of Completion
Mathura	575.0	May 2003
Panipat	467.0	May 2003
Gujarat	621.0	Oct 2003
Haldia	283.0	Dec 2003
Barauni	624.0	Oct 2003
Guwahati	36.0	Sept 2003
Digboi	52.0	Sept 2003

Table 2.6. Investment Requirement for HSD Quality Improvement

(Rs. Crores)

Refinery	Investment Requirement	Expected Date of Completion
Mathura	872.0	Aug 2003
Panipat	560.0	Sept 2002
Gujarat	905.0	Jan 2003
Haldia	1405.0	Dec 2003
Barauni	925.0	May 2002
Guwahati	497.0	May 2002
Digboi	343.0	May 2002

2.2 Technology for Refinery Upgradation

Options for meeting gasoline norms :

Motor gasoline is basically composed of various components like straight-run naphtha, reformate, FCC (fluidized catalytic cracking) gasoline, coker and visbreaker naphtha, isomerate, alkylate and oxygenate. All these components have their own characteristics. Each one has its own impact on gasoline characteristics and finally on the performance of engine leading to CO, HC, NOX and PM emissions and deposits. The fuel norms, as explained earlier are in terms of upper limits on sulphur, benzene, aromatics and olefins and lower limit on octane number (RON or Research Octane Number) of gasoline. Major new facilities may be required to meet the limitations on olefins, aromatics, benzene and sulphur and these include :

(a) *Reduction of Sulphur :* Major sources of sulphur in gasoline pool are (1) straight-run naphtha, (2) FCC gasoline, and (3) coker and visbreaker naphtha. Sulphur reduction in gasoline can be achieved by conventional hydrotreating processes. However this is accompanied by appreciable loss of RON (of more than 10). Also, for the process of hydrodesulphurization, large amount of hydrogen is required which has to be produced from hydrocarbons which is relatively costly. New hydrotreating processes have been developed to desulphurize the FCC gasoline with minimum octane loss and reduction in consumption of hydrogen.

(b) *Reduction of Benzene :* Benzene reduction may be achieved by the following options:

(i) Change in operation

- Prefractionation of reformer feed: Catalytic reformate is an important component of gasoline. Substantial amount of benzene can be reduced if fractions below 90-95 degrees Celsius are excluded from the reformer feed.
- Post fractionation of reformate : In this option, the benzene-rich concentrate fraction is separated from the catalytic reformate to reduce the benzene content.
- Low pressure, low severity CCR (Continuous Catalytic Reforming) operation: In this process, benzene content is significantly reduced due to selectivity, reduced dealkylation and reduced hydrocracking at decreasd operating pressure. As pressure is decreased, a reduction in benzene content takes place.

(ii) Dilution with high octane components: Reduction of benzene reduces the octane number of motor gasoline which has to be pushed up by adding high octane components like isomerates, alkylates and oxygenates till the octane norm is met.

(iii) Conversion of benzene (to cyclohexane or alkylation of benzene) : Hydrogen is used to saturate benzene to cyclohexane with minimal impact on RVP (Reid Vapour Pressure) in a low-cost process called Benzene Saturation. Benzene alkylation is an alternative to the above which does not consume hydrogen.

(c) *Reduction of Aromatics can be achieved through HydroDeAromatization.*

Major components of the diesel pool in a refinery are straight-run gas oil (SRGO), coker and visbreaker oil, light cycle oil (LCO) and hydrocracked gas oil. All these components differ widely in characteristics and these characteristics determine emissions.

Options for meeting diesel norms :

The aim is to increase Cetane Number and reduce the Sulphur content, Polyaromatics content and distillation temperature. The various options are as follows ·

(a) Sulphur reduction :

(i) Hydrodesulphurization (HDS) is the most important process. In HDS most of the sulphur present in hydrocarbons comes out as hydrogen sulphide. To meet the diesel sulphur specification various refineries in the country are installing new HDS units. Refineries can meet the required diesel sulphur and other qualities by managing the extent of hydrotreatment to different feedstocks by various modes of HDS listed below.

- Deep HDS at moderate pressure
- High-pressure single-state hydrotreatment
- Two-stage low-pressure hydrotreatment

(ii) RDS/VRDS Hydrotreating Unit (HDT) : The Residuum Desulpherization (RDS) and Vacuum Residuum Desulphurization (VRDS) hydrotreating processes are used by refiners to produce low sulpur fuel oils and to prepare feeds for other units. RDS/VRDS hydrotreaters upgrade residual oils by removing impurities and cracking heavy molecules in the feed to produce lighter product oils. Today these processes perform equally well removing sulphur, nitrogen, carbon residues, nickel and vanadium from the oil simultaneously cracking heavy VR molecules to VGO, distillates and naphtha products. The amount of impurities removed depends on the feed and on the product specifications desired by the refinery.

(iii) Sulphur Recovery Unit (SRU) : Raw crude contains sulphur and nitrogen. During processing the sulphur and nitrogen are principally converted to hydrogen sulphide, H_2S

and ammonia NH_3. More stringent environmental standards on the emission of sulphur and nitrogen compounds, together with the low sulphur specifications for petroleum products have resulted in making sulphur management critical for today's refineries

(b) Benzene reduction: Isomerization is the conversion of C5-C6 paraffins to the corresponding branched isomers to increase their octane number. This is accomplished by the Isomerization Process, which uses a highly active, low temperature hydroisomerization catalyst. In addition to increasing octane, another benefit of all Isomerization-based flow schemes is the saturation of all benzene to cyclohexane. This aspect is particularly important to refiners who want to reduce the level of benzene in their gasoline pool.

(c) Reduction of PolyAromatics:

Reduction in polyaromatics can be achieved by HydroDeAromatization, i.e. saturation of polyaromatics using hydrogen.

Some related facilities that are also required for some of the above processes of pollutant reduction in MS and HSD:

Hydrogen (H_2) Generation Unit : The hydrogen plant is designed for the production of Hydrogen. Steam reforming of naphtha/refinery gases is the dominant method for producing hydrogen. This is combined with pressure-swing adsorption system to purify the hydrogen to greater than 99 vol. %.

Fluid Catalytic Cracking Unit (FCCU) : This is a catalytic process for converting higher molecular weight hydrocarbons into lighter, more valuable products through contact with catalyst at appropriate process conditions.

Alkylation Process: The contribution of alkylation process is critical in the production of quality motor fuels. The alkylate product possesses excellent antiknock properties because of its considerable content of highly branched paraffins. Alkylate is one of the components of gasoline which is clean burning and low-sulphur.

Indian refineries can be divided into four categories with respect to refinery configuration:

(i) *Refineries with only catalytic reforming* (eg Digboi Refinery). It would be costly to meet future aromatic specifications in motor spirit and cetane specification in diesel with such configuration. However it can take advantage of low sulphur and low olefins to blend catalytic gasoline. Such refineries would require investment in light naptha isomerisation unit / FCC and DHDT for saturating aromatics.

(ii) *Refineries with only Catalytic Cracking Unit:* (eg Guwahati Refinery): It would be costly to meet future sulphur, aromatics and olefins specifications in motor spirit and it would be difficult to handle LCO (Light Cycle Oil) stream for producing diesel. Such refineries would require significant investment for post treating of cracked naptha and DHDT for saturating aromatics. The other option is to route it to Hydrocracker unit.

(iii) *Refineries with Catalytic Reforming and Catalytic Cracking* (Barauni and Haldia Refineries*):* Relatively cheap to meet future specification of motor spirit with only minimal investment for post treatment. However, for production of diesel it would be difficult to handle LCO stream and would require significant investment in DHDT for saturating aromatics. The other option is to route it to Hydrocracker unit.

(iv) *Refineries with Catalytic Reforming, Catalytic Cracking and Hydro cracking (*eg Gujarat, Mathura and Panipat Refineries*):* These refineries provide the cheapest option for meeting future specification for motor spirit and diesel.

Though the refineries can be broadly classified in the four groups mentioned above but each refinery has some unique characteristics. The requirement of investment for quality upgradation has therefore varied from refinery to refinery due to variation in process characteristics as well as due to refinery specific features. It is therefore necessary to take a closer look at the status of present refinery configuration and requirement of facilities for quality upgradation which are summarized below.

Mathura Refinery :

The refinery has Commissioned a DHDS unit in August '99 to produce 0.25% sulphur diesel. Additional reactor in the DHDS unit has been installed to further improve diesel quality to 0.05% sulphur maximum. Setting up of hydro-cracker unit to provide sulphur free feed to its FCC unit along with three chains of high-efficiency (99%) sulphur recovery units. Benzene saturation and isomerization selective hydrotreatment scheduled for completion in May 2003 for meeting MS norms. Additional high-pressure reactor for diesel to be completed by August 2003.

Required – upgradation of Isomerization, HDT, H_2 generation unit, Sulphur Recovery unit.

Panipat Refinery:

DHDS unit comissioned in July '99 for Extra low sulphur diesel (0.25%) from September 1999 and Ultra low sulphur diesel (0.05%) from December 1999. Benzene saturation and isomerization selective hydrotreatment scheduled for completion in May 2003 for meeting MS norms. Additional high-pressure reactor for diesel by August 2003.

Required – upgradation of HDT, H_2 generation unit, Sulphur Recovery Unit.

Gujarat Refinery:

DHDS unit along with hydrogen and sulphur recovery unit comissioned in June '99 to produce 0.25% sulphur diesel. Isomerization selective hydrotreatment scheduled for completion in December 2003 for meeting MS norms. Residue DeSulphurization (RDS) unit coupled with Residual Fluidized Catalytic Cracking (RFCC) and associated facilities is under implementation expected to be completed by end 2002-03. DFR scheduled for completion in July 2003.

Required – upgradation of Isomerization, HDT, H_2 generation unit, Sulphur Recovery Unit.

Haldia Refinery:.

DHDS unit including hydrogen unit and sulpher recovery unit comissioned in September '99. Benzene saturation and selective Hydrotreatment scheduled for completion in December 2003 for meeting MS norms. Second crude distillation unit has been designed for processing of Low Sulphur Crude. DFR scheduled for completion in December 2003. FCCU has been completed.

Required – upgradation of Isomerization, HDT, H_2 generation unit, OHCU

Barauni Refinery:.

Adopted - A feasibility report is underway for installation of facilities to meet less than 1% of benzene and less than 50 ppm of sulphur in petrol, approved by IOC. Benzene saturation and Isomerization selective Hydrotreatment scheduled for completion in December 2003 for meeting MS norms. An expansion plan approved by the IOC Board in Feb.'99 has been chalked out which includes a diesel hydrotreating unit and hydrogen generation unit. The project is under execution and is expected to be commissioned by 2002. Additional reactor required for 51 Cetane diesel scheduled for completion in May 2002.

Required – upgradation of Isomerization, benzene saturation unit and selective hydrotreatment

Guwahati Refinery:

Among several projects in various phases of completion is the installation of hydrotreater unit for production of HSD meeting the future specifications. Revamp of NSF and KTU scheduled for completion in October 2003 for meeting MS norms. Additional reactor required for 51 Cetane diesel scheduled for completion in 2002.

Digboi Refinery:

For improvement of diesel quality and meeting the future specifications with respect to cetane number and sulphur content, a new diesel hydrotreater project is under implementation and is expected to be commissioned by June 2002. Benzene saturation and ISOSIV Unit scheduled for completion in October 2003 for meeting MS norms. Additional reactor required for 51 Cetane diesel scheduled for completion in 2002.

2.3 Modelling Framework for Cost computation

This section attempts to derive the cost of quality upgradation of BIS 2000 compliant MS and HSD to Euro IV and Euro III specifications, respectively (with certain exceptions as mentioned in the pervious sections). The cost of upgradation is derived by computing the difference between the unit cost of production of MS/HSD in the existing plants and in the upgraded plants with additional facilities required for meeting the quality norms.

The unit cost of the refined products depends on:

i. The total capital invested or the fixed assets of each refinery. This constitutes the net block and capital work in progress, reported in Table 2.7.
ii. The cost of crude incurred by each refinery. Refineries may be totally dependent on imported or indigenous crude. However, most of them use a mix of the two. The price (including cost, insurance and freight) along with landing charges, entry tax and demurrage has been taken as cost for the imported crude utilized. The unit cost has been computed for international price of crude at $ 28 per barrel. In the sensitivity analysis, two other scenarios of international crude prices have been

Table 2.7 Basic Refinery Statistics

Refinery Name	Barauni	Gujarat	Haldia	Panipat	Mathura	Digboi	Guwahati
Throughput Capacity (in MMT)	6.00	12.00	6.00	12.00	8.00	0.65	1.00
Net Block (Rs.Million)	2,855	18,289	9,154	22,663	11,763	6,080	904
Capital Work In Progress (Rs.Million)	5,461	2,067	2,458	1,290	5,704	1,935	10832
Total Petro Products (MMT)	5.4	11.6	5.6	10.9	7.7	0.57	0.9
HSD (MMT)	2.496	3.925	2.728	6.117	3.467	0.088	0.453
MS (MMT)	0.6	0.9	0.27	0.8	0.8		

considered for computing the cost of upgradation of MS/HSD. These scenarios pertain to a low crude price of $20 per barrel and a high crude price of $35 per barrel. For the sake of comparability the results of these two scenarios are presented alongwith the $ 28 per barrel crude price scenario.

iii. The operating costs include the cost of power and fuel, chemicals, catalysts etc., stores, spares, repair and maintenance, establishment and general administrative expenses. For calculating the unit cost of upgraded plants, the project cost of additional facilities is added to the capital invested. The incremental operating cost due to additional demand of power and fuel, chemical and catalyst etc. are also added to the existing operating cost before upgradation.

To calculate the average unit cost of production of all the products of a refinery, the present value of the total capital invested, crude and operating cost over the life period of the plants is divided by the total output of the plant over its life period. The problem of netting out the unit cost of production of a particular product from the stream of total products of the refineries is a typical problem associated with joint products. There is no universally accepted method for solving this problem. Hence, alternative methods may be conceived for allocating the total cost among the stream of products as follows.

a) By allocating the cost in proportion to the revenue earned by each product at import parity prices.
b) In proportion to the calorific value of each product
c) Netting out from total cost the revenue earned from all other products except the one whose unit cost has to be determined.

The first two methods are not very relevant since the cost of refinery products are allocated neither in proportion to their energy value nor the revenue earned from each product. The third appears to be a more acceptable method and has been used for the derivation of unit cost of MS/HSD. In this method, the present value of the revenue earned during the life period of the plant from all other products except MS/HSD is subtracted from the present value of the total cost of all products including MS/HSD. The residual amount is the cost incurred on account of the present equivalent of the tonnage of MS/HSD produced during the lifetime of the plant. The unit cost of MS/HSD is obtained by dividing the residual amount by the present equivalent total tonnage of MS/HSD.

For deriving the unit cost of the MS/HSD with upgradation, the present value of the project investment is added to the present value of the total capital invested, and the present value of incremental operating cost due to upgradation over the life period of the plant is added to the present value of the existing operating cost of the plants over the life period. For computing the present value of revenue from all other products except MS/HSD, the new product mix with upgradation has been considered. The present value of tonnage of MS/HSD over the life period of the plant has been computed according to new tonnage of MS/HSD after upgradation. The product-mix without upgradation and with upgradation is presented in Annexure Tables 2.1 and 2.2, respectively. The international product prices used for computing revenues are given in Table 2.3. The unit cost of upgraded MS/HSD has been calculated by the same method as in the case of without upgradation. The difference between the unit cost of upgraded and existing quality of MS/HSD is taken as the unit cost of upgradation. The total capital employed, crude cost, operating cost, revenue and tonnage of output over the life period of the refineries have been discounted to the present value at year 2000.

2.3.1 *The Model*

For deriving the results, the following assumptions have been made in the model.

i. The life period of the plant is 15 years from the implementation of the upgradation projects. Implementation of upgradation takes 3 years for completion.
ii. The refineries operate at full capacity throughout the lifetime of the project. The requirement of crude is determined by the throughput capacity of the refineries.
iii. The operating cost of the refineries and the incremental operating cost of the refineries remain constant over the life period of the refineries.

iv. The product mixes of the refineries with upgradation and without upgradation remains constant over the life period of the plants.

v. The net block depreciates uniformly during upgradation project implementation as well as life period of the refinery. The net block of the refineries is depreciated to the terminal year of project investment, then added to the total capital invested and discounted to its present value.

vi. The life span of the refineries is 15 years with and without upgradation.

vii. All costs and prices are in 2000 prices

Notations of the model.

t = Relevant year.

NB_o = Net block in the year 2000.

NB_t = Net block in the 't' th year.

CW_t = Capital work in progress in the 't' th year.

PI_t = Project investment for quality upgradation in the 't' th year.

r = Rate of discount.

PV_I = Present value of total capital invested.

PV_I^U = Present value of total capital invested in the upgradation scenario.

CR_t = Crude cost in the 't' th year

PV_{CR} = Present value of crude cost

OC_t = Operating cost in the 't' th year.

ΔOC_t = Incremental operating cost due to quality upgradation in the 't' year.

PV_{OC}^W = Present value of operating cost without upgradation.

PV_{OC}^U = Present value of operating cost with upgradation.

R_t^W = Without upgradation Revenue in the 't' th year from product mix except MS / HSD

R_t^U = With upgradation Revenue in the 't' th year from product mix except MS / HSD

PV_R^W	=	Without upgradation Present value of revenue from product mix except MS / HSD
PV_R^U	=	With upgradation Present value of revenue from product mix except MS /HSD
TP_t^W	=	Tonnage of total products per year without upgradation.
TP_t^U	=	Tonnage of total products per year with upgradation.
PV_x^W	=	Present equivalent of tonnage of MS/HSD without upgradation.
PV_x^U	=	Present equivalent of tonnage of total MS/HSD with upgradation.
x_t^W	=	Tonnage of MS / HSD per year without upgradation.
x_t^U	=	Tonnage of MS / HSD per year with upgradation.
Z_x^W	=	Unit cost of MS / HSD without upgradation
Z_x^U	=	Unit cost of MS / HSD with upgradation
C_Z	=	Cost of upgradation of MS / HSD

$$NB_t = NB_O(1-\frac{t}{18}) \quad (1)$$

$$PV_I = \sum_{i=1}^{3} \frac{NB_t + CW_t}{(1+r)^t} \quad (2)$$

$$PV_{CR} = \sum_{i=4}^{18} \frac{CR_t}{(1+r)^t} \quad (3)$$

Case : without upgradation

$$PV_{OC}^W = \sum_{i=4}^{18} \frac{OC_t}{(1+r)^t} \quad (4)$$

$$PV_R^W = \sum_{i=4}^{18} \frac{R_t}{(1+r)^t} \quad (5)$$

$$PV_{TP}^{W} = \sum_{i=4}^{18} \frac{TP_t}{(1+r)^t} \quad (6)$$

$$PV_x^{W} = \sum_{i=4}^{18} \frac{x_t^{w}}{(1+r)^t} \quad (7)$$

$$Z_x^{W} = \frac{PV_I^{W} + PV_{CR} + PV_{OC}^{W} - PV_R^{W}}{PV_x^{Wi}} \quad (8)$$

Case: With Upgradation

$$PV_I^{W} = \sum_{i=1}^{3} \frac{NB_t + CW_t + PI_t}{(1+r)^t} \quad (9)$$

$$PV_{OC}^{U} = \sum_{i=4}^{18} \frac{OC_t + \Delta OC_t}{(1+r)^t} \quad (10)$$

$$PV_R^{U} = \sum_{i=4}^{18} \frac{R_t}{(1+r)^t} \quad (11)$$

$$PV_x^{U} = \sum_{i=4}^{18} \frac{x_t^{U}}{(1+r)^t} \quad (12)$$

$$Z_x^{U} = \frac{PV_I^{U} + PV_{CR} + PV_{OC}^{U} - PV_R^{U}}{PV_x^{U}} \quad (13)$$

Upgradation cost

$$C_x = Z_x^{U} - Z_x^{W} \quad (14)$$

2.3.2 Results of the Model

The amortised cost of MS in each refinery has been reported in Table.2.8. The amortised cost in this table reflects the unit cost of MS production in the present plants of the refineries without upgradation. Table 2.9 presents the ammortised cost of MS in each refinery with upgradation. The relative cost efficiency of the refineries can be judged from the unit cost of MS . The cost of upgradation of MS are presented in Table 2.10.

Table 2.8 Cost Without Upgradation of Motor Spirit
Rate of Discount: 15%

Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*
Ammortised Cost/Ton Of MS/HSD ($20/Bl)	10456	10468	14111	10848	9653
Ammortised Cost/Ton Of MS/HSD ($28/Bl)	14873	16084	17201	16547	13803
Ammortised Cost/Ton Of MS/HSD ($35/Bl)	16046	16633	17798	17778	15518
Ammortised Cost/Litre Of MS/HSD ($20/Bl)	7.42	7.42	10.01	7.69	6.85
Ammortised Cost/Litre Of MS/HSD ($28/Bl)	10.55	11.41	12.20	11.74	9.79
Ammortised Cost/Litre Of MS/HSD ($35/Bl)	11.38	11.80	12.62	12.61	11.01

Table 2.9 Cost With Upgradation of Motor Spirit (in Rs)
Rate of Discount: 15%

Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*
Ammortised Cost/Ton Of MS/HSD ($20/Bl)	13022	11267	16037	13306	11735
Ammortised Cost/Ton Of MS/HSD ($28/Bl)	17470	17818	19583	19185	15915
Ammortised Cost/Ton Of MS/HSD ($35/Bl)	19214	20067	20780	21058	18220
Ammortised Cost/Litre Of MS/HSD ($20/Bl)	9.24	7.99	11.37	9.44	8.32
Ammortised Cost/Litre Of MS/HSD ($28/Bl)	12.39	12.64	13.89	13.61	11.29
Ammortised Cost/Litre Of MS/HSD ($35/Bl)	13.63	14.23	14.74	14.93	12.92

Table 2.10 Cost Of Upgradation of Motor Spirit (in Rs)
Rate of Discount: 15%

Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*
Upgradation Cost/Ton Of MS ($20/Bl)	2566	799	1926	2458	2082
Upgradation Cost/Ton Of MS ($28/Bl)	2597	1734	2382	2638	2112
Upgradation Cost/Ton Of MS ($35/Bl)	3168	3434	2982	3280	2702
Upgradation Cost/Litre Of MS ($20/Bl)	1.82	0.57	1.37	1.74	1.48
Upgradation Cost/Litre Of MS ($28/Bl)	1.84	1.23	1.69	1.87	1.50
Upgradation Cost/Litre Of MS ($35/Bl)	2.25	2.44	2.11	2.33	1.92

The amortised cost of HSD in each refinery has been reported in Table.2.11. The amortised cost in this table reflects the unit cost of HSD production in the present plants of the refineries without upgradation. Table 2.12 presents the ammortised cost of HSD in each refinery with upgradation. The relative cost efficiency of the refineries can be judged from the unit cost of HSD . The cost of upgradation of HSD are presented in Table 2.13.

Table 2.11 Cost Without Upgradation of HSD
Rate of Discount: 15%

Product	Barauni	Gujarat	Haldia	Panipat	Mathura	Digboi	Guwahati
Ammortised Cost/Ton Of HSD ($20/Bl)	9189	8190	9510	9041	9016		12109
Ammortised Cost/Ton Of HSD ($28/Bl)	12552	11358	12591	12395	12295	13910	15520
Ammortised Cost/Ton Of HSD ($35/Bl)	15099	13769	15372	15111	14581		18205
Ammortised Ccst/Litre Of HSD ($20/Bl)	7.59	6.72	7.86	7.47	7.45		10.01
Ammortised Cost/Litre Of HSD ($28/Bl)	10.37	9.39	10.41	10.24	10.16	11.49	12.83
Ammortised Cost/Litre Of HSD ($35/Bl)	12.48	11.38	12.70	12.48	12.05		15.05

Table 2.12 Cost With Upgradation of HSD (in Rs)

Rate of Discount: 15%

Product	Barauni	Gujarat	Haldia	Panipat	Mathura	Digboi	Guwahati
Ammortised Cost/Ton Of HSD ($20/Bl)	10689	9535	10920	9589	10070		15579
Ammortised Cost/Ton Of HSD ($28/Bl)	14281	12814	14132	12947	13536	17027	19235
Ammortised Cost/Ton Of HSD ($35/Bl)	17047	15454	17038	15666	16230		22169
Ammortised Cost/Litre Of HSD ($20/Bl)	8.83	7.88	9.02	7.92	8.32		12.86
Ammortised Cost/Litre Of HSD ($28/Bl)	11.80	10.59	11.68	10.70	11.19	14.07	15.90
Ammortised Cost/Litre Of HSD ($35/Bl)	14.09	12.77	14.08	12.95	13.41		18.32

Table 2.13 Cost Of Upgradation of HSD (in Rs) Rate of Discount: 15%							
Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*	*Digboi*	*Guwahatia*
Upgradation Cost/Ton Of HSD ($20/Bl)	1500	1345	1410	548	1054		3470
Upgradation Cost/Ton Of HSD ($28/Bl)	1729	1456	1541	552	1241	3117	3715
Upgradation Cost/Ton Of HSD ($35/Bl)	1948	1685	1666	555	1649		3964
Upgradation Cost/Litre Of HSD ($20/Bl)	1.24	1.16	1.16	0.45	0.87		2.85
Upgradation Cost/Litre Of HSD ($28/Bl)	1.43	1.20	1.27	0.46	1.03	2.58	3.07
Upgradation Cost/Litre Of HSD ($35/Bl)	1.61	1.39	1.38	0.47	1.36		3.27

Sensitivity Analysis

A sensitivity analysis has been carried out for cost of upgradation of MS/HSD with 10 percent and 12 percent rate of discount with different crude price scenarios. These results have been presented in Table 2.14 and 2.15. A sensitivity analysis of two crude price scenarios for $20 per barrel and $35 per barrel have been have been carried out. The results of these scenarios are presented alongwith the $28 per barrel scenario.

Table 2.14 Cost Of Upgradation of HSD (in Rs) Rate of Discount: 10%							
Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*	*Digboi*	*Guwahati*
Upgradation Cost/Ton Of HSD ($20/Bl)	1311	1996	575	505	1164		2971
Upgradation Cost/Ton Of HSD ($28/Bl)	1539	1447	1306	509	1350	2274	3216
Upgradation Cost/Ton Of HSD ($35/Bl)	1759	1674	1430	513	1758		3465
Upgradation Cost/Litre Of HSD ($20/Bl)	1.08	1.15	0.97	0.41	0.96		2.46
Upgradation Cost/Litre Of HSD ($28/Bl)	1.27	1.20	1.08	0.36	1.12	1.88	2.66
Upgradation Cost/Litre Of HSD ($35/Bl)	1.46	1.38	1.18	0.43	1.45		2.87

Table 2.15 Cost Of Upgradation of HSD (in Rs) Rate of Discount: 12%							
Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*	*Digboi*	*Guwahati*
Upgradation Cost/Ton Of HSD ($20/Bl)	1383	1400	1325	521	1164		3163
Upgradation Cost/Ton Of HSD ($28/Bl)	1617	1441	1397	526	1350	2416	3407
Upgradation Cost/Ton Of HSD ($35/Bl)	1831	1678	1521	529	1760		3656
Upgradation Cost/Litre Of HSD ($20/Bl)	1.14	1.15	1.05	0.43	0.96		2.62
Upgradation Cost/Litre Of HSD ($28/Bl)	1.33	1.20	1.33	0.44	1.12	2.15	2.82
Upgradation Cost/Litre Of HSD ($35/Bl)	1.52	1.38	1.26	0.43	1.45		3.02

Chapter III

Savings in Health Cost from Upgraded Fuel

1. Introduction

Estimating the health cost of urban transport pollution involves two steps: first, estimating the physical impact of transport emission on health, and second, putting a money value on the physical damage of health. While the former has to be estimated in terms of volume of emission per day of various urban passenger and freight transport modes for various cities for a given year, the latter involves the estimation of health cost in monetised unit per unit of emission of the pollutants. The combustion of gasoline and diesel introduces harmful compounds into the air and the flow of emission has an impact on the morbidity and mortality rates of a city. Epidemiological literature suggests that vehicular air pollution causes a variety of harmful effects including eye irritation, headache, acute and chronic respiratory illness like asthma, and even death. The size of population along with such morbidity and mortality rates provide the estimate of physical health damage.

The health cost in monetary unit because of morbidity, in turn, involves two major components, namely wage loss from loss of working days and treatment cost for the illness caused by pollution. The mortality, on the other hand, can be monetised in terms of the statistical value of life, which essentially represents the discounted present equivalent of income loss from the shortening of working life. All these have to be captured in the estimate of cost coefficients per unit of emission of each pollutant.

With the ongoing debate about a possible move to higher quality and more environment-friendly fuels, it is important to ask what the costs and benefits of such a move will be. For example, how much will it cost the country to upgrade its refineries to be able to produce the better quality fuels, and to modernize its vehicles to be compatible with the higher quality fuels? How much will the urban areas save in terms of health costs? This chapter is an attempt to quantify the health costs.

The chapter is organized as follows. Section 2 discusses the methodology. Section 3 analyses the results, while Section 4 concludes. Detailed results are summarized in the Annexure Tables.

2. Methodology

This chapter estimates the volume of emission of the different pollutants for Indian urban agglomerates with more than one million population for the 2002 base line scenario. The data situation in India on the epidemiological determinants of health cost, particularly the precise relation of physical health damage with air pollution, is highly inadequate. Given this inadequacy, the US research based health cost estimates in 1991 US dollar per kilogram of emission flow for each of the concerned pollutants as obtained by Delucchi for US cities[1], are used after making appropriate adjustments for the Indian situation. The adjustments are mainly for the variations in the purchasing power of the currencies, real income and density of population between the two countries.

Delucchi obtained the marginal cost per kg of emission of particular types by dividing the estimated health cost per pollutant by their estimated emissions. The basis of Delucchi's estimates is the US official Environment Protection Agency (EPA) emission-factor model for mobile sources called "MOBILE5" and other stationary-source emission models. The criteria pollutants considered were carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter less than 10 microns (PM_{10}),and sulphur oxides (SO_x). The areas considered were the whole of the US, all urban areas of the US and Los Angeles. Delucchi provides lower- and upper-bound estimates of the health costs. According to Delucchi: "Of course, at every stage of the modelling process there is considerable uncertainty...For several of the emission estimates, the differences between the upper and lower-bound estimates is roughly a factor of two, and for most of the valuation functions or parameters, the difference is at least a factor of four. Overall, the uncertainty compounds into an order-of-magnitude difference between the low and the high estimates of total cost."[2] Delucchi's lower-bound estimates have been used in this paper for estimating the savings on health cost on account of shift to Euro II and Euro III emission norms. The reason for using the lower-bound estimates as well as the sensitivity of the results to using the upper-bound estimates are discussed later. The method

1 Delucchi Mark (2000), Environmental Externalities of Motor – Vehicle Use in the U.S., Journal of Transport and Policy, Vol. 34, part 2.

2 Delucchi, ibid., p. 145.

of obtaining aggregate health cost per annum for different Indian cities for alternative environmental standards from Delucchi's lower-bound estimates is as follows:

(a) Base line emission for India

The base line emission for vehicular population of 2002 of selected Indian cities as per pre- Euro quality of fuel and vintage of vehicles is estimated using distance traveled and emission coefficients for each vehicular mode for the different pollutants and the modal composition of vehicular population for the different cities.[3] While estimating emission for Euro II, Euro III and Euro IV specifications it is assumed that both, fuel and vehicle engine specification of the entire modal composition comply with these norms.

(b) Converting Delucchi's estimate for the U.S.

Delucchi's estimate of US dollar cost (at 1991 prices) coefficients per kilogram of each pollutant are corrected as follows to take into account the differences in temporal and cross country situations between United States and India:

(i) First, the US dollar costs of emission per kilogram of different pollutants in 1997 US prices are obtained from the corresponding cost estimates at 1991 prices (Delucchi, 2000) by using the inflation in US GDP deflator between 1991 and 1997.

(ii) Second, the ratio of Indian GDP in US dollars to the same in PPP (Purchasing Power Parity) dollar – that is, the PPP exchange dollar-rupee exchange rate -- is used for adjusting the cost estimates of step 1 for the difference between the purchasing power of the US dollar and the Indian Rupee in 1997.

(iii) Third, to adjust for the variation in per capita real income between the US and the Indian cities, the ratio of per capita income for the selected Indian cities to the US per capita income in PPP dollar in 1997 is used to adjust the costs obtained in step 2. The variation in urban and rural per capita income in the US is not considered with more than three-quarters of the population of the country in urban

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3 For inflation and exchange rate purposes 1997 is taken as the financial year 1997-98.

areas and the absence of data on urban– rural income distribution. This rural-urban variation in the US is in any case likely to be of second order of importance.

(iv) Fourth, the values obtained in step three is adjusted for variation in exposed population to the pollutants by using the ratio of density of the population in the concerned Indian city to the average density of the nine US cities of relevance for an inter-country adjustment.

(v) Fifth, the estimated cost in Indian Rupee for 1997 by using purchasing power parity dollar exchange rate between the two currencies for 1997 is converted into Indian Rupees of 2000-01 by using the inflation in GDP deflator between 1997 and 2000-01.

Health costs can be thought of as consisting of two components, namely income loss and treatment cost because of pollution-related sickness. For any two countries, both these components are sensitive to the relative purchasing powers of the currencies and the relative average incomes in comparable purchasing power terms. Similarly, in any country over time, both the components are sensitive to inflation. Thus, to derive the estimates for Indian cities, Delucchi's estimates for the US in 1997 in dollars at 1991 prices have been adjusted by correcting for two components of variation: (i) difference in purchasing power of currencies of the two economies and (ii) variation in the income level in PPP terms between the two countries . The method of conversion between the currencies and of adjustment for real income variation have led virtually to the use of the same ratio of damage cost per kilogram of pollutant to per capita income in Indian cities as in the US in 1997.

(c) The derived health cost in rupees per kilogram of a pollutant in 2000-01 prices as obtained from (b) has been multiplied by the total volume of emission of the concerned pollutant to obtain the total health cost per day and per annum for each city for the base line scenario. It may be noted that our damage estimate relates to the pollution situation for the selected Indian cities in 1997 expressed in 2000-01 prices.

(d) Given the emission load per day and per annum for different cities, the health costs for improved environmental standards of Euro II and Euro III are calculated to derive the savings in health cost for such upgradation by comparing the estimates with the base line.

The highlights of our health cost results and certain crucial determining parameters are presented below, with the details of the results in Annexure tables. The results are crucial indicators of benefit and cost of environmental upgradation, which may be useful for policy decisions regarding investments and regulatory regime.

Data Source and Generation

City Income: Because of the lack of data on rural-urban distribution of income, for all the Indian cities, the per capita income has been taken as the same as per capita Gross State Domestic Product (GSDP) in the State. The data for GSDP is from Economic Survey 2002.

Population and Population Density: For the Indian cities, the data sources are (i) Census of India, 1991, Series I,Part II-A(ii) - A Series, *Towns and Urban Agglomerations 1991* (ii) Census of India 2001,*Provisional Population Totals, India*, Part 1.

For the representative US cities we have considered New York, Los Angeles, Chicago, Philadelphia, Detroit, Baltimore, San Francisco, Washington D.C. and Boston. The data source on population density is the official web-site of the US Census Bureau, www.census.gov.

Purchasing Power Parity: The purchasing power parity figures are from the World Bank's World Development Report, 1993.

US Inflation Rate: The US inflation rate is from the International Monetary Fund's International Financial Statistics, 1999

Total Distance Traveled by different modes of vehicles per day: For all vehicles apart from Buses trucks and light commercial vehicles (L.C.Vs), the data source is *Impact of Transportation Systems on Energy and Environment- an Analysis of Metropolitan Cities of India*, Tata Energy Research Institute, August, 1992. For trucks and buses the source of Data is the Central Road Research Institute, the exact data generation procedure for different cities have been stated in the notes of Annexure Table 3.2. The procedure of estimating total distances traveled by LCVs is also stated in the notes of Annexure Table 3.2

Vehiclewise Emission Factors: Vehicle-wise emission factors are from *Transport Fuel Quality, 2005*, Central Pollution Control Board and revised norms of emission as communicated by the Central Pollution Control Board by fax to NIPFP dated 1, May 2002.

Vehicular Population: Population of vehicles is from PPAC, Ministry of Petroleum and Natural Gas, Govt. of India.

3. Analyses of Results

As per the revised norms and assumptions regarding emission of different pollutants the total annual health cost for 35 urban agglomerates of India works out to be Rs. 737.97 crores in the low cost scenario and Rs. 10071.5 crores in the high cost scenario. These estimates are based on population of 2001, income of 1997–98 and prices of 2000-01. The low and high estimates, as already noted are based on Delucchi's low and high estimates of basic health cost parameters for individual pollutants for American cities, which were taken as the starting point for our calculations in our earlier report. The health cost for the same set of urban agglomerates as per the low cost scenario comes down to Rs.90.33 crores for Euro II, Rs.62.80 crores for Euro III and Rs.43.84 crores for Euro IV. The corresponding high cost estimate for health damage are Rs. 10071.5 crores for Pre- Euro, Rs.1231.6 crores for Euro II, Rs.869.05 for Euro III and Rs.605.83 crores for Euro IV norms.

Delhi has a dominant share of urban vehicular population in India. It may be noted that under the low cost scenario the health damage cost for Delhi worked out to be Rs.269 crores at 2000-01 prices for Pre Euro norms with 2001 population and 1997-98 income. The corresponding estimate under high cost scenario is Rs. 3689 crores. As per the low cost scenario, Delhi is followed by Hyderabad (78.82) Mumbai (Rs. 71.98 crore), Chennai (Rs.55.36 crore), Ahmedabad (Rs 50.93 crores), Bangalore (43.52 crores) and Kolkata (Rs.11.95 crore) . The cities with the lowest health damage cost are Asansol and Jamshedpur. Table 1 gives the similar cost estimates for all 35 urban agglomerates for low cost scenario for Pre Euro, Euro II, Euro III and Euro IV emission norms. The results for the high cost scenario are given in Appendix Table A20.

Table 3.1 : Annual Health Cost Across Cities in India

(Low Cost Estimates) *(In Rs.)*

Cities	Pre Euro	Euro II	Euro III	Euro IV
Agra	19,604,428	2,148,922	1,531,732	1,062,671
Ahmedabad	509,348,757	69,693,096	50,501,138	33,690,134
Allahabad	125,795,153	8,564,985	5,128,512	4,358,708
Amritsar	51,997,804	4,886,185	3,287,555	2,429,362
Asansol	1,617,322	653,004	587,105	312,671
Bangalore	435,271,458	45,918,433	30,591,982	22,601,651
Bhopal	19,792,384	2,068,700	1,400,111	1,015,433
Chennai	553,629,571	50,783,269	31,760,500	25,025,702
Coimbatore	11,791,078	1,784,964	1,357,897	862,798
Delhi	2,699,244,784	333,779,402	236,724,186	163,434,032
Dhanbad	4,025,571	583,583	444,094	284,881
Faridabad	17,852,336	2,660,774	1,893,403	1,275,771
Hyderabad	788,201,249	94,965,417	67,085,199	46,523,221
Indore	58,361,730	4,041,834	2,390,008	2,064,847
Jabalpur	16,035,808	1,107,621	678,541	566,282
Jaipur	59,170,115	4,249,272	2,516,038	2,151,825
Jamshedpur	3,572,876	609,259	484,392	295,117
Kanpur	37,450,776	3,583,241	2,503,581	1,777,110
Kochi	20,348,272	2,625,047	1,766,914	1,261,224
Kolkata	119,575,850	29,196,200	24,460,243	14,026,595
Lucknow	38,815,416	3,425,844	2,239,042	1,707,047
Ludhiana	113,658,343	8,186,327	4,765,611	4,136,821
Madurai	25,481,108	2,982,954	2,149,879	1,458,538
Meerut	15,045,332	1,509,053	1,072,976	748,630
Mumbai	719,812,464	132,337,512	89,838,118	60,707,810
Nagpur	109,115,976	9,590,561	6,171,833	4,755,980
Nasik	11,707,048	1,175,239	730,226	572,955
Patna	11,721,131	1,019,464	627,948	508,832
Pune	213,836,290	29,720,951	21,676,787	14,539,808
Rajkot	47,327,786	4,306,874	2,915,886	2,142,000
Surat	431,995,946	36,819,747	21,434,207	17,995,563
Vadodara	39,627,631	3,646,853	2,101,020	1,768,062
Varanasi	20,472,672	1,444,537	880,927	735,726
Vijayawada	15,506,017	2,119,336	1,583,736	1,031,307
Vishakhapatnam	12,964,732	1,158,038	723,669	574,636
Total	7,379,775,213	903,346,501	626,004,996	438,403,749

The percentage of savings in health cost for a shift to Euro II from Pre-Euro emission levels is above 60 percent for every city, the additional saving by moving to Euro IV is only 7 percent more at an average (Table 2). For a shift to Euro III from Euro II emission levels, the saving is 30.07 percent . For a shift to Euro IV from Euro III emission levels, the saving is 29.97 percent. Thus, the percentage savings in health cost is much higher for shifts from Pre-Euro to Euro II levels of emission than for shifts from Euro II to Euro III and from Euro III to Euro IV levels of emission for the same vehicular traffic as of 2002 as per the low cost scenario. The high cost scenario presented in Annexure Table A 19 yields similar trend with very minor variations in the proportions.

The estimated savings of health cost for upgradation of motor fuels presented below should factor in three additional considerations:

(i) The savings will accrue over a period of time from the introduction of new standards. For example, if Euro II is introduced from 2003, it is likely that a transition period will be allowed to phase out the older vehicles with pre Euro standards. A progressively larger proportion of savings will accrue as more and more older vehicles with pre Euro specifications get phased out. The full savings will accrue only when all vehicles with pre Euro specification are fully off the road.

(ii) The vehicle population is likely to grow over time. Thus the absolute savings on health cost benchmarked with the 2002 vehicle population is an underestimate of the true absolute savings that would accrue relative to what would happen without the upgraded specifications. The savings in percentage terms, of course, impervious to the vehicle population.

Table 2 : Savings In Health Cost

(Low Cost Estimates) *(Percent)*

Cities	Euro II over Pre Euro	Euro III over Pre Euro	Euro IV over Pre Euro	Euro III over Euro II	Euro IV over Euro III
Agra	89.04	92.19	94.58	28.72	30.62
Ahmedabad	86.32	90.09	93.39	27.54	33.29
Allahabad	93.19	95.92	96.54	40.12	15.01
Amritsar	90.60	93.68	95.33	32.72	26.10
Asansol	59.62	63.70	80.67	10.09	46.74
Bangalore	89.45	92.97	94.81	33.38	26.12
Bhopal	89.55	92.93	94.87	32.32	27.47
Chennai	90.83	94.26	95.48	37.46	21.20
Coimbatore	84.86	88.48	92.68	23.93	36.46
Delhi	87.63	91.23	93.95	29.08	30.96
Dhanbad	85.50	88.97	92.92	23.90	35.85
Faridabad	85.10	89.39	92.85	28.84	32.62
Hyderabad	87.95	91.49	94.10	29.36	30.65
Indore	93.07	95.90	96.46	40.87	13.61
Jabalpur	93.09	95.77	96.47	38.74	16.54
Jaipur	92.82	95.75	96.36	40.79	14.48
Jamshedpur	82.95	86.44	91.74	20.49	39.07
Kanpur	90.43	93.32	95.25	30.13	29.02
Kochi	87.10	91.32	93.80	32.69	28.62
Kolkata	75.58	79.54	88.27	16.22	42.66
Lucknow	91.17	94.23	95.60	34.64	23.76
Ludhiana	92.80	95.81	96.36	41.79	13.19
Madurai	88.29	91.56	94.28	27.93	32.16
Meerut	89.97	92.87	95.02	28.90	30.23
Mumbai	81.62	87.52	91.57	32.11	32.43
Nagpur	91.21	94.34	95.64	35.65	22.94
Nasik	89.96	93.76	95.11	37.87	21.54
Patna	91.30	94.64	95.66	38.40	18.97
Pune	86.10	89.86	93.20	27.07	32.92
Rajkot	90.90	93.84	95.47	32.30	26.54
Surat	91.48	95.04	95.83	41.79	16.04
Vadodara	90.80	94.70	95.54	42.39	15.85
Varanasi	92.94	95.70	96.41	39.02	16.48
Vijayawada	86.33	89.79	93.35	25.27	34.88
Vishakhapatnam	91.07	94.42	95.57	37.51	20.59
Total	87.76	91.52	94.06	30.70	29.97

(iii) The absolute savings on health cost are likely to vary directly with the size of the vehicle population, provided the composition of the vehicle population in terms of 2 wheelers, 3 wheelers, passenger cars, goods carriages and buses remain constant. Thus, a doubling of the vehicle population with the relative composition remaining unchanged will lead to a doubling of absolute savings. But, if the composition of the vehicle population tilts in favor of more polluting vehicles, then the absolute savings in health cost will increase more than proportionately relative to the vehicle population, and vice versa.

According to the Interim Report of the Expert Committee on Auto Fuel Policy, an investment of Rs.60,000 on capital equipment in refineries and vehicle manufacturing units will be required for shifting to Euro III regime from the pre-Euro regime. Our estimates of savings for the health damage cost for 35 urban agglomerates India for 2000-01 as given in Table 1 for the low cost scenario implies a payback period of 88 years and the corresponding rate of return works out to 1.12 per cent. For the high cost scenario the counterpart estimates for upgradation from Pre Euro to Euro III work out to 6.5 year for payback period and 15.33percent as rate of return.

Detailed Tables

The Annexure tables presents the derivation of health cost estimates for 35 Indianurban agglomerates. Table 3.1 presents the vehicular population and composition in these cities for the year 2002. Table 3.2 contains the assumptions about total distance traveled for each type of vehicles in the different cities considered for this study. Emission coefficients of different pollutants for each type of vehicle according to pre-Euro, Euro II , Euro III and Euro IV norms are in Table 3.3. The total daily flow of emission of pollutants in these cities as per pre-Euro, Euro II and Euro III emission norms are in Tables 3.4, 3.5 , 3.6 and 3.7 respectively. Table 3.8 contains lower estimate of the health cost per kilogram of pollutant in Indian rupees at 2000-01 prices. Table 3.9 contains higher estimate of the health cost per kilogram of pollutant in Indian rupees at 2000-01 prices The total health cost estimate of low cost scenario for the concerned cities according to Pre Euro, Euro II, Euro III and Euro IV emission norms are presented in Tables 3.10, 3.11, and 3.12 and 3.13 respectively. The corresponding numbers for the high cost scenario is presented in 3.14, 3.15, 3.16, and 3.17. Savings in Health cost due to upgradation.to higher Euro norms are given in Table 3.18 and 3.19 for low cost and high cost scenario respectively. Finally the health damage cost in the High cost scenario is summarized in Table 3.20

4. Concluding Remarks

Our estimate is based on Delucchi's basic cost parameters, the method essentially is one of following the dose–response approach through epidemiological impacts of pollution on human population. In this approach, there is considerable flexibility in the choice of lower or upper-bound estimates of the health costs. The uncertainty regarding health costs as seen in the low and high cost estimate is a reflection of the limitation of information and knowledge in this critical area.

Furthermore, it is possible to try the methods of hedonic or contingent valuation by conducting primary survey to estimate the damage cost. Under this approach, the epidemiological damage function of air pollution because of automotive emissions will have to be estimated and valued in money terms for the Indian situation through an independent interdisciplinary research initiative. It is the utter lack of such interdisciplinary work and database that forces one to fall back on studies conducted for other countries. It is high time that appropriate research initiatives are taken in this direction so that better environmental economics can be worked out in the Indian context. Any such study would involve extensive data collection, primary survey and econometric analysis, which would require substantive time, financial resources and institutional support.

Chapter IV

Cost Benefit Analysis of Upgraded Fuel Across Locations in India

Cost benefit analysis has been an important criterion to rank investment in prioritizing projects. In the second chapter the cost of upgrading a liter of petroleum product from pre Euro to Euro III / Euro IV quality has been derived. In the Chapter III the benefit from this upgradation in terms of savings in health cost due to reduction in vehicular emission in the most populous urban regions have been estimated in monetary units. To make the cost and benefit comparable both need to be expressed in the same units. Since the cost of upgradation has been derived in rupees per unit volume and weight, the benefits also need to be brought to the same dimension i.e. in terms of health cost saved per unit use of MS / HSD which could vary across urban locations depending on the transport situation. This chapter primarily expresses the cost and benefit in the same comparable units. The result would indicate the effectiveness of the investment and the economic viability of fuel upgradation project for different urban agglomerates..

It may be clarified at this juncture that fuel upgradation is only one of the alternatives of reducing vehicular pollution. Reduction in vehicular pollution actually requires an integrated approach where road conditions, traffic congestion, maintenance of vehicles and engine design are also addressed and improved. Poor road conditions as well as congested roads invariably reduce efficiency of the vehicle and fuel. This leads to higher consumption of fuel and therefore higher emission of pollutants. Proper maintenance of vehicle is extremely important for deriving the optimal mileage a vehicle is capable of achieving. Optimal mix of engine oil and fuel are effective means of achieving fuel economy and lower emission. Aspects of engine design like multi point fuel injection are important ways to ensure complete combustion of fuel thereby allowing for higher fuel efficiency and less emission. In this study the focus is mainly on fuel upgradation, its cost and benefit. This in no way implies that fuel upgradation is the most effective way to reduce vehicular pollution. The rate of return on investment on the above aspects would have been extremely insightful for prioritizing investment for reducing vehicular pollution. In the absence of any such information a cost benefit analysis may be accepted as an useful tool for evaluation of viable investment for fuel quality upgradation.

In order to quantify the benefit from upgradation of fuel quality a simple approach has been adopted. The reduction in health cost per liter of fuel due to upgradation from pre Euro norms to Euro III norms has been derived for each vehicle type. The total fuel consumption of each type of vehicle has been calculated by taking into consideration the total number of registered vehicle in that city and the average distance traveled by that vehicle category per day. The share of fuel consumption in one liter of fuel for each vehicle type is also calculated. The savings in health cost for each vehicle type is determined by taking into consideration the reduction in health cost per liter of upgraded fuel and the share of fuel consumed by each vehicle category. Summing up health cost saving across vehicle type would give the savings in health cost from a liter of fuel. The formal framework of derivation of benefit from a liter of upgraded fuel is given below.

Notations

h_i = Health cost per Kg of the ith pollutant

E_{ij}^{PE} = Emission coefficient in Kg per kilometer of ith pollutant from jth vehicle with pre euro emission norms.

E_{ij}^{E-III} = Emission coefficient in Kg per kilometer of ith pollutant from jth vehicle with Euro III emission norms.

F_j = Fuel efficiency in kilometers per litre of jth vehicle.

ε_{ij}^{PE} = Emission coefficient in Kg per litre of ith pollutant from jth vehicle with pre euro emission norms.

ε_{ij}^{E-III} = Emission coefficient in Kg per litre of ith pollutant from jth vehicle with Euro III emission norms

${}^{PE}M_{ij}^{E-III}$ = Reduction in emission in kg per litre of the ith pollutant from the jth vehicle due to due to upgradation of vehicle and fuel type from Pre Euro to Euro III norms

${}^{PE}S_{j}^{E-III}$ = Savings in health cost per litre of MS / HSD of jth vehicle type due to upgradation of fuel and engine to Euro III from Pre Euro norms.

L_j = Average distance traveled by jth vehicle type in kilometers per day.

N_j = Total number of vehicles of jth type registered in a city.

D_j = Total distance traveled by all vehicles of jth type in a day.

C_j = Total consumption of MS / HSD of jth vehicle type in a day.

R_j = Share of MS / HSD consumed by jth vehicle type per litre

${}^{PE}\hat{S}^{E-III}$ = Total Savings in health cost per litre of MS / HSD due to upgradation from pre Euro to Euro III norms

The Model

$$\varepsilon_{ij}^{PE} = F_j.E_{ij}^{PE} \quad (1)$$

$$\varepsilon_{ij}^{E-III} = F_j.E_{ij}^{E-III} \quad (2)$$

$${}^{PE}M_{ij}^{E-III} = \varepsilon_{ij}^{PE} - \varepsilon_{ij}^{E-III} \quad (3)$$

$${}^{PE}S_j^{E-III} = \sum_i h_i.{}^{PE}M_{ij}^{E-III} \quad (4)$$

$$D_j = L_j.N_j \quad (5)$$

$$C_j = \frac{D_j}{F_j} \quad (6)$$

$$R_j = \frac{C_j}{\sum_j C_j} \quad (7)$$

$${}^{PE}\hat{S}^{E-III} = \sum_j {}^{PE}S^{E-III}.R_j \quad (8)$$

Results of the model:

The results of the benefit analysis per liter of upgraded MS / HSD in 35 urban agglomerated are stated below. The results include savings in health cost from both low cost and high cost scenario of health damage calculation. The estimates of fuel consumption and vehicle-wise savings on health cost are stated in Annexure Tables 4.1 to 4.10.

Table 4.1

Savings in Health cost per Liter of MS/HSD

(Low Cost Estimate)		*Rs/L*
Cities	**MS**	**HSD**
Agra	0.96	0.06
Ahmedabad	2.12	0.18
Allahabad	1.37	0.07
Amritsar	1.80	0.12
Asansol	0.13	0.03
Bangalore	1.40	0.14
Bhopal	0.58	0.04
Chennai	1.18	0.12
Coimbatore	0.73	0.05
Delhi	3.02	0.46
Dhanbad	0.24	0.02
Faridabad	0.79	0.08
Hyderabad	3.28	0.25
Indore	1.25	0.07
Jabalpur	0.74	0.04
Jaipur	1.41	0.08
Jamshedpur	0.30	0.03
Kanpur	0.87	0.05
Kochi	0.48	0.04
Kolkata	0.71	0.14
Lucknow	0.59	0.04
Ludhiana	2.18	0.13
Madurai	1.70	0.11
Meerut	0.73	0.04
Mumbai	1.57	0.24
Nagpur	2.20	0.13
Nasik	0.65	0.06
Patna	0.66	0.05
Pune	1.55	0.14
Rajkot	1.95	0.11
Surat	4.30	0.30
Vadodara	1.18	0.10
Varanasi	1.05	0.06
Vijayawada	1.59	0.10
Vishakhapatnam	0.90	0.06
Total	1.32	0.11

Table 4.2

Savings in Health cost per Liter of MS/HSD

(High Cost Estimate) Rs/l

Cities	MS	HSD
Agra	3.91	2.59
Ahmedabad	10.98	7.94
Allahabad	5.20	2.76
Amritsar	7.67	4.67
Asansol	1.44	1.43
Bangalore	7.14	5.87
Bhopal	2.45	1.41
Chennai	6.13	4.88
Coimbatore	3.34	2.23
Delhi	19.46	18.91
Dhanbad	1.13	0.75
Faridabad	4.66	3.18
Hyderabad	15.14	10.16
Indore	4.76	1.66
Jabalpur	2.57	1.49
Jaipur	5.72	2.93
Jamshedpur	1.57	1.20
Kanpur	3.55	2.15
Kochi	2.72	1.78
Kolkata	5.38	5.77
Lucknow	2.60	1.63
Ludhiana	9.25	4.14
Madurai	7.26	4.79
Meerut	2.78	1.77
Mumbai	13.78	10.17
Nagpur	9.00	5.33
Nasik	3.30	2.55
Patna	3.07	1.70
Pune	7.78	6.06
Rajkot	7.65	4.85
Surat	20.31	12.62
Vadodara	6.18	4.42
Varanasi	4.01	2.54
Vijayawada	6.91	4.34
Vishakhapatnam	3.88	2.44
Total	6.36	4.37

Some observations may be made by comparing the cost and benefit from a liter of upgraded fuel:

(a) The benefit (ie savings in health cost) from a liter of upgraded motor spirit exceeds the average cost of upgradation for 12 urban agglomerates by the low cost estimate.

(b) The benefit from a liter of HSD is lower than the average cost of upgradation for all urban agglomerates by the low cost estimate with a single exception of Delhi whose benefit exceeds the cost of upgradation of HSD in Panipat refinery.

(c) The benefit from a liter of upgraded motor spirit exceeds the average cost of upgradation for all but two urban agglomerates by the high cost estimate

(d) The benefit from a liter of upgraded HSD exceeds the average cost of upgradation for all but one urban agglomerates by the high cost estimate.

(e) The benefit from upgraded MS / HSD is higher for some urban agglomerates with high population density and vehicular density in comparison to its area, these agglomerates may not be metropolitan cities or state capitals. On the other hand some state capitals or even metropolitan cities have much less benefit in terms of savings in health cost from a liter of MS / HSD. This aspect urges rethinking on the policy of introducing upgraded MS / HSD in the metropolitan cities and state capitals earlier than the rest of the cities.

Chapter V

Engine Design and Fuel Quality

In order to realize the full benefit of upgrading fuel type engine design also need to be upgraded concomitantly. Outdated engine design causes a wash out of a portion of the benefit of upgraded fuel. The fuel injection system in older vintages of engine design like that of pre Euro is not capable of burning the fuel efficiently, thus increasing the load of pollutant emission. In this chapter the attempt is to quantify the loss of benefit due to older vintages of engine design and upgraded fuel quality. In the exercise below the loss in benefit due to use of fuel quality of Euro III variety in Engine design of pre Euro vintage rather than Euro III vintage of vehicles has been quantified. There is also a detailed discussion on some important technical aspects of engine design and fuel quality in the Appendix.

The Model

Variables

a_{ij} - Annual load emission of the ith type of pollutant from the jth vehicle type with pre Euro vintage and pre Euro fuel quality.

b_{ij} - Annual load emission of the ith type of pollutant from the jth vehicle type with pre Euro vintage and Euro III fuel quality

c_{ij} - Annual load emission of the ith type of pollutant from the jth vehicle with Euro III vintage and Euro III fuel quality.

α_{ij} - Proportion of benefit loss in reduction of ith pollutant due to use of Euro III fuel type in pre Euro vintage of jth vehicle instead of Euro III vintage.

P_{ij}^{PE} - Pollution load of ith type of pollutant from the entire population of jth type of vehicles with pre Euro vintage of engine design and pre Euro fuel quality

P_{ij}^{E-III} - Pollution load of ith type of pollutant from the entire population of jth type of vehicles with pre Euro vintage of engine design and Euro III fuel quality

f_{ij} - Amount of forgone benefit in terms of annual pollution load of ith type of pollutant from jth type of vehicle using fuel quality of Euro III variety in pre

Euro vintage of engine design instead of Euro II

h_i - Health cost per kg of i th pollutant

Proportion of forgone benefit in terms of reduction in the ith pollutant due to use of fuel quality of Euro III type in pre Euro vintage of engine design of jth type of vehicle instead of Euro III vintage of engine design.

$$\alpha_{ij} = 1 - \frac{a_{ij} - b_{ij}}{a_{ij} - c_{ij}} \quad (1)$$

Amount of forgone benefit in terms of annual pollution load of ith type of pollutant from jth type of vehicle using fuel quality of Euro III variety in pre Euro vintage of engine design instead of Euro III

$$f_{ij} = \alpha_{ij}\left(P_{ij}^{PE} - P_{ij}^{E-III}\right) \quad (2)$$

Total amount of ith pollutant will be given by

$$F_i = \sum_j f_{ij} \quad (3)$$

Health benefit forgone from annual pollution load of ith type of pollutant use of fuel quality of Euro III variety in pre Euro vintage of engine design instead of Euro II is given by

$$H = \sum_i F_i h_i \quad (4)$$

Estimation of the Model

The estimation of the above model, specially the value of α_{ij}, poses great challenge due to lack of data. The reason for this is the fact that the upgraded vintages are yet to be on the road. The α_{ij} model has therefore been estimated with secondary data published by CPCB, New Delhi in the report titled "Transport fuel quality for year 2005". This data is on pollution load for the city of Delhi with different combination of vintages of engine and fuel quality. It has been assumed that vintage and fuel quality of the year 2000 comply with pre Euro standards while that of 2005 comply with Euro III standards. This assumption will have an impact on the value of α_{ij} but that will be marginal. The α_{ij} will be an underestimate and the result will give the lower bound of benefit forgone.

Results of the model

The annual health benefit forgone is presented in Annexure Tables 5.1 and 5.2 for low cost estimate and high cost estimate respectively. In the table below the percent of health cost savings forgone due to use of older pre Euro vintage of engine instead of Euro III vintage has been presented.

A close look at the above table reveals that a large portion of the benefit of upgrading fuel quality is lost if engine design is not upgraded simultaneously. Both engine design and fuel quality has to be upgraded to extract the full benefit of lower emission of pollutants due to superior technology.

Table 5.1
Benefit Loss
(In Percent)

Urban Agglomerates	Low Cost Estimate	High Cost Estimate
Agra	91.14	91.12
Ahmedabad	86.52	86.70
Allahabad	94.36	94.67
Amritsar	91.13	91.37
Asansol	39.46	38.98
Bangalore	90.35	90.62
Bhopal	90.31	90.59
Chennai	91.67	91.99
Coimbatore	85.01	85.10
Delhi	87.28	87.43
Dhanbad	84.62	84.69
Faridabad	84.67	84.92
Hyderabad	88.27	88.49
Indore	93.84	94.17
Jabalpur	94.47	94.77
Jaipur	93.80	94.13
Jamshedpur	81.80	81.74
Kanpur	90.85	91.03
Kochi	87.22	87.55
Kolkata	69.56	69.27
Lucknow	91.81	92.07
Ludhiana	93.58	93.92
Madurai	89.09	89.27
Meerut	90.93	91.10
Mumbai	79.73	80.13
Nagpur	92.30	92.60
Nasik	91.25	91.64
Patna	91.68	92.02
Pune	86.59	86.77
Rajkot	91.99	92.23
Surat	92.81	93.22
Vadodara	92.11	92.57
Varanasi	94.16	94.46
Vijayawada	86.46	86.59
Vishakhapatnam	92.18	92.52
Total	87.83	88.06

Chapter VI

Cost Sharing of Upgraded Petroleum Products

The environmental upgradation of the public sector refineries in India has become imperative because of the dictate of the regulatory authority of the country. This upgradation is also supported by the findings of the previous chapter for 58.08 percent of uses of Motor spirit in urban India. Out of the 35 urban agglomerate the upgradation is justified for 12 of them according to the present status of population density and vehicular pollution load by the low cost estimate. It is possible that the indigenous private sector refineries or international sources of supply may provide MS and HSD of the required quality without involving any additional cost for the change in the stipulation of the environmental standard of petroleum products. Given that the market price of MS and HSD in India are import parity linked after the dismantling of the APM regime, the public sector refineries like those of IOC will find it difficult to cover their cost of upgradation with competition from other sources such as private refineries or imports. The competitors will not require any change in the price to absorb additional cost.

In order to ensure the supply of upgraded oil at competitive prices, one may argue that it is only those public sector refineries which can cover the cost of upgradation of MS and HSD at the ruling price that should operate and remain in business while others should be closed down or sold off by way of privatization so that the new buyers of the loss making refineries can introduce necessary business, financial and technological restructuring to make them competitive.

This solution of meeting the changed cost situation on account of upgradation has certain serious difficulties. First of all, India cannot rely heavily on product imports replacing crude imports for two reasons: a) the limited port handling capacity of oil in the form of products and, b) strategic reasons of security. There can also arise a problem of India facing rising price of MS and HSD if it has to buy a large part of its requirement from the international market where it no longer remains a small buyer without influencing prices. It is thus imperative that the indigenous refining industry is capable of meeting the petroleum product requirements by and large from domestic refinery sources.

So far as the public sector refining industry is concerned there may be three kinds of situations with reference to decisions regarding investment cum fiscal support for prices in the short or medium run.

(a) Some of the efficient public sector refineries can absorb the upgradation cost, remain competitive and earn normal profit at the ruling market prices of MS and HSD.

(b) A second category of refineries that cannot absorb the upgradation cost at the ruling market price, and remain competitive, but that have the potential of attracting a reasonable price if they are privatized after upgradation. The company may be able to make capital gains. This may be possible if the losses after modernization is not too high for the concerned refineries and these offer opportunities to private entrepreneurs to convert them into profitable units through appropriate business, financial and managerial restructuring.

(c) A third category of refineries which have outmoded technology, the vintage is such that it neither can absorb the MS and HSD upgradation cost at the ruling market price, nor offers any future potential of economic viability through restructuring of ownership and management.

While the refineries of category (c) should not be upgraded as they deserve closure, the refineries which qualify conditions of (a) and (b) need surely to be upgraded for higher quality of MS and HSD. For such public sector refineries we need to ensure financial and economic viability at least in the short and medium run. While for refineries in the first category there should be no problems of cost absorption and competitiveness, it is for the refineries under second category that it becomes economically justifiable to find ways of providing support through fiscal adjustment for a limited period.

Selective support to any particular segment of the refining industry through tax incentives would introduce distortions and inefficiencies in resource allocation. Thus any price benefit through fiscal support has to be extended to the entire refining industry and other suppliers of the concerned petroleum products. We submit below some options for providing such support to the industry without violating the basic tenets of market orientation established with the decontrol of prices. It should also be emphasized here that the suggestion made below for financing the incremental cost of upgradation of the public sector refining industry are only for a limited period. It provides the industry with some time for adapting itself to a new regime of technological and managerial dynamics that incorporates environmental concern as an endogenous element of the decision making system.

The average marginal cost as obtained for MS and HSD for the IOC refineries may be considered as the incremental support to be given to any seller of these products irrespective of their private or public ownership, indigenous or import sources, for every unit of such supply. The benchmarking with respect to IOC refineries is justified on the ground that a substantial proportion of petroleum products are produced by the IOC. Rendering such a large proportion of refining capacity uneconomical would entail a huge cost that would fall on the public exchequer in any case because of the nature of public ownership of IOC. The support can take either of these forms:

(1) Increasing basic customs duty on MS and HSD by the amount of the incremental average cost of upgradation. As the refinery-gate price of the products can be expected to be import parity linked, domestic prices will adjust upwards and all sellers of these products will be able to realize this additional value. While this incremental price will help the potentially viable public sector refineries to absorb the additional cost, it will give an opportunity to all the suppliers from more efficient sources of earning a rent. The rent thus earned will be an unintended consequence of this option, but will absolve the policy measure from the charge of preferential treatment to public sector units and damaging the private sector by not providing a level playing field.
(2) Without imposing any additional customs duty, imposing an environmental cess on every unit of sale of MS or HSD. The proceed can be transferred to all suppliers of such upgraded product in the country, irrespective of their public or private ownership sector or indigenous and import sources, for every unit of such supply.
(3) Statutorily transferring a part of the current OIDB cess to cover the incremental value of environmental upgradation of the entire improved supply of MS and HSD at the rate of the incremental cost estimates. If any firm already has an improved quality of supply from a modern plant, it should also get this transfer, with additional profit

accruing as a reward for their contribution to environmental resource conservation. If the resource generated by the OIDB cess at the current rate cannot be released for this purpose, one option is to revise the payment to the industry, which is really a compensation to the industry for better level of environmental services. In this latter case, the rate increase should be calibrated to ensure that the additional resource equals the transfer made for environmental upgradation.. While the OIDB cess is on crude oil these transfers will have to be made as per the sale of upgraded MS and HSD, this would amount to a refund to the refineries for their part of the payment of OIDB cess on crude oil use. In this case however it will not be possible for the seller of MS and HSD from import sources to benefit from such transfer.

(4) Any appropriate combination of (1) and (2) or (1) and (3) can be thought of as a way of sharing and compensating of the cost of environmental upgradation. This would mean that part of the value of improved MS and HSD which is to be transferred to sellers of oil will be obtained from higher import parity linked prices due to marginal rise in the customs duty (i.e. a fraction of incremental upgradation cost per unit of the product) and the balance may be covered from environmental cess on the same product or from a transfer from the existing OIDB cess on crude oil.

The following points may be added which would elaborate some of the implications of the above policy suggestions;

(1) The change in customs duty is not likely to have major impact on government revenue since the import of these two products are not significant. India imports the deficit of oil by import of crude oil and not products. The customs duty adjustment to the market price will get appropriately adjusted to cover environmental cost in the price that is paid by the consumer on the one hand and for the refineries to be able to include in its net realization price.

(2) The imposition of an environmental cess on MS and HSD and its transfer to the seller of these products also makes the consumer pay for the higher quality and enables the seller of upgraded product to either cover costs of upgradation or benefit for supplying better product.

(3) Utilization of the existing OIDB cess to meet the additional cost of upgrading refineries to supply the improved quality of oil would mean the appropriate utilization of a fund which was after all meant for the development of oil industry and not for meeting the revenue expenditure commitment of the government.

Concluding Remarks:

It is obvious that there are three groups of stakeholders who are involved in the process (i) the suppliers of refined oil (ii) the people as consumers of oil and of the "public bad" called automotive pollution and (iii) the State. Our above recommendations imply the sharing of the costs mainly by the consumers in the form of higher prices and/or by the State by way of sacrificing a share of the OIDB cess, if required. In view of the problem of market failure in the arena of environmental externality, the State has to intervene as a regulator of environmental standard for pollution decreasing activity, including oil refining. As the consumers are the beneficiaries of environmental upgradation, they need to pay for the improved environmental quality, at least in principle. One may, however, argue that the real beneficiary of improved oil is not the user of oil alone but the population exposed to pollution caused by automobiles. As it is difficult to impose a charge for better air quality on citizens at large and transfer the amount to the refining industry and as the user of oil is quite large in number and extensive, the population of user of oil is taken as a proxy for the population of beneficiary of environmental upgradation. The incidence of cost of upgradation on the users of automotive fuel would depend on to what extent, if at all, the government as a stakeholder is willing to share in the responsibility of providing better environmental service. Since environmental good has become an economic good, the problem of sharing the incremental cost among the stakeholders cannot be ignored at least in the short and medium run. Loading all the cost on oil suppliers and asking them to absorb the cost through erosion of profit in tight time frame may lead to a lot of bankruptcy, waste of installed refinery capacity, and devolvement of cost to the public sector through its ownership of these refineries. If resource allocation problem encompasses the multi dimensionality including provision of environmental service of life support through proper air quality which has no explicit market, the principle of environmental economics would warrant such policy suggestion as made above.

Epilogue:

In this chapter, the sharing of cost of refinery upgradation has been recommended keeping in mind the strategic importance of the oil sector and their nature of ownership, as well as the regimes under which these refineries have operated. The support recommended to the refineries of all vintages is identical to ensure a level playing field as well as promotion of efficiency. It may be noted that given the introduction of market determined policy in this sector, the efficient refineries with the proposed support would be earning rent and could cut prices to drive out the inefficient refineries. This is a usual phenomenon in a competitive market. However, the high cost refineries in the public sector under the proposed dispensation would get a breathing space to quickly adjust their operation and become competitive.

For achieving higher well being of the urban population through cleaner air and better health condition, higher quality of oil is only one of the many determining factors even within the domain of urban transportation. The effectiveness of cleaner fuel would depend on a number of complementary factors like road condition, traffic congestion, vintage of vehicles with appropriate engine design specifications and proper maintenance of vehicles, among others. The benefit of upgradation will be higher only if the complementary conditions are satisfied. The sharing of the substantive cost of refinery upgradation would appear to be highly justified if investments can be encouraged not only for upgradation but also for meeting the conditions of complementarity.

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Appendix

Fuel Quality and Engine Design

Fuel quality and engine technology are intimately related, in that certain features must be incorporated into the engine design for optimal use of an advanced fuel and vice-versa. The Euro fuel norms are in terms of upper limits on the content of sulphur, benzene, aromatics and olefins and lower limit on octane number (RON or Research Octane Number) of MS and cetane number of HSD. The relevant components of the fuels and their effect on the level of emission of different pollutants and on fuel economy is as follows:

Motor Spirit

Sulphur : The effect of reduction in sulphur content on different emissions for given engine technologies is given below:

Effect of Sulphur Reduction on Emissions

			Sulphur Range (ppm)		Reduction in emissions (%)		
	Study	Vehicle technology	High	Low	HC	CO	NOX
U.S.	AQIRP	Tier 0	450	50	18	19	8
Europe	EPEFE	Euro 2+	382	18	9	9	10

AQIRP : Air Quality Improvement and Research Programme

EPEFE : European Program on Emissions, Fuels and Engine Technologies

Sulphur adversely affects the efficiency of catalyst used in after treatment devices by temporarily 'poisoning' it. It also adversely affects heated exhaust gas oxygen sensors. Both catalyst and oxygen sensors are features in Euro I onwards engine design requirement.

Octane number : Octane number denotes the ability of the fuel to resist auto-ignition (knocking) which can cause engine damage. The measures used are called RON (Research Octane Number), MON (Motor Octane Number) and AKI (Anti-knock Index) which is the average of the two. RON does not directly affect emissions but a higher octane number fuel allows the use of higher compression ratio engine technology leading to better fuel economy which is the most important way of meeting emission norms.

Lead : Lead was used as an additive to increase the octane number of petrol. Engine technology using catalytic converters and oxygen sensors necessitates the use of unleaded petrol. Tolerance to lead contamination is very low as the vehicle catalyst efficiencies are increased and even slight lead contamination can destroy a modern catalyst. Hence the mandatory availability of unleaded petrol all over the country has been enforced.

Aromatics : In order to meet octane specificatons, unleaded gasoline normally contains 30 to 50 percent aromatic hydrocarbons. Aromatics, due to their slightly higher flame temperature are thought to contribute to NOX emissions. However, tests conducted by EOEFE show that over the full European driving cycle reducing aromatic content reduced HC and CO emissions but increased NOX. The presence of heavy aromatics in petrol leads to engine deposit formation particularly in combustion chamber which in turn leads to increased emissions of hydrocarbons and oxides of nitrogen.

In the case of 2-Stroke engines, a relatively high percentage of gasoline escapes unburned into the atmosphere. This calls for a reduction in harmful components like lead and benzene in gasoline. High gum content and low octane number of gasoline leads to increased engine deposits which alter the air-fuel ratio to less than optimal and lead to increased emission of hydrocarbon and particulate matter (which includes oil droplets). In India, as in most countries, there is a minimum level for the RON of gasoline.

Another related issue is that of lubricants for 2-Stroke vehicles. The presence of extensive oil films in the combustion chamber is one factor in HC emissions. The correct amount and type of 2T has to be mixed in gasoline, otherwise emissions increase. Many drivers use excessive quantities and wrong types of lubricant. The sale of premixed gasoline i.e. gasoline in which lubricant is already mixed, encourages the use of not only suitable quality but also correct amount of 2T oil. Low smoke lubricant gives a lower amount of visible smoke. However it is not clear whether this translates to less particulate matter emission or not.

Diesel

For diesel the Euro norms are in terms of lower limit on cetane number and upper limits on sulphur, benzene, polyaromatics and olefins.

Sulphur : The European Auto Oil Programme predicted a reduction of particulate matter emission of 7% in light and 4% in heavy vehicles if sulphur content in diesel is reduced from 500 ppm to 30 ppm. Particulate matter emission due to sulphur is a result of the formation of sulphates in exhaust as well as in the atmosphere later. Although sulphates are not the major component in particulate matter, those being carbon and hydrocarbons, the use of exhaust catalysts raises its percentage in particulate matter emissions. Sulphur also adversely affects exhaust after-treatment systems.

Cetane Number : Cetane number measures the readiness of a diesel fuel to ignite spontaneously under the temperature and pressure conditions in the combustion chamber. The higher the cetane number, the shorter the delay between injection ad ignition and the better the ignition quality. Higher cetane number leads to less "white smoke" emission upto a cetane number of 50 but not beyond. The two major emissions from diesel engines, namely oxides of nitrogen and particulate matter, increase with a decrease in cetane number. However, there is some tradeoff between cetane number and emission benefits. Beyond a certain level, emission benefits do not materialize with increase in cetane number.

Poly-Aromatics : Aromatic content in diesel can increase engine deposits and lead to increased tailpipe emissions like particulate matter and hydrocarbons (of the variety called polyaromatic hydrocarbons or PAH). The PAH content also contributes significantly to soot formation. The effect of reduction of polyaromatic content in diesel from 9% to 1% reduces particulate matter emission by 6.5% for light and 4.2% for heavy vehicles respectively, according to a study conducted by EPEFE.

Distillation temperature: The heavy end of the distillation curve of diesel is the most important (known as T95 i.e. temperature at which 95% of the fuel evaporates). Too much fuel in the heavy end results in coking and increased emission of soot and particulate matter. A study conducted by EPEFE found that exhaust gas emission from heavy diesel vehicles were not significantly influenced by varying T95 with some tendency for lower oxides of nitrogen and higher hydrocarbons. The same variation in light vehicles however, resulted in a 7% reduction in particulate matter and 4.6% *increase* in oxides of nitrogen.

The results of an EPEFE study gives the changes in emissions of CO, HC, NOX and PM with changes in the fuel characteristics mentioned above, for heavy duty diesel vehicles.

Change in Heavy-Duty Diesel Vehicle Emissions with Variations in Diesel Fuel Properties

Diesel Fuel Property	CO	HC	NOX	PM
Sulphur				
2000 to 500 ppm				-13.0
Cetane				
50 to 58	-10.26	-6.25	-0.57	0
Polyaromatics				
8 to 1 percent	0	-4.02	-1.66	-3.58
T95				
370 to 325 degrees C	+6.54	+13.22	-1.75	0

-No value means not applicable
-Positive values indicate *increase* in emissions
-0 means not significant

The first step for achieving vehicle emission norms for vehicles is to achieve highest possible fuel efficiency and to that extent to reduce the pollution load by combusting less fuel. Engines that burn gasoline or diesel fuel propels almost all passenger cars and light-duty trucks. About two-thirds of the available energy in the fuel is rejected as energy in the exhaust and heat to the coolant and frictional losses. The remainder is transformed into mechanical energy or "work". Some of the work is used to overcome frictional losses in the transmission and other parts of the driveline and to operate the vehicle accessories (airconditioner, alternator etc.). In addition standby losses occur just to overcome engine friction and cooing when the engine is idling or the vehicle is decelerating. As a result only about 12 to 20 percent of the original energy contained in the fuel is actually used to propel the vehicle. This propulsion energy overcomes (1) inertia (weight) when accelerating or climbing hills; (2) the resistance of the air to vehicle motion (aerodynamic drag); and (3) the rolling resistance of the tires on the road.

Consequently, reduction in fuel consumption in a vehicle can, in general be achieved in two ways : increase in the overall efficiency of the power train (engine, transmission, power drive) in order to deliver more work from the fuel consumed, and reduction in the required work (weight, aerodynamics, rolling resistance, accessory load) to propel the vehicle. We are concerned here only with changes in *engine* design to increase the efficiency of the *power output*.

Moreover, high fuel economy is only one of many attributes that may be desirable to buyers of vehicles. Vehicle performance, handling, safety, comfort, reliability, passenger and load carrying capacity, size, styling, quietness and costs are also important. Manufacturers must, therefore assess trade-offs among these sometimes-conflicting characteristics to produce vehicles that consumers find comfortable and appealing.

The technology options available for meeting the various Euro norms for a given fuel quality are as follows:

Petrol engines

Euro I :

- Better designed combustion ports and chamber
- Multi point fuel injection with knock sensed ignition control and electronic engine management
- 2/3 way catalytic converters
- Air-fuel control by sensing of exhaust oxygen

Euro II : in addition to the above,

- Exhaust gas recirculation
- 3 way catalyst (heated in some cases)

Euro III : in addition to the above,

- closed loop catalyst with air- fuel ratio control
- on-board diagnostics

Euro IV :

- Heated and more advanced catalyst
- Exhaust trap
- Oxides of nitrogen adsorbers
- Variable valve timing and variable compression ratio

The advantages of these technologies are as follows:

(a) Tail pipe emissions are mainly due to the incomplete combustion of air-fuel mixture, the most important reasons for which are the cool metal surfaces of the combustion chamber (called quenching effect) and imperfect air-fuel mixture ratio. The ratio of air to fuel in the combustible mixture is a key design parameter for spark-ignition engines. An air-fuel mixture that has exactly enough air to burn the fuel, with neither left over, is 'stoichiometric'. Mixtures with more air are 'lean' and those with more fuel are 'rich'.

(b) The quenching effect is responsible for most of hydrocarbon (HC) emissions and better design of combustion chamber and ports would reduce the area of cool metal surface and consequently, HC emissions. Another reason for incomplete combustion of hydrocarbons in the fuel is the trapping of fuel in the interstices between piston, rings, cylinder walls etc. and these 'crevices' can also be minimized by better design

(c) Multi point fuel injection to completely replace carburetors, has many advantages due to its flexibility and possibilities for precision control of fuel. The purpose of the carburetor is to supply and meter the mixture of fuel vapour and air in relation to the load and speed of the engine. In multi point fuel injection, the fuel spray is in several small streams instead of one large stream, so there is less opportunity for it to condense or drop out of the airflow. Therefore it is more precise and efficient in combusting. Sequential multi-point fuel injection and air-assisted fuel injectors achieve better 'timing' of fuel injection and are the technologies of the future.

(d) A knock-sensor is an acoustic sensor, which listens for pre-ignition (or knocking). Knock sensing enables the engine to run at the threshold of knock due to various reasons and achieve optimal efficiency.

(e) Electronic engine management achieves more precise control of air-fuel ratio at all operating modes such as acceleration, deceleration (fuel cut-off), idling, altitude, high and low temperature. It enables accurate regulation of fuel supply to the cylinders by sensing various engine parameters. Electronic engine management system consists of a self contained custom built computer and various sensors for sensing rpm, air mass and temperature for optimal control.

(f) The most important factors governing oxides of nitrogen (NOX) emissions are the fuel-air ratio, fraction of burnt gases within the unburnt mixture in the cylinder, and the ignition timing. Carbon monoxide (CO) is the product of incomplete combustion due to insufficient amount of air in the air-fuel mix or insufficient time in the cycle for completion of combustion. Thus, means to reduce CO emissions consist mainly in improving the uniformity of the composition of air-fuel mixture and making the mixture leaner. Since petrol engines run on a richer mixture than diesel engines (being spark ignition while diesel engines are compression ignition), they produce, in general, more carbon monoxide. The factors behind CO and NOX, therefore are controlled by all the features mentioned above.

(g) Oxygen sensor monitors the oxygen content in the exhaust and provides this information to Electronic Control to make necessary correction in the air-fuel mixture to obtain maximum conversion of pollutant in the catalytic converter.

(h) Catalytic converters are the backbone of all the pollution control technologies in petrol and diesel engines. There are two types of catalytic converters, 2-way or oxidation catalyst and 3-way. 2-way only controls carbon monoxide (CO) and hydrocarbons (HC) and it works by transforming these into harmless compounds by oxidizing them. 3-way catalytic converter can remove three of the major pollutants CO, HC and NOX (oxides of nitrogen).

(i) NOX emissions are influenced by highest local peak temperature. Exhaust gas recirculation (EGR) is one of the most effective means of reducing NOX emissions. By recirculating spent exhaust gases into the combustion chamber, the air-fuel mixture is diluted (i.e., has a lower concentration of oxygen than fresh air mixture), lowering peak combustion temperatures and lowering propensity of oxygen to oxidize N_2 to NO and NO to NO_2 thus reducing NOX. Cooled EGR also reduces soot/particulate matter.

(j) A four valve system is to replace the 2-valve system along with improved design of combustion chamber. Conventional engines have two valves per cylinder, one for intake of the air-fuel mixture and one for exhaust of the combustion products. By doubling the number of intake and exhaust valves, pumping losses are reduced, improving the volumetric efficiency and useful power output.

(k) Sensing of air-fuel ratio in the exhaust helps precise control of the volume required for catalytic converter's efficient functioning as well as air-fuel control in lean-burn system.

(l) On board diagnostics helps to warn the user of malfunctioning of the system and its components, thus shortening the time between when a malfunction occurs and when necessary repairs are performed.

(m) Variable valve timing helps in improving fuel efficiency and consequently reducing carbon monoxide, and to some extent oxides of nitrogen emission. In conventional engines the duration and lift (distance the valve head is pushed away from its seat) of valve openings is constant regardless of engine speed, that is, fixed valve timing and lift. Typically the valve timing is set at a level that is a compromise between low speed torque and high engine speed horsepower. Variable valve timing can enhance both with no necessary compromise between the two. Variable valve lift systems are also available in advanced vehicles.

(n) The compression ratio of conventional gasoline engines is limited to between 9:1 and 11:1 by their octane requirement at high load. However, maximum thermal efficiency and therefore fuel economy is obtained in the range of 13:1 to 14:1. An engine with variable compression ratio has the potential to be optimised with a high ratio for best fuel economy at the part load conditions typical of normal driving, while allowing detonation-free full load operation at a lower ratio.

(o) Some other features available are turbo-charged and turbo-charged after cooled engines and turbo compounded engines, which are 18% better than conventional ones.

(p) Another option is positive crankcase ventilation valves which prevent blow-by gases from escaping into the atmosphere and recycles them to intake air system. Since it is a low cost feature, all cars manufactured after 1996 have this feature.

(q) Also, evaporative emission control which uses activated charcoal to adsorb fuel vapours from the fuel tank and purges them into the engine when it operates.

Diesel engines

Euro I:

- Optimised design for combustion chambers, fuel ports and fuel spray mixing system and good tuning
- Turbo charging with or without intercooling
- Moderate to high fuel injection pressure (600-800 bars)

Euro II : in addition to the first feature above,

- Turbo charging with intercooling
- High fuel injection pressure (800-1000 bars)
- Valve closing nozzle or oxidation catalyst
- In some cases exhaust gas recirculation

Euro III :

- Turbo charging with intercooling
- Four valve cylinder system
- Closed loop cooled exhaust gas recirculation
- Very high injection pressure (1000-1200 bars)
- High pressure common rail fuel injection with electronic control
- Oxidation catalyst for light vehicles
- Regenerative particulate trap in some cases

- Euro IV : in addition to the above,
- Particulate traps
- Oxides of nitrogen adsorbers and de-NOX catalyst
- Catalyst and scrubbing system and water injection

The advantages of these technologies are as follows:

(a) Optimized through careful design of combustion system like chamber, ports etc. and matching fuel spray distribution. The quenching effect and trapping of fuel in crevices, as mentioned in the case of petrol engines holds equally for diesel engines. A uniform distribution of fuel in the chamber is attainable with centralized vertical injectors. Four valve/cylinder configuration facilitates the centralized vertical injectors.

(b) The most fundamental difference in combustion chamber design in diesel engines is between Direct Injection (DI) and Indirect Injection (IDI) designs. In an IDI engine, fuel is injected into a separate pre-chamber where it mixes and partly burns before jetting into the main combustion chamber. In a DI engine, fuel is injected directly into a single combustion chamber. Due to the disadvantages of extra heat and frictional losses owing to the prechamber, DI engines are much more common among heavy duty diesel vehicles and there is an increasing trend towards them among light duty vehicles as well.

(c) Turbo charging with intercooling offers a great advantage in reducing emissions and can be retrofitted in old vehicles as well, which will provide significant reduction in particulate matter emission. Some authorities believe it is essential in the present context.

(d) A turbocharger consists of a centrifugal air compressor mounted on the same shaft as an exhaust gas turbine. By increasing the mass of air in the cylinder prior to compression, turbocharging correspondingly increases the amount of fuel that can be burned without excessive smoke and thus increases the potential maximum power output and fuel efficiency. The process of compressing the air, however, increases its temperature, increasing the thermal load on critical engine components. By cooling the compressed air in an intercooler before it enters the cylinder, the adverse thermal effects can be reduced. Turbocharging and intercooling offers an inexpensive means to simultaneously increase power, fuel economy and reduce NOX and PM emissions.

(e) A fuel injection system is the machinery by which the fuel is transferred from the fuel tank to the engine, then injected into the cylinders at the right time for optimal combustion and in the correct amount to provide the desired power output. The major areas of concentration in fuel injection system development have been on increased injection pressure, increasingly flexible control of ignition timing and more precise control of the fuel quantity injected. Higher the injection pressure more will be the atomization and dispersion of air-fuel mixture. This will improve the combustion quality and hence fuel efficiency and emissions.

(f) Although diesel engines have inherently lower emission of CO (due to leaner burning), NOX and PM are the two biggest emission related challenges for them. There is a trade-off between NOX and PM control measures in diesel vehicles. The trade-off is not absolute i.e. both can be reduced simultaneously. However, there are limits on the extent to which either can be reduced without increasing the other.

(g) Among the recent technological advancements in the fuel injection systems of diesel vehicles, high pressure common rail system offers large reductions in PM and NOX emissions. A hydraulic pump in a common rail mounted to the engine block generates high fuel injection pressure even at low engine speeds. The common rail feature enables higher rate of exhaust gas recirculation.

(h) Electronic control, though not mentioned in the options above, is more required in fuel injection system and is yet to come to India and both these have not been adopted by domestic vehicle manufacturers due to very high import duty.

(i) Electronically controlled injection system provides variable injection timing, which allows more dynamic response to engine load, speed and temperature as mentioned earlier in the case of petrol engines.

(j) Four valve cylinder system improves volumetric efficiency and provides better mixing of fuel and air as explained in the case of petrol engines.

(k) In diesel engines, hydrocarbon (HC) emissions increase if the fuel-air mixture is either too lean or too rich. The major source of light-load HC emissions is excessive air-fuel mixing, which results in air-fuel mixtures that are too lean to burn. Other factors are the quenching effect and trapping of fuel in 'crevices'. The engine design features mentioned above control the air-fuel ratio in diesel engines and hence HC emissions.

(l) The factors affecting NOX emissions in diesel engines are air-fuel mixing, fuel injection and combustion timing, charge temperature and composition. The mixing-rate during the ignition delay period determines how much fuel is burned in the pre-mixed burning phase. The higher the mixing rate the greater the amount of fuel burning in the pre-mixed mode and higher the NOX emission. On the other hand, earlier injection timing tends to reduce PM and light-load HC emissions. Fuel injection and combustion timing determine the maximum temperature and pressure attained in the cylinder, increase in which tends to increase NOX emissions. The process of compressing the intake air in turbo-charged engines increases its temperature. Reducing the charge temperature of the compressed air charge going into the cylinder has benefits for both NOX and PM emissions.

(m) Exhaust gas recirculation (explained in section on petrol engines) is another way to reduce emission of oxides of nitrogen. NOX emissions are heavily dependent on flame temperature. By altering the composition of the air charge it is possible to decrease the flame temperature. The most common way of accomplishing this is through EGR. With conventional EGR upto 30% reduction in NOX in European driving cycle and upto 70% reduction at 2000 rpm/cruising and constant soot level has been achieved. With the introduction of cooled EGR further reductions are possible. However, EGR has some potential drawbacks like possibly higher PM emission, slight increase in fuel consumption and increased lube oil contamination. To get around these disadvantages, more sophisticated electronic control systems will be necessary to control the EGR.

(n) Oxidation catalysts, which are the most used catalytic converters in diesel vehicles, help in the reduction of emission of hydrocarbon, carbon monoxide and particulate matter.

(o) In general, diesel engines produce more particulate matter than do petrol engines with or without catalytic converters. Particulate traps can eliminate upto 90% of diesel particulate matter (PM) emissions and is the most effective control system available for diesel engines today. The simplest system consists of some form of trap located in the exhaust muffler and takes the full flow of the exhaust gas. After a given period of time it becomes necessary to remove the particulate from the trap, which is regeneration, and some particulate traps are continuously regenerative. Removal of the particulate from the trap is done by burning (oxidizing) it, but the temperature for that has to be reduced otherwise the particulate filter itself will melt or crack. Regeneration techniques can be divided into 'passive' and 'active'. Passive systems attain the conditions required for regeneration as a result of normal vehicle operation. Active systems monitor particulate matter in the trap and trigger specific actions to regenerate it when needed. These regenerative particulate matter traps are the most advanced technology for PM abatement.

(p) Since diesel engines operate with lean air-fuel ratios, three-way catalytic converters do not reduce the emission of NOX. Zeolite-based lean NOX catalysts that reduce NOX emissions using unburnt hydrocarbons in the exhaust are being developed. There are several kinds of De- NOX catalysts like de-NOX catalyst passive, de-

NOX catalyst active, diesel NOX absorber/storage catalyst (DNSC) and selective catalytic reduction (SCR).

(q) Water injection is applicable to heavy duty diesel vehicles and affords substantial reduction in NOX (15 to 30 percent) and PM (10 to 50 percent). It can be done by either injecting pre-mixed water-fuel emulsion or separately injecting water and fuel into the combustion chamber.

The Indian emission norms for two and three wheeled vehicles do not follow the European norms. In fact they are ahead of them, that is, more stringent. The population of two wheelers in India is very large because they are the most popular form of personal transport. Among these and among three wheelers, the proportion of two-stroke variety is very high. It is estimated that 60% of petrol consumed is by two-stroke vehicles. Two-stroke engines are widely used for motorcycles, scooters and mopeds primarily because of high specific power output, simple and compact design, better cold startability, lighter weight and lower production and maintenance cost compared to four-stroke. Four-stroke has the advantage of superior fuel efficiency. Two-stroke engines are 20% poorer in fuel efficiency and much more polluting than four-stroke, except in brake-specific oxides of nitrogen emission.

Since the technology required for upgrading two-stroke vehicles has not been developed in the west, where the single-track vehicle population is very small, it must be indigenously developed by India.

A summary of main technological routes adopted for meeting progressively stricter norms is given below.

<u>Technological evolution of two-stroke engines</u>:

1996

- Scavenging improvements through multiple and better ports, and improved exhaust

- Leaner mixture through improved carburetors
- Better combustion through higher compression ratio and better combustion chamber
- Electronic ignition

2000

- Further improvements in scavenging, and combustion
- Use of catalytic converter (oxidative type)
- Reduced 2T oil dosage

Future

- Further improvements in scavenging and combustion
- Electronic engine management
- Improved catalytic converters
- Dual catalytic converter
- Fuel injection (not yet commercialized) smokeless oils, and tighter production tolerances

The biggest contributor to the emission of particulate matter along with heavy-duty diesel vehicles is 2-Stroke two and three wheelers. Particulate matter (PM_{10} of particle size less than 10 microns) is of extra concern in South Asia including India because of already high ambient concentration and its documented adverse impact on health.

Emissions are higher in 2-Stroke engines because of the design of the engine. Gas is exchanged through ports located in the cylinder, usually opposite each other. A fresh fuel and air mixture compressed in the crankcase enters through the intake opening while exhaust gases exit through the exhaust port. While both the intake and exhaust ports are open some of the fresh fuel and air mixture escapes through the exhaust port (whereas in a four stroke engine the intake and exhaust ports are never simultaneously open). As a result of these "scavenging losses", which can amount to 15-40 percent of the unburnt fresh charge, the exhaust contains a high level of unburned fuel and lubricant i.e. HC content. The other reason for high HC emission from 2-Strokes is their tendency to misfire under low-load conditions. This happens when fresh charge fails to ignite because it is mixed with left-over exhaust. The fuel vapour then passes unburnt into the exhaust and raises the unburnt HC content.

In 2-Stroke engines, the crankcase is not used as an oil reservoir as in 4-Stroke engines. Instead, a small amount of lubricating oil is added to the fuel or introduced continuously mechanically. Because lubrication is on a once-through basis, incompletely combusted lubricant and other heavy hydrocarbons are emitted as small oil droplets. These contribute to visible smoke and PM emissions.

The goal of several technologies being tested for 2-Stroke engines is to retain the advantages of the 2-Stroke engine while gaining control over the air-to-fuel ratio and eliminating the loss of air-fuel mixture through the exhaust port.

Two-stroke engines make a strong case for fuel injection to enhance their fuel efficiency and control their hydrocarbon emission. Injecting fuel into the engine instead of introducing it through the carburetor may dramatically reduce or eliminate scavenging losses. However, due to their high speed, compact size and very limited available space, a suitable design for fuel injection presents challenges. The various options are injection directly from the cylinder head, through the cylinder bore or in the transfer port. An attractive option is in-cylinder injection of fuel-vapour air mixture in a two-stroke engine by a mechanical system. The concept design can be used to provide retro-fitted system for in-use vehicles and modified to fit in an integrated manner on new engines. Using "skip-firing" along with fuel injection to shut off fuel injection in some cycles allows sufficient time for the exhaust gases to be purged from the combustion chamber. All of these measures would require an electronic engine management system for precise control of the fuel injection timing and quantity, depending on the engine load and speed.

The catalytic converters for 2-Stroke engines mentioned above are oxidation catalysts, which reduce the level of carbon monoxide and hydrocarbons but not nitrogen oxides rather than the 3-way catalysts installed in passenger cars which also reduce nitrogen oxide emissions. However a reduction by half is typically achieved by the catalyst in 2-Stroke engines. Catalytic converters for 2-Stroke deactivate more rapidly due to higher exhaust gas temperature and therefore have to be replaced more often. In India, the Society of Automobile Manufacturers (SIAM) is offering the government a warranty of 30,000 km. for all two and three wheelers equipped with catalytic converters. This kind of durability would mean catalyst replacement at the same intervals as engine overhauling, which is satisfactory.

Several technologies are being tested to reduce emissions from 2-Stroke engines. The emissions generated by various engine technologies for 2-Stroke vehicles is given below, where HC is hydrocarbons, CO is carbon monoxide and NOX is oxides of nitrogen :

Emissions generated by various engine technologies (gm./km.)

Technology	*HC*	*CO*	*NOX*
Carburetor system	3.8	3.7	0.03
Cylinder wall injector	2.9	3.4	0.06
Semi-direct injection	0.8	0.8	0.1
Electromechanical direct Injection	0.8	0.8	0.1
Loop-scavenged two-stroke engine with air-assisted direct injection	0.5	0.4	0.05
Air-assisted cylinder head injector with skip injection and catalytic converter	0.28	0.09	0.16

The impact of technological upgradation for the increasing number of two and three wheelers has been significant as shown by a study conducted for Delhi, which makes quantitative estimates to illustrate the magnitude of pollution avoided. It is estimated that the contribution of pollutants from these vehicles in 1991 was about 200 tonnes a day. At the rate at which the population of two and three-wheelers was growing, in the absence of the upgradation, the level would have been 500 tonnes a day in 2005. The introduction of progressively cleaner vehicles will restrict this figure to 360 tonnes instead.

Annexure Tables

Table 2.1 Product Mix Without Upgradation (in MMT)							
Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*	*Digboi*	*Guwahati*
LPG	0.275	0.378	0.139	0.444	0.286	0.010	0.021
Benzene	-	0.051	-	-	-	-	-
SKO	1.096	2.430	0.359	0.730	0.640	0.028	0.099
ATF	-	0.400	0.174	0.766	0.531	-	-
LOBS	-	-	0.338	-	-	-	-
Naphtha	0.658	1.318	0.335	-	-	-	0.012
HSD	2.496	3.925	2.729	6.117	3.472	0.026	0.110
MS	0.580	0.900	0.270	0.780	0.800	0.102	-
LDO	-	-	-	-	0.060	-	0.453
FO	-	0.400	0.800	-	0.782	0.077	-
LSHS	0.101	1.750	-	-	-	-	0.017
CPC	0.043	-	-	-	-	-	-
MTBE	-	-	-	-	-	-	-
MRN	-	-	-	-	-	-	-
SRN	-	-	-	1.047	-	-	0.042
LAN	-	-	-	-	0.560	-	-
Wax	0.036	-	0.023	-	-	0.049	-
RPC	0.120	-	-	0.706	-	0.026	0.063
Microcrystalline Wax						0.011	-
Solar oil						0.002	-
Bitumen	-	-	0.350	0.150	0.500	0.019	-
Sulpher	0.025	-	0.037	0.156	0.054	-	-

Table 2.2 Product Mix With Upgradation(in MMT)

Product	*Barauni*	*Gujarat*	*Haldia*	*Panipat*	*Mathura*	*Digboi*	*Guwahati*
LPG	0.275	1.038	0.173	0.439	0.286	0.012	0.025
Benzene	-	0.051	-	-	-	-	-
SKO	1.086	2.800	0.359	0.730	0.640	0.093	0.183
ATF	-	0.400	0.198	0.766	0.530	-	-
LOBS	-	-	0.338	-	-	-	-
Naphtha	0.483	1.253	0.312	-	-	-	0.120
HSD	2.496	6.093	2.729	6.117	3.603	0.258	0.462
MS	0.704	1.240	0.293	0.888	1.018	0.112	-
LDO	-	-	-	-	0.060	-	-
FO	-	0.200	0.495	-	0.782	0.046	-
LSHS	0.084	0.887	-	-	-	-	0.0003
CPC	0.043	-	-	-	-	-	-
MTBE	-	-	-	-	-	-	-
MRN	-	-	-	-	-	-	-
SRN	-	-	-	0.801	-	-	0.042
LAN	-	-	-	-	0.337	-	-
RPC	0.120	-	-	0.706	-	0.002	0.060
Microcrystalline Wax						0.049	-
Solar oil						0.011	-
WAX	0.036	-	0.023		-	0.049	-
Bitumen	-	0.400	0.400	0.150	0.500	0.019	-
Vaccum Residue	-	0.900	-	-	-	-	-
Sulpher	0.027	-	0.047	0.156	0.055	0.001	0.002

Table 2.3
International Product Prices (cif)
(Rs/MT)

At Crude price/BL	$20	$28	$35
LPG	11,222	14,999	18,748
SKO	7,812	10,634	13,292
ATF	8,984	12,229	15,286
LOBS	12,143	17,000	21,250
Naphtha	8,429	11,189	13,986
HSD (0.5%)	9,118	12,218	15,273
HSD (0.25%)	9,222	12,373	15,467
HSD (0.05%)	9,548	13,129	16,411
MS	10,135	13,434	16,793
LDO	9,118	12,218	15,273
FO	5,318	7,366	9,207
LSHS	5,316	7,621	9,526
CPC	2,857	4,000	5,000
MTBE	10,153	11,682	14,603
MRN	9,317	12,327	15,409
SRN	8,429	11,189	13,986
LAN	8,429	11,189	13,986
RPC	1,607	2,250	2,813
WAX	21,429	30,000	37,500
Bitumen	4,857	6,800	8,500
Microcrystalline Wax		40,000	
Solar oil		30,000	
Sulpher	2,250	2,250	2,250
Benzene	18,220	18,220	18,220

Table 3.1 : Vehicular Population and Composition in 35 Major urban agglomerates as on 1st April 2002

Cities	2-wheelers	3-wheelers	Cars	Jeeps	Taxis	Buses	Trucks	L.C.V.s	All Vehicles
Agra	80466	2910	5387	1219	210	389	73	9	90663
Ahmedabad	607276	35349	92929	8188	5432	5511	10021	8783	773489
Allahabad	437262	2557	28161	6370	1100	1259	5843	707	483258
Amritsar	106429	2785	11685	4182	1106	212	3883	n.a.	130281
Asansol	2090	150	2414	0	51	186	690	n.a.	5582
Bangalore	669206	35300	124406	5641	5366	4241	16619	8306	869086
Bhopal	133157	6063	5392	5566	386	1167	1452	648	153830
Chennai	866507	38656	186525	7680	346	1596	16492	2630	1120432
Coimbatore	47643	2480	3543	146	7	558	798	127	55302
Delhi	1565540	52870	702289	0	14938	31606	98488	n.a.	2465730
Dhanbad	45290	1501	6634	3653	875	772	2558	1841	63125
Faridabad	47248	5007	8521	3050	807	626	25244	n.a.	90501
Hyderabad	761141	45401	68294	37607	9006	6849	9891	7118	945306
Indore	223583	3577	11725	12103	840	6772	7991	3565	270155
Jabalpur	122553	859	1843	1903	132	1648	2405	1073	132416
Jaipur	178789	2872	15167	5428	1435	3964	14855	n.a.	222510
Jamshedpur	24673	818	5830	240	11	421	2067	330	34389
Kanpur	163768	397	19147	4331	748	190	1043	126	189750
Kochi	100014	9930	16308	5836	1543	3707	14423	n.a.	151762
Kolkata	307200	22035	178521	0	23822	27348	101413	n.a.	660339
Lucknow	232689	3685	31198	7057	1218	1098	3034	367	280347
Ludhiana	205447	5376	22556	8073	2135	409	6318	n.a.	250314
Madurai	53609	2791	3987	164	7	628	898	143	62228
Meerut	89118	521	5740	158	1365	257	1191	144	98494
Mumbai	620189	180511	245920	19024	46094	9840	32319	45559	1199456
Nagpur	206936	6713	12024	4097	1225	1351	4879	2783	240008
Nasik	54119	4566	6394	563	374	133	3462	1544	71155
Patna	59253	1963	8079	4055	927	1010	5643	112	81043
Pune	367716	29851	42610	8976	3115	3834	13288	4410	473801
Rajkot	104323	1581	6816	601	398	343	4257	3731	122049
Surat	347733	17965	33115	2918	1936	662	8863	7767	420958
Vadodara	99449	7103	12796	1128	748	59	1676	1469	124427
Varanasi	91556	535	5897	1334	230	264	1223	148	101188
Vijayawada	32453	1647	1970	1085	260	17	546	393	38371
Vishakhapatnam	56102	2846	3427	1887	452	29	1117	803	66664

-- Data for vehicular population of urban agglomerates has been generated from data on vehicular population of districts as follows :
No. of vehicles in urban agglomerate = (Population of urban agglomerate / Population of district) x No. of vehicles in district.

-- Data for Car, Taxis and Jeeps in 2002 have been generated by breaking up the data for Cars/Cabs in the same proportion as they occur in data published by Ministry of Surface Transport for 1997. Similarly, data for Trucks and L.C.V.s for 2002 has been generated from data on Goods Carraiges in 2002 by breaking up the data in the same proportion as they occur in data supplied by Ministry of Surface Transport for 1997. The above data for 1997 was available for Ahmedabad, Bangalore, Bhopal, Chennai, Delhi, Hyderabad, Jaipur, Kanpur, Kolkata, Mumbai, Nagpur, Patna and Pune. For the cities for which data for 1997 is unavailable, they are broken up in the same proportion as a representative city of the same state.

-- In the Table with million plus Urban Agglomerates (35 in number), for the cities for which data on vehicular population is not available, it has been generated in proportion to its population vis-à-vis a city in the same state with similar population. They are Coimbatore (by Madurai), Meerut (by Varanasi), Jamshedpur (by Patna), Dhanbad (by Patna), Allahabad (by Varanasi), Amritsar (by Ludhiana), Vijayawada (by Vishakhapatnam) and Asansol (by Kolkata).

-- Since the vehicular population figures are cumulative, to eliminate vehicles older than 15 years, the number of vehicles in 1985 has been been subtracted from that in 2002.

Table 3.2 : Total Distances Travelled vehicle wise and city wise (in Km./day) for 35 urban agglomerates

Cities	2-wheelers	3-wheelers	Cars	Jeeps	Taxis	Buses	Trucks	L.C.V.s
Agra	2011662	145486	140066	31684	11570	81000	190000	2070
Ahmedabad	15181895	3075355	2416144	212896	298784	931647	2264474	288389
Allahabad	10931549	127861	732182	165608	60476	46871	145075	3575
Amritsar	2660737	139239	303807	108729	60827	55056	170407	3575
Asansol	22015	4295	26447	0	1191	82722	256039	3575
Bangalore	21545260	3091279	4165507	188873	380043	848000	1018000	89963
Bhopal	3328919	472927	140188	144708	21244	85620	265009	3575
Chennai	32525783	3946767	7281586	299831	28539	610000	1040000	3575
Coimbatore	1191063	215754	92127	3792	358	88571	274144	3575
Delhi	39138491	3595149	18259517	0	821574	2851000	2514000	1885500
Dhanbad	1132245	117058	172493	94990	48114	76853	237872	3575
Faridabad	1181197	390531	221550	79290	44358	67722	209612	3575
Hyderabad	19027990	3087161	1775592	977756	495289	1052000	1603000	486815
Indore	5589571	178846	304853	314681	46197	25744	26495	3575
Jabalpur	3063813	42936	47927	49472	7263	29953	30826	3575
Jaipur	4469735	195266	394336	141128	78952	29537	30398	3575
Jamshedpur	616837	55596	151590	6240	592	64073	198318	3575
Kanpur	4094199	19833	497820	112611	41123	73000	392000	5080
Kochi	2500360	774561	424006	151747	84892	89968	278466	3575
Kolkata	3235687	631288	1955546	0	552009	1681000	974000	730500
Lucknow	5817234	287415	811153	183490	67007	93189	288437	3575
Ludhiana	5136180	268781	586456	209885	117417	23201	23878	3575
Madurai	1340227	139526	103660	4267	410	54882	169870	3575
Meerut	2227960	40653	149235	4105	75060	67597	209224	3575
Mumbai	12649078	10013995	5216300	403519	2068242	1000000	2542000	2071152
Nagpur	5173407	456483	312621	106516	67398	76730	237493	3575
Nasik	1352984	310488	166233	14647	20557	35359	36391	3575
Patna	1481314	161001	210059	105425	51003	23416	24099	3575
Pune	9192901	2029898	1107868	233364	171326	854375	866097	288389
Rajkot	2608065	107475	177208	15614	21914	54596	168983	3575
Surat	8693325	1562932	860990	75864	106472	54671	169216	3575
Vadodara	2486216	617949	332705	29316	41143	27981	28797	3575
Varanasi	2288904	36410	153314	34681	12665	22594	23253	3575
Vijayawada	811322	111964	51231	28211	14290	47693	147618	3575
Vishakhapatnam	1402553	193555	89109	49069	24856	28748	29586	3575

– Total distances travelled of 2-wheelers, 3-wheelers, Cars, Jeeps and Taxis have been calculated from assumed lea distances and vehicular population of these vehicle categories, that is, Total Distance Travelled (in km./day) = Lead Distance (in km./day) x Number of Vehicles, for each vehicle category.

– Total distances travelled of Buses and Trucks have been calculated from data on total distances for Buses and Trucks given for 8 cities. These are Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Kanpur and Agra. For Ahmedabad and Pune, Total distance travelled = 0.5 x (Intra City Distance for Hyderabad / No. of vehicles in Hyd Intra City Distance for Bangalore / No. of vehicles in Bangalore) x ((Square root of urban agglomerate area / Number of vehicles) / (0.5 x (Square root of urban agglomerate area of Hyderabad / Number of vehicles in Hyderaba Square root of urban agglomerate area of Bangalore / Number of vehicles in Bangalore)) x (0.5 x (Total Distance Tra Hyderabad / Intra City Distance for Hyderabad + Total Distance Travelled for Bangalore / Intra City Distance for Ban x Number of vehicles. For the rest Hyderabad and Bangalore are replaced by Agra and Kanpur.

– For L.C.V.s, Total Distance Travelled = 0.75 x number of L.C.V.s x (Intra City distance travelled by Trucks / No. of for the 8 cities whose data for total distance is given. For Ahmedabad and Pune, an average of Hyderabad and Bang has been used and for all others an average of Agra and Kanpur.

Table 3.3 : Emission Coefficients

(Kg./Km.

Vehicle		CO	HC	NOX	PM
2 wheeler	Pre control	0.0065	0.0039	0.0003	0.0023
	1996 norms	0.004	0.0033	0.00006	0.0001
	2000 norms	0.0022	0.00213	0.00007	0.00005
	2005 norms	0.0014	0.00132	0.00008	0.00005
3 wheeler	Pre control	0.014	0.0083	0.00005	0.00035
	1996 norms	0.0086	0.007	0.00009	0.00015
	2000 norms	0.0043	0.00205	0.00011	0.00008
	2005 norms	0.00245	0.00075	0.00012	0.00008
Car	Pre Euro	0.0039	0.0008	0.0011	0.00005
	Euro II	0.00198	0.00025	0.0002	0.00003
	Euro III	0.00139	0.00015	0.00012	0.00002
	Euro IV	0.001	0.000125	0.000127	0.000016
Jeep	Pre Euro	0.0012	0.00037	0.00069	0.00042
	Euro II	0.0009	0.00013	0.0005	0.00007
	Euro III	0.00058	0.00005	0.0005	0.00005
	Euro IV	0.0005	0.00025	0.00045	0.000025
Taxi	Pre Euro	0.0039	0.0008	0.0011	0.00005
	Euro II	0.00198	0.00025	0.0002	0.00003
	Euro III	0.00139	0.00015	0.00012	0.00002
	Euro IV	0.001	0.000125	0.000127	0.000016
Bus	Pre Euro	0.0045	0.00121	0.0168	0.0016
	Euro II	0.0032	0.00087	0.011	0.00024
	Euro III	0.0025	0.00077	0.01	0.00024
	Euro IV	0.0014	0.00039	0.0049	0.00022
Truck	Pre Euro	0.0045	0.00121	0.0084	0.0008
	Euro II	0.0032	0.00097	0.0055	0.00012
	Euro III	0.0028	0.00077	0.005	0.0001
	Euro IV	0.0014	0.00039	0.00245	0.00006
L.C.V.	Pre Euro	0.0069	0.00028	0.00249	0.0005
	Euro II	0.00072	0.000063	0.00059	0.00007
	Euro III	0.00064	0.000058	0.0005	0.00005
	Euro IV	0.0005	0.00003	0.000025	0.000025

Table 3.4 : Total Daily Flow of Emission of Pollutants across 35 urban agglomerates in India (as per Pre-Euro coefficients) (in Kgs.)

Cities	CO	HC	NOX	PM
Agra	16975.79	9514.53	3761.39	4981.27
Ahmedabad	168953.41	156529.04	43232.99	39666.30
Allahabad	77023.65	76368.48	6287.02	25489.34
Amritsar	21835.93	21070.49	3646.55	6458.53
Asansol	1860.11	721.92	3586.58	392.49
Bangalore	210294.14	203559.44	34770.18	53158.83
Bhopal	30664.68	29487.44	4973.13	8241.67
Chennai	302991.28	297539.12	37196.00	78491.89
Coimbatore	12784.59	11567.59	4272.16	3183.99
Delhi	416300.99	386168.13	106619.80	99746.44
Dhanbad	11413.69	10354.59	3951.88	3011.11
Faridabad	15550.06	14613.97	3628.47	3177.87
Hyderabad	192238.45	180280.78	41386.34	48578.09
Indore	40842.52	40646.98	2953.07	13132.50
Jabalpur	21088.67	20865.04	1787.19	7159.71
Jaipur	34096.55	33875.70	2729.15	10505.04
Jamshedpur	6594.22	5707.28	3110.74	1711.37
Kanpur	31254.52	29691.04	6431.64	9930.78
Kochi	30945.61	29709.80	5312.81	6479.61
Kolkata	65887.91	43441.93	45340.15	12292.78
Lucknow	47222.83	45943.62	6849.47	13982.85
Ludhiana	40381.60	40203.04	3072.63	12088.64
Madurai	12111.88	11348.78	2884.30	3363.85
Meerut	17200.91	16266.51	3821.98	5428.80
Mumbai	281538.83	256174.63	55896.82	37800.66
Nagpur	43066.47	42009.01	5359.27	12436.89
Nasik	14234.82	13975.10	1545.62	3323.50
Patna	13265.69	13085.70	1417.07	3579.24
Pune	103173.34	95603.85	26774.31	24220.18
Rajkot	20283.16	19523.92	3363.17	6277.01
Surat	83283.97	82523.71	6151.49	20846.54
Vadodara	26585.04	26374.58	1929.10	6035.18
Varanasi	16307.53	16133.03	1478.80	5356.63
Vijayawada	8034.04	7367.80	2390.67	2116.54
Vishakhapatnam	12616.88	12401.30	1330.05	3391.38

Table 3.5 : Total Daily Flow of Emission of Pollutants across 35 urban agglomerates in India (as per Euro II coefficients) (in Kgs.)

Cities	CO	HC	NOX	PM
Agra	10495.27	8473.32	2117.18	272.14
Ahmedabad	103178.03	85140.71	24710.00	2591.36
Allahabad	47161.11	39073.95	2224.34	1176.61
Amritsar	13384.28	11011.13	1844.42	339.42
Asansol	1266.33	484.86	2327.50	54.50
Bangalore	127972.19	108585.42	17554.56	3099.78
Bhopal	18957.30	15834.25	2748.41	471.40
Chennai	184071.80	157560.90	16350.81	4356.34
Coimbatore	7969.53	6315.73	2595.46	208.91
Delhi	243778.37	202893.60	52788.54	6143.46
Dhanbad	7067.67	5563.23	2325.87	191.29
Faridabad	9571.25	8116.84	2098.77	231.88
Hyderabad	116884.37	97219.09	23038.30	2981.36
Indore	25044.39	21010.28	1010.04	627.95
Jabalpur	12975.37	10689.82	724.60	329.08
Jaipur	20816.72	17548.95	945.19	511.33
Jamshedpur	4094.64	3068.97	1873.24	114.45
Kanpur	19207.48	15293.95	3373.53	501.36
Kochi	18988.42	16405.21	2920.70	447.37
Kolkata	33324.01	23609.53	25822.45	1158.79
Lucknow	28868.38	23933.63	3255.87	721.25
Ludhiana	24592.03	20887.05	966.73	598.43
Madurai	7492.51	6045.32	1656.02	192.18
Meerut	10597.65	8411.66	2080.65	277.49
Mumbai	164328.86	146115.10	29521.85	3703.81
Nagpur	26475.77	22143.65	2633.10	651.83
Nasik	8697.33	7584.36	745.02	201.60
Patna	8076.27	6928.70	600.52	196.26
Pune	62684.71	52138.12	15438.60	1607.66
Rajkot	12482.89	10150.85	1745.86	317.63
Surat	50917.38	44324.97	2427.87	1171.78
Vadodara	16210.09	14337.98	762.50	365.00
Varanasi	9977.88	8268.80	569.68	250.22
Vijayawada	4990.87	3980.28	1424.60	131.28
Vishakhapatnam	7733.84	6616.74	629.96	186.84

Table 3.6 : Total Daily Flow of Emission of Pollutants across 35 urban agglomerates in India (as per Euro III coefficients) (in Kgs.)

Cities	CO	HC	NOX	PM
Agra	6016.22	4816.20	1951.89	155.38
Ahmedabad	59375.64	41537.54	22616.29	1534.53
Allahabad	26322.73	23821.50	2153.07	606.88
Amritsar	7639.32	6186.75	1704.06	187.34
Asansol	1031.32	320.90	2114.53	47.63
Bangalore	72147.91	54361.84	16103.09	1734.74
Bhopal	10623.89	8361.74	2559.80	261.97
Chennai	103302.09	79753.01	15039.87	2353.80
Coimbatore	4670.15	3272.82	2378.32	127.70
Delhi	143459.96	97837.61	47447.64	3656.07
Dhanbad	4216.49	2932.04	2125.77	117.55
Faridabad	5452.02	3574.14	1924.27	136.98
Hyderabad	66289.95	49320.40	21211.34	1729.80
Indore	13877.41	12381.24	1002.12	325.55
Jabalpur	7193.91	6671.70	706.00	170.65
Jaipur	11574.03	10045.24	910.87	265.94
Jamshedpur	2529.02	1653.22	1704.79	74.03
Kanpur	11190.32	9206.12	3102.29	279.68
Kochi	10633.70	7281.44	2690.96	254.37
Kolkata	21573.79	10726.76	23312.42	866.84
Lucknow	16403.75	13414.87	3011.81	391.98
Ludhiana	13682.62	11643.60	931.70	311.02
Madurai	4310.72	3329.80	1523.75	110.81
Meerut	6147.58	5076.10	1913.27	156.67
Mumbai	92190.84	51431.55	26808.46	2197.20
Nagpur	14793.47	12259.64	2467.77	350.46
Nasik	4772.38	3602.56	695.94	109.26
Patna	4503.52	3566.47	561.88	105.65
Pune	35611.95	25287.21	14155.41	965.37
Rajkot	7097.65	5978.51	1618.75	173.94
Surat	27847.47	22042.31	2329.06	613.06
Vadodara	8816.38	6663.90	727.11	192.46
Varanasi	5566.86	5012.15	545.48	130.34
Vijayawada	2908.64	2119.48	1307.89	78.63
Vishakhapatnam	4261.77	3448.90	594.87	100.38

Table 3.7 : Total Daily Flow of Emission of Pollutants across 35 urban agglomerates in India (as per Euro IV coefficients) (in Kgs.)

Cities	CO	HC	NOX	PM
Agra	3720.68	2897.14	1074.36	144.71
Ahmedabad	36229.41	23994.35	12144.43	1401.92
Allahabad	16763.40	14740.99	1650.25	592.73
Amritsar	4802.60	3777.40	1012.16	175.15
Asansol	545.03	167.96	1038.51	35.54
Bangalore	45034.37	32104.05	9408.40	1651.91
Bhopal	6545.61	4942.08	1477.58	245.31
Chennai	64977.50	47526.44	9676.07	2263.18
Coimbatore	2800.05	1888.09	1240.37	114.41
Delhi	91136.84	58893.22	26162.13	3375.03
Dhanbad	2582.44	1756.53	1134.84	103.15
Faridabad	3306.08	2013.41	1056.29	124.10
Hyderabad	40922.90	29010.67	11715.41	1598.94
Indore	8846.89	7655.40	845.97	314.61
Jabalpur	4561.34	4119.51	501.91	167.27
Jaipur	7365.58	6164.42	723.92	258.62
Jamshedpur	1524.22	978.94	878.08	63.97
Kanpur	7029.26	5696.24	1767.26	257.44
Kochi	6500.54	4126.74	1549.07	235.51
Kolkata	13336.75	6155.60	11328.05	732.45
Lucknow	10354.26	8198.89	1857.35	370.39
Ludhiana	8725.68	7140.27	799.27	301.45
Madurai	2640.80	1975.58	824.29	102.30
Meerut	3834.43	3108.53	1057.36	145.86
Mumbai	55723.68	26662.24	14500.00	1984.51
Nagpur	9236.13	7368.05	1522.77	335.15
Nasik	2951.22	2073.91	438.32	105.89
Patna	2850.37	2153.71	392.29	100.45
Pune	21792.04	14554.93	7562.08	895.48
Rajkot	4436.33	3639.35	935.47	164.82
Surat	17320.46	12874.71	1722.58	599.35
Vadodara	5464.46	3821.58	541.47	188.43
Varanasi	3542.96	3096.07	391.94	127.34
Vijayawada	1765.01	1246.44	694.81	70.72
Vishakhapatnam	2659.74	2045.91	385.42	96.85

Table 3.8 Health Cost of Pollutants

(Low Cost Estimate) Rs/Kg

	CO	HC	NOX	PM
Agra	0.01	0.09	1.13	9.73
Ahmedaba	0.02	0.29	3.49	30.16
Allahabad	0.01	0.12	1.48	12.77
Amritsar	0.01	0.19	2.32	20.08
Asansol	0.00	0.05	0.63	5.43
Bangalore	0.015	0.19	2.33	20.12
Bhopal	0.00	0.06	0.69	5.95
Chennai	0.01	0.17	2.04	17.67
Coimbator	0.01	0.08	0.98	8.51
Delhi	0.05	0.60	7.37	63.73
Dhanbad	0.00	0.03	0.36	3.09
Faridabad	0.01	0.12	1.51	13.05
Hyderabad	0.03	0.37	4.53	39.11
Indore	0.01	0.11	1.33	11.51
Jabalpur	0.00	0.05	0.67	5.80
Jaipur	0.01	0.14	1.68	14.52
Jamshedp	0.00	0.04	0.53	4.60
Kanpur	0.007	0.09	1.08	9.35
Kochi	0.01	0.07	0.87	7.54
Kolkata	0.01	0.17	2.11	18.20
Lucknow	0.01	0.07	0.81	6.98
Ludhiana	0.02	0.23	2.80	24.23
Madurai	0.01	0.17	2.12	18.30
Meerut	0.00	0.06	0.79	6.83
Mumbai	0.03	0.40	4.87	42.05
Nagpur	0.02	0.21	2.57	22.17
Nasik	0.01	0.08	1.02	8.80
Patna	0.01	0.08	0.96	8.28
Pune	0.02	0.20	2.40	20.70
Rajkot	0.01	0.18	2.19	18.89
Surat	0.04	0.50	6.11	52.84
Vadodara	0.01	0.16	1.92	16.63
Varanasi	0.01	0.09	1.14	9.85
Vijayawada	0.01	0.16	1.99	17.21
Vishakhap	0.01	0.09	1.12	9.67

Table 3.9 Health Cost of Pollutants

(High Cost Estimate) Rs/Kg

	CO	HC	NOX	PM
Agra	0.07	1.03	16.53	132.79
Ahmedabad	0.22	3.18	51.23	411.49
Allahabad	0.09	1.35	21.69	174.20
Amritsar	0.15	2.12	34.10	273.94
Asansol	0.04	0.57	9.23	74.12
Bangalore	0.146	2.12	34.18	274.58
Bhopal	0.04	0.63	10.10	81.14
Chennai	0.13	1.86	30.02	241.13
Coimbatore	0.06	0.90	14.45	116.08
Delhi	0.46	6.73	108.26	869.57
Dhanbad	0.02	0.33	5.24	42.10
Faridabad	0.09	1.38	22.17	178.09
Hyderabad	0.28	4.13	66.44	533.67
Indore	0.08	1.21	19.56	157.09
Jabalpur	0.04	0.61	9.85	79.09
Jaipur	0.11	1.53	24.66	198.09
Jamshedpur	0.03	0.48	7.81	62.70
Kanpur	0.068	0.99	15.88	127.52
Kochi	0.05	0.80	12.80	102.82
Kolkata	0.13	1.92	30.92	248.36
Lucknow	0.05	0.74	11.85	95.18
Ludhiana	0.18	2.56	41.15	330.55
Madurai	0.13	1.93	31.09	249.77
Meerut	0.05	0.72	11.60	93.16
Mumbai	0.31	4.44	71.43	573.78
Nagpur	0.16	2.34	37.66	302.47
Nasik	0.06	0.93	14.95	120.07
Patna	0.06	0.87	14.07	113.03
Pune	0.15	2.18	35.17	282.49
Rajkot	0.14	1.99	32.08	257.70
Surat	0.38	5.58	89.75	720.96
Vadodara	0.12	1.76	28.25	226.95
Varanasi	0.07	1.04	16.74	134.45
Vijayawada	0.13	1.82	29.23	234.80
Vishakhapatna	0.07	1.02	16.43	132.00

Table 3.10 : Total Health Cost as per Pre Euro Norms
(Low Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	120.24	876.10	4236.10	48478.32	53711	19,604,428
Ahmedabad	3708.28	44662.64	150875.43	1196229.69	1395476	509,348,757
Allahabad	715.68	9224.66	9288.27	325415.64	344644	125,795,153
Amritsar	319.06	4002.44	8472.01	129666.23	142460	51,997,804
Asansol	7.35	37.10	2254.52	2132.04	4431	1,617,322
Bangalore	3079.89	38756.34	80967.78	1069720.54	1192525	435,271,458
Bhopal	132.72	1659.12	3422.34	49011.53	54226	19,792,384
Chennai	3896.92	49748.32	76064.90	1387083.21	1516793	553,629,571
Coimbatore	79.16	931.12	4205.96	27088.09	32304	11,791,078
Delhi	19308.91	232846.74	786294.74	6356740.80	7395191	2,699,244,784
Dhanbad	25.63	302.26	1410.94	9290.13	11029	4,025,571
Faridabad	147.71	1804.69	5480.41	41477.69	48911	17,852,336
Hyderabad	5472.13	66712.81	187314.17	1899956.36	2159455	788,201,249
Indore	342.22	4427.55	3934.26	151191.12	159895	58,361,730
Jabalpur	88.97	1144.32	1198.81	41501.63	43934	16,035,808
Jaipur	360.27	4653.18	4585.03	152511.43	162110	59,170,115
Jamshedpur	22.05	248.14	1654.21	7864.30	9789	3,572,876
Kanpur	212.59	2625.42	6955.82	92811.04	102605	37,450,776
Kochi	169.72	2118.24	4632.90	48827.83	55749	20,348,272
Kolkata	872.83	7481.33	95500.69	223750.21	327605	119,575,850
Lucknow	239.75	3032.35	5529.23	97542.27	106344	38,815,416
Ludhiana	711.98	9214.81	8613.75	292852.18	311393	113,658,343
Madurai	161.36	1965.50	6109.67	61574.73	69811	25,481,108
Meerut	85.47	1050.76	3019.61	37064.25	41220	15,045,332
Mumbai	8616.40	101921.83	272001.91	1589548.79	1972089	719,812,464
Nagpur	694.81	8810.80	13747.78	275694.49	298948	109,115,976
Nasik	91.17	1163.52	1573.89	29245.52	32074	11,707,048
Patna	79.98	1025.58	1358.37	29648.76	32113	11,721,131
Pune	1554.57	18726.75	64144.44	501427.09	585853	213,836,290
Rajkot	278.80	3488.70	7350.19	118547.48	129665	47,327,786
Surat	3202.71	41255.13	37612.59	1101480.11	1183551	431,995,946
Vadodara	321.83	4150.62	3713.10	100383.30	108569	39,627,631
Varanasi	116.95	1504.07	1686.23	52782.26	56090	20,472,672
Vijayawada	100.62	1199.57	4760.58	36421.47	42482	15,506,017
Vishakhapatnam	88.83	1135.05	1488.91	32807.03	35520	12,964,732
Total						7,379,775,213

Table 3.11 : Total Health Cost as per Euro II Norms
(Low Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	74.34	780.22	2384.39	2648.51	5887	2,148,922
Ahmedabad	2264.61	24293.31	86233.50	78148.57	190940	69,693,096
Allahabad	438.20	4719.80	3286.18	15021.53	23466	8,564,985
Amritsar	195.57	2091.62	4285.13	6814.49	13387	4,886,185
Asansol	5.01	24.92	1463.06	296.06	1789	653,004
Bangalore	1874.23	20673.93	40878.52	62377.24	125804	45,918,433
Bhopal	82.05	890.92	1891.37	2803.34	5668	2,068,700
Chennai	2367.44	26344.07	33437.00	76983.75	139132	50,783,269
Coimbatore	49.35	508.38	2555.24	1777.35	4890	1,784,964
Delhi	11306.95	122338.20	389302.44	391516.52	914464	333,779,402
Dhanbad	15.87	162.40	830.41	590.18	1599	583,583
Faridabad	90.92	1002.36	3169.96	3026.56	7290	2,660,774
Hyderabad	3327.15	35975.87	104271.10	116605.09	260179	94,965,417
Indore	209.85	2288.59	1345.64	7229.44	11074	4,041,834
Jabalpur	54.74	586.27	486.05	1907.52	3035	1,107,621
Jaipur	219.95	2410.53	1587.93	7423.42	11642	4,249,272
Jamshedpur	13.69	133.43	996.13	525.94	1669	609,259
Kanpur	130.65	1352.36	3648.47	4685.62	9817	3,583,241
Kochi	104.14	1169.65	2546.93	3371.19	7192	2,625,047
Kolkata	441.45	4065.90	54390.24	21091.99	79990	29,196,200
Lucknow	146.57	1579.66	2628.30	5031.35	9386	3,425,844
Ludhiana	433.59	4787.45	2710.11	14497.14	22428	8,186,327
Madurai	99.82	1046.99	3507.86	3517.81	8172	2,982,954
Meerut	52.66	543.36	1643.85	1894.52	4134	1,509,053
Mumbai	5029.23	58133.47	143657.56	155748.27	362569	132,337,512
Nagpur	427.15	4644.32	6754.52	14449.52	26276	9,590,561
Nasik	55.70	631.45	758.65	1774.04	3220	1,175,239
Patna	48.69	543.03	575.64	1625.69	2793	1,019,464
Pune	944.51	10212.74	36986.95	33283.06	81427	29,720,951
Rajkot	171.58	1813.84	3815.56	5998.67	11800	4,306,874
Surat	1958.04	22158.87	14844.92	61914.18	100876	36,819,747
Vadodara	196.23	2256.40	1467.65	6071.10	9991	3,646,853
Varanasi	71.56	770.90	649.59	2465.60	3958	1,444,537
Vijayawada	62.51	648.04	2836.83	2259.03	5806	2,119,336
Vishakhapatnam	54.45	605.61	705.20	1807.45	3173	1,158,038
Total						903,346,501

Table 3.12 : Total Health Cost as per Euro III Norms
(Low Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	42.61	443.48	2198.24	1512.20	4197	1,531,732
Ahmedabad	1303.21	11851.96	78926.83	46277.28	138359	50,501,138
Allahabad	244.58	2877.43	3180.89	7747.81	14051	5,128,512
Amritsar	111.62	1175.20	3959.04	3761.13	9007	3,287,555
Asansol	4.08	16.49	1329.19	258.74	1609	587,105
Bangalore	1056.65	10350.13	37498.56	34908.31	83814	30,591,982
Bhopal	45.98	470.47	1761.57	1557.90	3836	1,400,111
Chennai	1328.62	13334.64	30756.16	41595.65	87015	31,760,500
Coimbatore	28.92	263.44	2341.46	1086.44	3720	1,357,897
Delhi	6653.97	58992.88	349914.66	232997.90	648559	236,724,186
Dhanbad	9.47	85.59	758.97	362.67	1217	444,094
Faridabad	51.79	441.37	2906.39	1787.85	5187	1,893,403
Hyderabad	1886.97	18250.99	96002.30	67654.81	183795	67,085,199
Indore	116.28	1348.65	1335.08	3747.95	6548	2,390,008
Jabalpur	30.35	365.90	473.57	989.20	1859	678,541
Jaipur	122.29	1379.82	1530.28	3860.86	6893	2,516,038
Jamshedpur	8.46	71.88	906.56	340.21	1327	484,392
Kanpur	76.12	814.05	3355.13	2613.83	6859	2,503,581
Kochi	58.32	519.15	2346.59	1916.80	4841	1,766,914
Kolkata	285.79	1847.30	49103.33	15777.93	67014	24,460,243
Lucknow	83.28	885.40	2431.28	2734.40	6134	2,239,042
Ludhiana	241.24	2668.79	2611.90	7534.54	13056	4,765,611
Madurai	57.43	576.69	3227.68	2028.28	5890	2,149,879
Meerut	30.55	327.90	1511.60	1069.61	2940	1,072,976
Mumbai	2821.47	20462.60	130453.78	92393.98	246132	89,838,118
Nagpur	238.67	2571.29	6330.39	7768.78	16909	6,171,833
Nasik	30.56	299.94	708.67	961.45	2001	730,226
Patna	27.15	279.52	538.61	875.13	1720	627,948
Pune	536.59	4953.22	33912.76	19985.88	59388	21,676,787
Rajkot	97.56	1068.29	3537.77	3285.11	7989	2,915,886
Surat	1070.88	11019.36	14240.79	32392.83	58724	21,434,207
Vadodara	106.73	1048.71	1399.53	3201.25	5756	2,101,020
Varanasi	39.92	467.28	621.99	1284.31	2413	880,927
Vijayawada	36.43	345.08	2604.41	1353.08	4339	1,583,736
Vishakhapatnam	30.01	315.67	665.93	971.06	1983	723,669
Total						626,004,996

Table 3.13 : Total Health Cost as per Euro IV Norms
(Low Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	26.35	266.77	1209.95	1408.36	2911	1,062,671
Ahmedabad	795.18	6846.34	42381.91	42278.31	92302	33,690,134
Allahabad	155.76	1780.59	2438.04	7567.28	11942	4,358,708
Amritsar	70.18	717.53	2351.55	3516.53	6656	2,429,362
Asansol	2.15	8.63	652.81	193.04	857	312,671
Bangalore	659.56	6112.39	21908.93	33241.45	61922	22,601,651
Bhopal	28.33	278.07	1016.82	1458.79	2782	1,015,433
Chennai	835.71	7946.39	19787.33	39994.14	68564	25,025,702
Coimbatore	17.34	151.98	1221.15	973.37	2364	862,798
Delhi	4227.12	35510.68	192939.28	215087.39	447764	163,434,032
Dhanbad	5.80	51.28	405.17	318.25	780	284,881
Faridabad	31.41	248.64	1595.41	1619.81	3495	1,275,771
Hyderabad	1164.88	10735.38	53023.83	62536.78	127461	46,523,221
Indore	74.13	833.88	1127.05	3622.06	5657	2,064,847
Jabalpur	19.24	225.93	336.67	969.61	1551	566,282
Jaipur	77.83	846.75	1216.21	3754.63	5895	2,151,825
Jamshedpur	5.10	42.56	466.94	293.94	809	295,117
Kanpur	47.81	503.69	1911.30	2406.00	4869	1,777,110
Kochi	35.65	294.23	1350.82	1774.71	3455	1,261,224
Kolkata	176.68	1060.08	23860.45	13331.82	38429	14,026,595
Lucknow	52.57	541.14	1499.35	2583.79	4677	1,707,047
Ludhiana	153.85	1636.60	2240.64	7302.67	11334	4,136,821
Madurai	35.18	342.15	1746.06	1872.60	3996	1,458,538
Meerut	19.05	200.80	835.38	995.81	2051	748,630
Mumbai	1705.40	10607.86	70559.10	83450.40	166323	60,707,810
Nagpur	149.01	1545.34	3906.26	7429.47	13030	4,755,980
Nasik	18.90	172.67	446.34	931.83	1570	572,955
Patna	17.18	168.80	376.04	832.04	1394	508,832
Pune	328.35	2851.00	18116.82	18538.92	39835	14,539,808
Rajkot	60.98	650.31	2044.47	3112.73	5868	2,142,000
Surat	666.06	6436.31	10532.53	31668.01	49303	17,995,563
Vadodara	66.15	601.41	1042.21	3134.23	4844	1,768,062
Varanasi	25.41	288.64	446.91	1254.72	2016	735,726
Vijayawada	22.11	202.94	1383.58	1216.88	2825	1,031,307
Vishakhapatnam	18.73	187.25	431.46	936.91	1574	574,636
Total						438,403,749

Table 3.14 : Total Health Cost as per Pre Euro Norms
(High Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	1202.41	9771.85	62182.80	661478.58	734636	268,142,005
Ahmedabad	37082.85	498160.20	2214737.44	16322353.91	19072334	6,961,402,055
Allahabad	7156.77	102890.48	136344.80	4440241.99	4686634	1,710,621,424
Amritsar	3190.64	44642.57	124362.67	1769273.99	1941470	708,636,503
Asansol	73.54	413.84	33094.65	29091.35	62673	22,875,783
Bangalore	30798.91	432282.26	1188545.84	14596157.64	16247785	5,930,441,397
Bhopal	1327.19	18505.52	50237.41	668754.14	738824	269,670,855
Chennai	38969.17	554885.09	1116575.30	18926518.24	20636948	7,532,485,945
Coimbatore	791.60	10385.58	61740.25	369612.42	442530	161,523,394
Delhi	193089.13	2597136.71	11542213.31	86736664.12	101069103	36,890,222,693
Dhanbad	256.29	3371.39	20711.58	126762.21	151101	55,152,037
Faridabad	1477.15	20129.28	80448.23	565956.19	668011	243,823,961
Hyderabad	54721.34	744104.42	2749630.67	25924586.50	29473043	10,757,660,669
Indore	3422.19	49384.23	57751.91	2062977.57	2173536	793,340,603
Jabalpur	889.68	12763.51	17597.62	566282.75	597534	218,099,750
Jaipur	3602.70	51900.83	67304.80	2080992.87	2203801	804,387,437
Jamshedpur	220.54	2767.74	24282.49	107307.03	134578	49,120,902
Kanpur	2125.90	29283.49	102106.16	1266391.14	1399907	510,965,940
Kochi	1697.19	23626.50	68007.47	666247.63	759579	277,246,260
Kolkata	8728.35	83445.62	1401878.05	3053034.19	4547086	1,659,686,469
Lucknow	2397.52	33822.34	81164.96	1330947.99	1448333	528,641,476
Ludhiana	7119.80	102780.57	126443.33	3995919.02	4232263	1,544,775,893
Madurai	1613.58	21922.84	89685.36	840176.89	953399	347,990,514
Meerut	854.71	11719.99	44325.58	505735.49	562636	205,362,057
Mumbai	86164.04	1136820.43	3992782.78	21689127.21	26904894	9,820,286,481
Nagpur	6948.14	98274.30	201807.04	3761805.11	4068835	1,485,124,625
Nasik	911.65	12977.76	23103.58	399050.25	436043	159,155,783
Patna	799.76	11439.17	19939.86	404552.38	436731	159,406,873
Pune	15545.73	208875.27	941591.95	6841888.68	8007902	2,922,884,097
Rajkot	2787.97	38912.39	107895.22	1617560.55	1767156	645,011,992
Surat	32027.07	460153.36	552124.48	15029511.69	16073817	5,866,943,059
Vadodara	3218.27	46295.43	54505.47	1369713.37	1473733	537,912,375
Varanasi	1169.49	16776.20	24752.57	720205.11	762903	278,459,729
Vijayawada	1006.18	13379.79	69881.78	496964.85	581233	212,149,901
Vishakhapatnam	888.29	12660.16	21856.05	447646.41	483051	176,313,585
Total						100,715,924,521

Table 3.15 : Total Health Cost as per Euro II Norms
(High Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	743.39	8702.47	35001.01	36138.48	80585	29,413,653
Ahmedabad	22646.09	270963.87	1265842.63	1066324.17	2625777	958,408,522
Allahabad	4382.05	52643.94	48238.65	204966.20	310231	113,234,259
Amritsar	1955.70	23329.57	62902.54	92982.55	181170	66,127,177
Asansol	50.06	277.95	21476.68	4039.73	25844	9,433,214
Bangalore	18742.34	230593.83	600065.78	851127.06	1700529	620,693,089
Bhopal	820.49	9937.14	27763.82	38251.10	76773	28,021,982
Chennai	23674.36	293837.65	490829.87	1050430.32	1858772	678,451,855
Coimbatore	493.46	5670.37	37508.93	24251.70	67924	24,792,426
Delhi	113069.52	1364541.46	5714665.99	5342177.43	12534454	4,575,075,852
Dhanbad	158.70	1811.35	12189.73	8052.97	22213	8,107,656
Faridabad	909.20	11180.13	46532.56	41296.89	99919	36,470,358
Hyderabad	33271.54	401269.37	1530621.11	1591056.96	3556219	1,298,019,929
Indore	2098.47	25526.53	19753.00	98644.56	146023	53,298,233
Jabalpur	547.40	6539.15	7134.84	26027.81	40249	14,690,956
Jaipur	2199.53	26886.67	23309.69	101291.38	153687	56,095,852
Jamshedpur	136.94	1488.29	14622.50	7176.37	23424	8,549,799
Kanpur	1306.47	15084.02	53556.80	63934.52	133882	48,866,860
Kochi	1041.41	13046.13	37386.97	45999.32	97474	35,577,945
Kolkata	4414.52	45350.47	798407.67	287796.70	1135969	414,628,816
Lucknow	1465.66	17619.23	38581.45	68651.97	126318	46,106,187
Ludhiana	4335.89	53398.52	39782.42	197811.00	295328	107,794,660
Madurai	998.18	11677.95	51492.80	47999.87	112169	40,941,610
Meerut	526.59	6060.39	24130.43	25850.43	56568	20,647,336
Mumbai	50292.31	648411.74	2108784.53	2125159.09	4932648	1,800,416,400
Nagpur	4271.48	51802.01	99151.26	197161.34	352386	128,620,924
Nasik	557.01	7043.09	11136.36	24206.43	42943	15,674,157
Patna	486.90	6056.89	8450.01	22182.23	37176	13,569,250
Pune	9445.07	113911.36	542940.57	454141.79	1120439	408,960,158
Rajkot	1715.81	20231.28	56009.57	81850.89	159808	58,329,756
Surat	19580.42	247156.67	217912.27	844808.63	1329458	485,252,167
Vadodara	1962.32	25167.53	21543.92	82839.17	131513	48,002,222
Varanasi	715.56	8598.45	9535.46	33642.66	52492	19,159,629
Vijayawada	625.06	7228.12	41642.48	30824.08	80320	29,316,706
Vishakhapatnam	544.50	6754.86	10351.79	24662.35	42314	15,444,428
Total						12,316,194,023

Table 3.16 : Total Health Cost as per Euro III Norms
(High Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	426.13	4946.45	32268.44	20633.73	58275	21,270,290
Ahmedabad	13032.10	132194.95	1158586.32	631445.75	1935259	706,369,580
Allahabad	2445.82	32094.47	46693.03	105717.63	186951	68,237,093
Amritsar	1116.25	13108.03	58115.70	51320.04	123660	45,135,909
Asansol	40.77	183.95	19511.54	3530.53	23267	8,492,382
Bangalore	10566.52	115443.72	550450.57	476318.06	1152779	420,764,287
Bhopal	459.81	5247.60	25858.50	21257.24	52823	19,280,451
Chennai	13286.18	148732.56	451477.21	567565.64	1181062	431,087,480
Coimbatore	289.17	2938.39	34370.90	14824.35	52423	19,134,329
Delhi	66539.74	657997.50	5136483.11	3179217.38	9040238	3,299,686,768
Dhanbad	94.68	954.65	11141.04	4948.60	17139	6,255,728
Faridabad	517.90	4923.02	42663.66	24394.87	72499	26,462,300
Hyderabad	18869.66	203568.73	1409241.29	923138.58	2554818	932,508,666
Indore	1162.79	15042.65	19598.01	51140.19	86944	31,734,428
Jabalpur	303.49	4081.20	6951.63	13497.46	24834	9,064,329
Jaipur	1222.93	15390.27	22463.35	52680.85	91757	33,491,452
Jamshedpur	84.58	801.73	13307.59	4642.06	18836	6,875,127
Kanpur	761.15	9079.75	49250.80	35665.29	94757	34,586,304
Kochi	583.20	5790.51	34446.15	26154.44	66974	24,445,619
Kolkata	2857.94	20604.55	720799.86	215287.27	959550	350,235,612
Lucknow	832.82	9875.63	35689.37	37310.40	83708	30,553,503
Ludhiana	2412.42	29767.29	38340.69	102807.48	173328	63,264,682
Madurai	574.29	6432.29	47379.89	27675.58	82062	29,952,650
Meerut	305.47	3657.32	22189.22	14594.65	40747	14,872,533
Mumbai	28214.71	228236.65	1914963.07	1260700.39	3432115	1,252,721,908
Nagpur	2386.71	28679.73	92925.42	106003.69	229996	83,948,372
Nasik	305.64	3345.46	10402.72	13118.82	27173	9,918,015
Patna	271.51	3117.72	7906.32	11940.99	23237	8,481,334
Pune	5365.86	55247.49	497813.77	272704.05	831131	303,362,875
Rajkot	975.59	11915.55	51931.75	44824.81	109648	40,021,410
Surat	10708.82	122908.21	209043.99	441994.75	784656	286,399,355
Vadodara	1067.27	11697.19	20544.06	43680.49	76989	28,100,989
Varanasi	399.23	5211.97	9130.34	17524.13	32266	11,776,967
Vijayawada	364.28	3848.93	38230.84	18462.59	60907	22,230,924
Vishakhapatnam	300.05	3520.89	9775.29	13249.92	26846	9,798,843
Total						8,690,522,492

Table 3.17 : Total Health Cost as per Euro IV Norms

(High Cost Estimate)

Cities	CO (in Rs.)	HC (in Rs.)	NOX (in Rs.)	PM (in Rs.)	Cost Per Day (in Rs.)	Annual Cost (in Rs.)
Agra	263.54	2975.49	17761.16	19216.78	40217	14,679,190
Ahmedabad	7951.84	76363.01	622134.42	576880.42	1283330	468,415,335
Allahabad	1557.60	19860.39	35788.51	103254.33	160461	58,568,204
Amritsar	701.75	8003.27	34518.94	47982.45	91206	33,290,340
Asansol	21.55	96.28	9582.70	2633.99	12335	4,502,098
Bangalore	6595.57	68176.71	321606.52	453574.04	849953	310,232,789
Bhopal	283.30	3101.51	14926.19	19904.95	38216	13,948,822
Chennai	8357.07	88632.76	290463.12	545713.35	933166	340,605,700
Coimbatore	173.37	1695.16	17925.50	13281.44	33075	12,072,548
Delhi	42271.18	396080.71	2832203.05	2934831.36	6205386	2,264,966,003
Dhanbad	57.99	571.92	5947.64	4342.45	10920	3,985,797
Faridabad	314.06	2773.27	23419.37	22102.07	48609	17,742,198
Hyderabad	11648.84	119740.82	778349.80	853303.93	1763043	643,510,837
Indore	741.28	9300.96	16544.24	49422.37	76009	27,743,232
Jabalpur	192.43	2519.98	4942.10	13230.20	20885	7,622,919
Jaipur	778.26	9444.49	17852.99	51231.31	79307	28,947,074
Jamshedpur	50.98	474.74	6854.32	4010.76	11391	4,157,638
Kanpur	478.12	5618.05	28056.38	32829.46	66982	24,448,435
Kochi	356.52	3281.76	19829.08	24215.56	47683	17,404,266
Kolkata	1766.76	11824.01	350253.40	181910.44	545755	199,200,432
Lucknow	525.69	6035.79	22009.27	35255.32	63826	23,296,513
Ludhiana	1538.45	18254.36	32890.94	99643.73	152327	55,599,527
Madurai	351.82	3816.30	25630.83	25551.36	55350	20,202,863
Meerut	190.53	2239.69	12262.76	13587.61	28281	10,322,416
Mumbai	17054.05	118318.44	1035754.33	1138666.78	2309794	843,074,664
Nagpur	1490.11	17236.53	57340.94	101373.86	177441	64,766,125
Nasik	189.01	1925.90	6551.90	12714.72	21382	7,804,260
Patna	171.84	1882.72	5519.98	11353.07	18928	6,908,578
Pune	3283.53	31799.61	265941.18	252960.47	553985	202,204,449
Rajkot	609.79	7253.45	30011.34	42472.70	80347	29,326,753
Surat	6660.63	71789.57	154609.61	432104.71	665165	242,785,049
Vadodara	661.50	6708.03	15298.91	42766.06	65435	23,883,593
Varanasi	254.08	3219.50	6560.33	17120.47	27154	9,911,349
Vijayawada	221.05	2263.51	20309.94	16604.07	39399	14,380,478
Vishakhapatnam	187.26	2088.61	6333.50	12783.92	21393	7,808,552
Total						6,058,319,026

Table 3.18 : Savings In Health Cost

(Low Cost Estimates) *(Percent)*

Cities	Euro II over Pre Euro	Euro III over Pre Euro	Euro IV over Pre Euro	Euro III over Euro II	Euro IV over Euro III
Agra	89.04	92.19	94.58	28.72	30.62
Ahmedabad	86.32	90.09	93.39	27.54	33.29
Allahabad	93.19	95.92	96.54	40.12	15.01
Amritsar	90.60	93.68	95.33	32.72	26.10
Asansol	59.62	63.70	80.67	10.09	46.74
Bangalore	89.45	92.97	94.81	33.38	26.12
Bhopal	89.55	92.93	94.87	32.32	27.47
Chennai	90.83	94.26	95.48	37.46	21.20
Coimbatore	84.86	88.48	92.68	23.93	36.46
Delhi	87.63	91.23	93.95	29.08	30.96
Dhanbad	85.50	88.97	92.92	23.90	35.85
Faridabad	85.10	89.39	92.85	28.84	32.62
Hyderabad	87.95	91.49	94.10	29.36	30.65
Indore	93.07	95.90	96.46	40.87	13.61
Jabalpur	93.09	95.77	96.47	38.74	16.54
Jaipur	92.82	95.75	96.36	40.79	14.48
Jamshedpur	82.95	86.44	91.74	20.49	39.07
Kanpur	90.43	93.32	95.25	30.13	29.02
Kochi	87.10	91.32	93.80	32.69	28.62
Kolkata	75.58	79.54	88.27	16.22	42.66
Lucknow	91.17	94.23	95.60	34.64	23.76
Ludhiana	92.80	95.81	96.36	41.79	13.19
Madurai	88.29	91.56	94.28	27.93	32.16
Meerut	89.97	92.87	95.02	28.90	30.23
Mumbai	81.62	87.52	91.57	32.11	32.43
Nagpur	91.21	94.34	95.64	35.65	22.94
Nasik	89.96	93.76	95.11	37.87	21.54
Patna	91.30	94.64	95.66	38.40	18.97
Pune	86.10	89.86	93.20	27.07	32.92
Rajkot	90.90	93.84	95.47	32.30	26.54
Surat	91.48	95.04	95.83	41.79	16.04
Vadodara	90.80	94.70	95.54	42.39	15.85
Varanasi	92.94	95.70	96.41	39.02	16.48
Vijayawada	86.33	89.79	93.35	25.27	34.88
Vishakhapatnam	91.07	94.42	95.57	37.51	20.59
Total	87.76	91.52	94.06	30.70	29.97

Table 3.19 : Savings In Health Cost

(High Cost Estimates) *(Percent)*

Cities	Euro II over Pre Euro	Euro III over Pre Euro	Euro IV over Pre Euro	Euro III over Euro II	Euro IV over Euro III
Agra	89.03	92.07	94.53	27.69	30.99
Ahmedabad	86.23	89.85	93.27	26.30	33.69
Allahabad	93.38	96.01	96.58	39.74	14.17
Amritsar	90.67	93.63	95.30	31.74	26.24
Asansoi	58.76	62.88	80.32	9.97	46.99
Bangalore	89.53	92.91	94.77	32.21	26.27
Bhopal	89.61	92.85	94.83	31.20	27.65
Chennai	90.99	94.28	95.48	36.46	20.99
Coimbatore	84.65	88.15	92.53	22.82	36.91
Delhi	87.60	91.06	93.86	27.88	31.36
Dhanbad	85.30	88.66	92.77	22.84	36.29
Faridabad	85.04	89.15	92.72	27.44	32.95
Hyderabad	87.93	91.33	94.02	28.16	30.99
Indore	93.28	96.00	96.50	40.46	12.58
Jabalpur	93.26	95.84	96.50	38.30	15.90
Jaipur	93.03	95.84	96.40	40.30	13.57
Jamshedpur	82.59	86.00	91.54	19.59	39.53
Kanpur	90.44	93.23	95.22	29.22	29.31
Kochi	87.17	91.18	93.72	31.29	28.80
Kolkata	75.02	78.90	88.00	15.53	43.12
Lucknow	91.28	94.22	95.59	33.73	23.75
Ludhiana	93.02	95.90	96.40	41.31	12.12
Madurai	88.23	91.39	94.19	26.84	32.55
Meerut	89.95	92.76	94.97	27.97	30.59
Mumbai	81.67	87.24	91.41	30.42	32.70
Nagpur	91.34	94.35	95.64	34.73	22.85
Nasik	90.15	93.77	95.10	36.72	21.31
Patna	91.49	94.68	95.67	37.50	18.54
Pune	86.01	89.62	93.08	25.82	33.35
Rajkot	90.96	93.80	95.45	31.39	26.72
Surat	91.73	95.12	95.86	40.98	15.23
Vadodara	91.08	94.78	95.56	41.46	15.01
Varanasi	93.12	95.77	96.44	38.53	15.84
Vijayawada	86.18	89.52	93.22	24.17	35.31
Vishakhapatnam	91.24	94.44	95.57	36.55	20.31
Total	87.77	91.37	93.98	29.44	30.29

Table 3.20 : Annual Health Cost Across Cities in India
(High Cost Estimates) *(In Rs.)*

Cities	Pre Euro	Euro II	Euro III	Euro IV
Agra	268,142,005	29,413,653	21,270,290	14,679,190
Ahmedabad	6,961,402,055	958,408,522	706,369,580	468,415,335
Allahabad	1,710,621,424	113,234,259	68,237,093	58,568,204
Amritsar	708,636,503	66,127,177	45,135,909	33,290,340
Asansol	22,875,783	9,433,214	8,492,382	4,502,098
Bangalore	5,930,441,397	620,693,089	420,764,287	310,232,789
Bhopal	269,670,855	28,021,982	19,280,451	13,948,822
Chennai	7,532,485,945	678,451,855	431,087,480	340,605,700
Coimbatore	161,523,394	24,792,426	19,134,329	12,072,548
Delhi	36,890,222,693	4,575,075,852	3,299,686,768	2,264,966,003
Dhanbad	55,152,037	8,107,656	6,255,728	3,985,797
Faridabad	243,823,961	36,470,358	26,462,300	17,742,198
Hyderabad	10,757,660,669	1,298,019,929	932,508,666	643,510,837
Indore	793,340,603	53,298,233	31,734,428	27,743,232
Jabalpur	218,099,750	14,690,956	9,064,329	7,622,919
Jaipur	804,387,437	56,095,852	33,491,452	28,947,074
Jamshedpur	49,120,902	8,549,799	6,875,127	4,157,638
Kanpur	510,965,940	48,866,860	34,586,304	24,448,435
Kochi	277,246,260	35,577,945	24,445,619	17,404,266
Kolkata	1,659,686,469	414,628,816	350,235,612	199,200,432
Lucknow	528,641,476	46,106,187	30,553,503	23,296,513
Ludhiana	1,544,775,893	107,794,660	63,264,682	55,599,527
Madurai	347,990,514	40,941,610	29,952,650	20,202,863
Meerut	205,362,057	20,647,336	14,872,533	10,322,416
Mumbai	9,820,286,481	1,800,416,400	1,252,721,908	843,074,664
Nagpur	1,485,124,625	128,620,924	83,948,372	64,766,125
Nasik	159,155,783	15,674,157	9,918,015	7,804,260
Patna	159,406,873	13,569,250	8,481,334	6,908,578
Pune	2,922,884,097	408,960,158	303,362,875	202,204,449
Rajkot	645,011,992	58,329,756	40,021,410	29,326,753
Surat	5,866,943,059	485,252,167	286,399,355	242,785,049
Vadodara	537,912,375	48,002,222	28,100,989	23,883,593
Varanasi	278,459,729	19,159,629	11,776,967	9,911,349
Vijayawada	212,149,901	29,316,706	22,230,924	14,380,478
Vishakhapatnam	176,313,585	15,444,428	9,798,843	7,808,552
Total	100,715,924,521	12,316,194,023	8,690,522,492	6,058,319,026

Table 4.1				
Reduction in Emission Per Litre				
(Due to Upgradation to Euro III) (Kg/L)				
	CO	HC	NOX	PM
2 Wheeler	0.306	0.155	0.013	0.135
3 Wheeler	0.347	0.227	-0.002	0.008
Car	0.038	0.010	0.015	0.000
Jeep	0.009	0.004	0.003	0.005
Taxi	0.038	0.010	0.015	0.000
Bus	0.009	0.002	0.031	0.006
Truck	0.008	0.002	0.015	0.003
L.C.V.	0.044	0.002	0.014	0.003

Table 4.2	
Fuel Efficiency	
Type	*Km/L*
2 Wheeler	60
3 Wheeler	30
Car	15
Jeep	14
Taxi	15
Bus	4.5
Truck	4.5
L.C.V.	7

Table 4.3				
Consumption of MS (Litres)				
Cities	2-wheelers	3-wheelers	Cars	Total
Agra	33528	4850	9338	47715
Ahmedabad	253032	102512	161076	516620
Allahabad	182192	4262	48812	235267
Amritsar	44346	4641	20254	69241
Asansol	367	143	1763	2273
Bangalore	359088	103043	277700	739831
Bhopal	55482	15764	9346	80592
Chennai	542096	131559	485439	1159094
Coimbatore	19851	7192	6142	33185
Delhi	652308	119838	1217301	1989448
Dhanbad	18871	3902	11500	34272
Faridabad	19687	13018	14770	47474
Hyderabad	317133	102905	118373	538411
Indore	93160	5962	20324	119445
Jabalpur	51064	1431	3195	55690
Jaipur	74496	6509	26289	107294
Jamshedpur	10281	1853	10106	22240
Kanpur	68237	661	33188	102086
Kochi	41673	25819	28267	95758
Kolkata	53928	21043	130370	205341
Lucknow	96954	9581	54077	160611
Ludhiana	85603	8959	39097	133659
Madurai	22337	4651	6911	33899
Meerut	37133	1355	9949	48437
Mumbai	210818	333800	347753	892371
Nagpur	86223	15216	20841	122281
Nasik	22550	10350	11082	43982
Patna	24689	5367	14004	44059
Pune	153215	67663	73858	294736
Rajkot	43468	3583	11814	58864
Surat	144889	52098	57399	254386
Vadodara	41437	20598	22180	84216
Varanasi	38148	1214	10221	49583
Vijayawada	13522	3732	3415	20670
Vishakhapatnam	23376	6452	5941	35768
Total	3935178	1221524	3322095	8478797

Table 4.4

Consumption of Diesel (Litres)

Cities	Jeeps	Taxis	Buses	Trucks	L.C.V.s	Total
Agra	2263	771	18000	42222	296	63552
Ahmedabad	15207	19919	207033	503216	41198	786573
Allahabad	11829	4032	10416	32239	511	59026
Amritsar	7766	4055	12235	37868	511	62435
Asansol	0	79	18383	56897	511	75870
Bangalore	13491	25336	188444	226222	12852	466346
Bhopal	10336	1416	19027	58891	511	90181
Chennai	21416	1903	135556	231111	511	390496
Coimbatore	271	24	19683	60921	511	81409
Delhi	0	54772	633556	558667	511	1247505
Dhanbad	6785	3208	17078	52860	511	80442
Faridabad	5664	2957	15049	46580	511	70761
Hyderabad	69840	33019	233778	356222	69545	762404
Indore	22477	3080	5721	5888	511	37677
Jabalpur	3534	484	6656	6850	511	18035
Jaipur	10081	5263	6564	6755	511	29174
Jamshedpur	446	39	14239	44071	511	59305
Kanpur	8044	2742	16222	87111	726	114844
Kochi	10639	5659	19993	61881	511	98883
Kolkata	0	36801	373556	216444	511	627311
Lucknow	13106	4467	20709	64097	511	102890
Ludhiana	14992	7828	5156	5306	511	33792
Madurai	305	27	12196	37749	511	50788
Meerut	293	5004	15022	46494	511	67324
Mumbai	28823	137883	222222	564889	511	954327
Nagpur	7608	4493	17051	52776	511	82440
Nasik	1046	1370	7858	8087	511	18872
Patna	7530	3400	5203	5355	511	22000
Pune	16669	11422	189861	192466	41198	451616
Rajkot	1115	1461	12132	37552	511	52771
Surat	5419	7098	12149	37604	511	62780
Vadodara	2094	2743	6218	6399	511	17965
Varanasi	2477	844	5021	5167	511	14020
Vijayawada	2015	953	10598	32804	511	46881
Vishakhapatnam	3505	1657	6388	6575	511	18636
Total	327286	396210	2518971	3796239	180625	7219332

Table 4.5				
Share of Consumption per Litre of MS				
Cities	2-wheelers	3-wheelers	Cars	Total
Agra	0.703	0.102	0.196	1.000
Ahmedabad	0.490	0.198	0.312	1.000
Allahabad	0.774	0.018	0.207	1.000
Amritsar	0.640	0.067	0.293	1.000
Asansol	0.161	0.063	0.776	1.000
Bangalore	0.485	0.139	0.375	1.000
Bhopal	0.688	0.196	0.116	1.000
Chennai	0.468	0.114	0.419	1.000
Coimbatore	0.598	0.217	0.185	1.000
Delhi	0.328	0.060	0.612	1.000
Dhanbad	0.551	0.114	0.336	1.000
Faridabad	0.415	0.274	0.311	1.000
Hyderabad	0.589	0.191	0.220	1.000
Indore	0.780	0.050	0.170	1.000
Jabalpur	0.917	0.026	0.057	1.000
Jaipur	0.694	0.061	0.245	1.000
Jamshedpur	0.462	0.083	0.454	1.000
Kanpur	0.668	0.006	0.325	1.000
Kochi	0.435	0.270	0.295	1.000
Kolkata	0.263	0.102	0.635	1.000
Lucknow	0.604	0.060	0.337	1.000
Ludhiana	0.640	0.067	0.293	1.000
Madurai	0.659	0.137	0.204	1.000
Meerut	0.767	0.028	0.205	1.000
Mumbai	0.236	0.374	0.390	1.000
Nagpur	0.705	0.124	0.170	1.000
Nasik	0.513	0.235	0.252	1.000
Patna	0.560	0.122	0.318	1.000
Pune	0.520	0.230	0.251	1.000
Rajkot	0.738	0.061	0.201	1.000
Surat	0.570	0.205	0.226	1.000
Vadodara	0.492	0.245	0.263	1.000
Varanasi	0.769	0.024	0.206	1.000
Vijayawada	0.654	0.181	0.165	1.000
Vishakhapatnam	0.654	0.180	0.166	1.000
Total	0.464	0.144	0.392	1.000

Table 4.6						
Share of Consumption per Litre of Diesel						
Cities	Jeeps	Taxis	Buses	Trucks	L.C.V.s	Total
Agra	0.036	0.012	0.283	0.664	0.005	1.000
Ahmedabad	0.019	0.025	0.263	0.640	0.052	1.000
Allahabad	0.200	0.068	0.176	0.546	0.009	1.000
Amritsar	0.124	0.065	0.196	0.607	0.008	1.000
Asansol	0.000	0.001	0.242	0.750	0.007	1.000
Bangalore	0.029	0.054	0.404	0.485	0.028	1.000
Bhopal	0.115	0.016	0.211	0.653	0.006	1.000
Chennai	0.055	0.005	0.347	0.592	0.001	1.000
Coimbatore	0.003	0.000	0.242	0.748	0.006	1.000
Delhi	0.000	0.044	0.508	0.448	0.000	1.000
Dhanbad	0.084	0.040	0.212	0.657	0.006	1.000
Faridabad	0.080	0.042	0.213	0.658	0.007	1.000
Hyderabad	0.092	0.043	0.307	0.467	0.091	1.000
Indore	0.597	0.082	0.152	0.156	0.014	1.000
Jabalpur	0.196	0.027	0.369	0.380	0.028	1.000
Jaipur	0.346	0.180	0.225	0.232	0.018	1.000
Jamshedpur	0.008	0.001	0.240	0.743	0.009	1.000
Kanpur	0.070	0.024	0.141	0.759	0.006	1.000
Kochi	0.110	0.057	0.202	0.626	0.005	1.000
Kolkata	0.000	0.059	0.595	0.345	0.001	1.000
Lucknow	0.127	0.043	0.201	0.623	0.005	1.000
Ludhiana	0.444	0.232	0.153	0.157	0.015	1.000
Madurai	0.006	0.001	0.240	0.743	0.010	1.000
Meerut	0.004	0.074	0.223	0.691	0.008	1.000
Mumbai	0.030	0.144	0.233	0.592	0.001	1.000
Nagpur	0.092	0.055	0.207	0.640	0.006	1.000
Nasik	0.055	0.073	0.416	0.429	0.027	1.000
Patna	0.342	0.155	0.237	0.243	0.023	1.000
Pune	0.037	0.025	0.420	0.426	0.091	1.000
Rajkot	0.021	0.028	0.230	0.712	0.010	1.000
Surat	0.086	0.113	0.194	0.599	0.008	1.000
Vadodara	0.117	0.153	0.346	0.356	0.028	1.000
Varanasi	0.177	0.060	0.358	0.369	0.036	1.000
Vijayawada	0.043	0.020	0.226	0.700	0.011	1.000
Vishakhapatnam	0.188	0.089	0.343	0.353	0.027	1.000
Total	0.045	0.055	0.349	0.526	0.025	1.000

Table 4.7			
Vehiclewise Savings in Health Cost (MS)			
(Low Cost Estimate)			(Rs/L)
Cities	2 Wheelers	3 Wheelers	Cars
Agra	1.345	0.100	0.022
Ahmedabad	4.168	0.309	0.068
Allahabad	1.765	0.131	0.029
Amritsar	2.775	0.206	0.046
Asansol	0.751	0.056	0.012
Bangalore	2.781	0.206	0.046
Bhopal	0.822	0.061	0.014
Chennai	2.442	0.181	0.040
Coimbatore	1.176	0.087	0.019
Delhi	8.808	0.653	0.145
Dhanbad	0.426	0.032	0.007
Faridabad	1.804	0.134	0.030
Hyderabad	5.406	0.401	0.089
Indore	1.591	0.118	0.026
Jabalpur	0.801	0.059	0.013
Jaipur	2.007	0.149	0.033
Jamshedpur	0.635	0.047	0.010
Kanpur	1.292	0.096	0.021
Kochi	1.042	0.077	0.017
Kolkata	2.516	0.187	0.041
Lucknow	0.964	0.072	0.016
Ludhiana	3.348	0.248	0.055
Madurai	2.530	0.188	0.042
Meerut	0.944	0.070	0.016
Mumbai	5.812	0.431	0.095
Nagpur	3.064	0.227	0.050
Nasik	1.216	0.090	0.020
Patna	1.145	0.085	0.019
Pune	2.861	0.212	0.047
Rajkot	2.610	0.194	0.043
Surat	7.303	0.542	0.120
Vadodara	2.299	0.171	0.038
Varanasi	1.362	0.101	0.022
Vijayawada	2.378	0.176	0.039
Vishakhapatn	1.337	0.099	0.022
Total	2.386	0.177	0.039

Table 4.8					
Vehiclewise Savings in Health Cost (HSD)					
(Low Cost Estimate) Rs/L					
Cities	**Jeeps**	**Taxis**	**Buses**	**Trucks**	**L.C.V.s**
Agra	0.05	0.02	0.09	0.05	0.05
Ahmedabad	0.17	0.07	0.29	0.15	0.15
Allahabad	0.07	0.03	0.12	0.06	0.06
Amritsar	0.11	0.05	0.19	0.10	0.10
Asansol	0.03	0.01	0.05	0.03	0.03
Bangalore	0.11	0.05	0.19	0.10	0.10
Bhopal	0.03	0.01	0.06	0.03	0.03
Chennai	0.10	0.04	0.17	0.09	0.08
Coimbatore	0.05	0.02	0.08	0.04	0.04
Delhi	0.35	0.14	0.62	0.32	0.31
Dhanbad	0.02	0.01	0.03	0.02	0.01
Faridabad	0.07	0.03	0.13	0.06	0.06
Hyderabad	0.22	0.09	0.38	0.19	0.19
Indore	0.06	0.03	0.11	0.06	0.06
Jabalpur	0.03	0.01	0.06	0.03	0.03
Jaipur	0.08	0.03	0.14	0.07	0.07
Jamshedpur	0.03	0.01	0.04	0.02	0.02
Kanpur	0.05	0.02	0.09	0.05	0.04
Kochi	0.04	0.02	0.07	0.04	0.04
Kolkata	0.10	0.04	0.18	0.09	0.09
Lucknow	0.04	0.02	0.07	0.03	0.03
Ludhiana	0.13	0.06	0.23	0.12	0.12
Madurai	0.10	0.04	0.18	0.09	0.09
Meerut	0.04	0.02	0.07	0.03	0.03
Mumbai	0.23	0.10	0.41	0.21	0.20
Nagpur	0.12	0.05	0.21	0.11	0.11
Nasik	0.05	0.02	0.09	0.04	0.04
Patna	0.05	0.02	0.08	0.04	0.04
Pune	0.11	0.05	0.20	0.10	0.10
Rajkot	0.10	0.04	0.18	0.09	0.09
Surat	0.29	0.12	0.51	0.26	0.25
Vadodara	0.09	0.04	0.16	0.08	0.08
Varanasi	0.05	0.02	0.10	0.05	0.05
Vijayawada	0.10	0.04	0.17	0.09	0.08
Vishakhapat	0.05	0.02	0.09	0.05	0.05
Total	0.10	0.04	0.17	0.09	0.08

Table 4.9

Vehiclewise Savings in Health Cost (MS)

(High Cost Estimate) (Rs/L)

Cities	2 Wheelers	3 Wheelers	Cars
Agra	4.472	3.498	2.116
Ahmedabad	13.859	10.841	6.558
Allahabad	5.867	4.589	2.776
Amritsar	9.226	7.217	4.366
Asansol	2.496	1.953	1.181
Bangalore	9.247	7.234	4.376
Bhopal	2.733	2.138	1.293
Chennai	8.121	6.353	3.843
Coimbatore	3.910	3.058	1.850
Delhi	29.286	22.909	13.859
Dhanbad	1.418	1.109	0.671
Faridabad	5.998	4.692	2.838
Hyderabad	17.973	14.060	8.505
Indore	5.291	4.139	2.504
Jabalpur	2.664	2.084	1.261
Jaipur	6.672	5.219	3.157
Jamshedpur	2.112	1.652	0.999
Kanpur	4.295	3.360	2.032
Kochi	3.463	2.709	1.639
Kolkata	8.364	6.543	3.958
Lucknow	3.206	2.508	1.517
Ludhiana	11.133	8.708	5.268
Madurai	8.412	6.580	3.981
Meerut	3.137	2.454	1.485
Mumbai	19.324	15.116	9.144
Nagpur	10.187	7.969	4.821
Nasik	4.044	3.163	1.914
Patna	3.807	2.978	1.801
Pune	9.514	7.442	4.502
Rajkot	8.679	6.789	4.107
Surat	24.281	18.994	11.490
Vadodara	7.644	5.979	3.617
Varanasi	4.528	3.542	2.143
Vijayawada	7.908	6.186	3.742
Vishakhapatn	4.445	3.477	2.104
Total	7.935	6.207	3.755

Table 4.10
Vehiclewise Savings in Health Cost (HSD)
(High Cost Estimate) Rs/L

Cities	Jeeps	Taxis	Buses	Trucks	L.C.V.s
Agra	0.433	2.116	4.103	2.068	1.882
Ahmedabad	1.342	6.558	12.715	6.409	5.831
Allahabad	0.568	2.776	5.383	2.713	2.469
Amritsar	0.894	4.366	8.464	4.267	3.882
Asansol	0.242	1.181	2.290	1.154	1.050
Bangalore	0.896	4.376	8.484	4.277	3.891
Bhopal	0.265	1.293	2.507	1.264	1.150
Chennai	0.787	3.843	7.450	3.756	3.417
Coimbatore	0.379	1.850	3.587	1.808	1.645
Delhi	2.837	13.859	26.869	13.544	12.323
Dhanbad	0.137	0.671	1.301	0.656	0.597
Faridabad	0.581	2.838	5.503	2.774	2.524
Hyderabad	1.741	8.505	16.490	8.312	7.563
Indore	0.512	2.504	4.854	2.447	2.226
Jabalpur	0.258	1.261	2.444	1.232	1.121
Jaipur	0.646	3.157	6.121	3.085	2.807
Jamshedpur	0.205	0.999	1.937	0.977	0.889
Kanpur	0.416	2.032	3.940	1.986	1.807
Kochi	0.335	1.639	3.177	1.601	1.457
Kolkata	0.810	3.958	7.674	3.868	3.520
Lucknow	0.311	1.517	2.941	1.482	1.349
Ludhiana	1.078	5.268	10.214	5.148	4.684
Madurai	0.815	3.981	7.717	3.890	3.539
Meerut	0.304	1.485	2.878	1.451	1.320
Mumbai	1.872	9.144	17.729	8.937	8.131
Nagpur	0.987	4.821	9.346	4.711	4.286
Nasik	0.392	1.914	3.710	1.870	1.702
Patna	0.369	1.801	3.492	1.760	1.602
Pune	0.922	4.502	8.728	4.400	4.003
Rajkot	0.841	4.107	7.962	4.014	3.652
Surat	2.352	11.490	22.277	11.229	10.217
Vadodara	0.740	3.617	7.013	3.535	3.216
Varanasi	0.439	2.143	4.154	2.094	1.905
Vijayawada	0.766	3.742	7.255	3.657	3.327
Vishakhapat	0.431	2.104	4.078	2.056	1.871
Total	0.769	3.755	7.280	3.669	3.339

Table 5.1
Annual Benefit Loss
Low Cost Estimate (Rs).

	CO	HC	NOX	PM	Total
Agra	1,804	5,926	234,234	16,228,705	16,470,670
Ahmedabad	75,780	247,264	7,001,553	389,679,952	397,004,549
Allahabad	6,075	42,699	1,236,642	112,579,205	113,864,620
Amritsar	4,310	19,951	611,676	43,754,651	44,390,588
Asansol	600	-1,681	56,719	350,864	406,503
Bangalore	42,579	226,004	4,887,303	360,458,564	365,614,450
Bhopal	1,927	9,835	209,715	16,387,859	16,609,335
Chennai	40,711	295,527	5,612,001	472,429,598	478,377,838
Coimbatore	1,663	3,673	164,581	8,698,947	8,868,865
Delhi	384,885	1,014,610	42,428,258	2,105,573,719	2,149,401,472
Dhanbad	563	1,216	62,026	2,966,910	3,030,715
Faridabad	2,887	13,132	232,512	13,264,302	13,512,834
Hyderabad	110,496	386,067	10,213,193	625,792,711	636,502,466
Indore	3,083	23,910	551,432	51,947,321	52,525,746
Jabalpur	798	5,020	152,622	14,349,886	14,508,326
Jaipur	3,521	26,012	588,763	52,520,935	53,139,232
Jamshedpur	530	287	60,593	2,465,082	2,526,492
Kanpur	2,850	9,274	467,376	31,269,800	31,749,301
Kochi	2,882	16,611	232,648	15,953,897	16,206,038
Kolkata	66,774	-6,464	4,422,577	61,675,938	66,158,825
Lucknow	2,768	15,029	431,014	33,130,908	33,579,718
Ludhiana	7,052	55,151	1,144,300	100,697,959	101,904,461
Madurai	2,629	8,301	311,391	20,464,284	20,786,605
Meerut	1,373	3,833	196,386	12,503,046	12,704,639
Mumbai	276,922	1,078,770	14,803,439	486,117,882	502,277,014
Nagpur	8,586	49,741	1,133,634	93,821,933	95,013,895
Nasik	1,209	8,586	110,102	9,896,533	10,016,431
Patna	1,007	6,928	124,459	10,038,011	10,170,405
Pune	33,772	100,383	2,838,741	163,426,607	166,399,503
Rajkot	3,552	14,800	533,106	40,304,295	40,855,754
Surat	36,639	302,819	3,875,336	376,823,963	381,038,757
Vadodara	3,914	33,474	342,810	34,186,303	34,566,501
Varanasi	1,052	6,834	202,283	18,237,249	18,447,418
Vijayawada	2,044	5,230	212,667	11,817,231	12,037,171
Vishakhapatnam	1,128	7,466	125,944	11,148,720	11,283,259
Total	1,138,365	4,036,220	105,812,038	5,820,963,770	5,931,950,393

Table 5.2
Annual Benefit Loss
High Cost Estimate

	CO	HC	NOX	PM	Total
Agra	18043	66101	3438385	221437965	224,960,493
Ahmedabad	757800	2757945	102777516	5317117714	5,423,410,975
Allahabad	60747	476253	18152965	1536124406	1,554,814,372
Amritsar	43098	222536	8978944	597024884	606,269,462
Asansol	6005	-18747	832599	4787483	5,607,340
Bangalore	425786	2520817	71741912	4918396771	4,993,085,287
Bhopal	19272	109697	3078451	223609588	226,817,008
Chennai	407112	3296266	82379943	6446222785	6,532,306,106
Coimbatore	16634	40967	2415931	118695678	121,169,211
Delhi	3848849	11316809	622814800	28730200931	29,368,181,389
Dhanbad	5633	13559	910496	40482993	41,412,681
Faridabad	28865	146475	3413106	180989187	184,577,633
Hyderabad	1104955	4306129	149921958	8538836788	8,694,169,831
Indore	30827	266688	8094608	708812500	717,204,623
Jabalpur	7980	55989	2240380	195801793	198,106,142
Jaipur	35214	290133	8642603	716639367	725,607,315
Jamshedpur	5298	3197	889458	33635637	34,533,591
Kanpur	28500	103445	6860734	426671189	433,663,867
Kochi	28816	185277	3415097	217688253	221,317,444
Kolkata	667744	-72100	64920098	841557843	907,073,586
Lucknow	27676	167627	6326960	452065690	458,587,953
Ludhiana	70517	615148	16797458	1374006788	1,391,489,910
Madurai	26288	92586	4570987	279231728	283,921,589
Meerut	13727	42758	2882801	170601974	173,541,261
Mumbai	2769217	12032439	217303315	6632997130	6,865,102,102
Nagpur	85864	554800	16640894	1280184574	1,297,466,133
Nasik	12092	95772	1616215	135036536	136,760,615
Patna	10066	77274	1826961	136966982	138,881,283
Pune	337719	1119660	41670575	2229928691	2,273,056,645
Rajkot	35525	165077	7825593	549945362	557,971,558
Surat	366393	3377601	56887007	5141699893	5,202,330,894
Vadodara	39144	373361	5032196	466466381	471,911,082
Varanasi	10524	76224	2969355	248844211	251,900,314
Vijayawada	20435	58334	3121793	161244135	164,444,697
Vishakhapatnam	11280	83280	1848767	152122418	154,065,745
Total	11,383,649	45,019,376	1,553,240,862	79,426,076,246	81,035,720,134