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Sushmita Chatterjee, Kishore K. Dhavala and M.N.Murty

Institute of Economic Growth
Delhi University Enclave
Delhi-110007
India

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Abstract

This paper provides a method of estimation of physical and monetary accounts of air pollution from the road transport. Using the data from the secondary sources and a vehicular survey, estimates of annual air pollution abatement cost for the vehicles (passenger cars, trucks, buses and two wheelers) complying with Euro norms are made for the road transport sector in Andhra Pradesh (AP) and Himachal Pradesh HP) states. The pollution abatement cost of each vehicle comprises the cost of upgrading the vehicular technology and the cost of improving fuel quality. For example, this cost estimate is Rs. 32309.54 million for AP in the year 2001-2002 and Rs. 3688. 72 million for HP in the year 2002-2003 at current prices and it forms 2.134 percent and 5.88 percent of State Domestic Product of the respective states.

Contact Address of authors:
Institute of Economic Growth,
Delhi University Enclave,
Delhi-110007,
India.
Phone: 91-11-55176326 (Res.)
91-11-27667101 (O)
Fax: 91-11-27667410
Email: mnm@iegindia.org

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I Introduction

Transport, especially the road transport is one of most air polluting activities in the economy. Burning of fossil fuels by vehicles contribute air pollution loads in the form of Carbon Monoxide (CO), Hydrocarbons (H), Nitric Oxide (NO_x), Particulate Matter (PM). For example a passenger car without an emission reduction technology (pre Euro technology) emits 0.0002 kilograms (kgs) of PM and 0.0009 kgs of NO_x per every kilometer (km) distance traveled[1]. The pollution concentration in the atmosphere particularly in the metropolitan areas in India has been much above the safe standards due to a phenomenal growth of traffic demand in India during the recent years. The number of vehicles on roads have increased from mere 306 thousands in the year 1951 to 58863 thousands in the year 2002 as shown in Table A1.1 in Appendix A1. Currently roads carry 85 percent of the passenger and 70 percent of the freight traffic of the country.

Some recent estimates show that a passenger car travels on the average 30-35 kms per day in India[2] and there are about 7571 thousand cars on road. The per day pollution loads of PM from the passenger cars without an emission reduction technology is estimated as 62.25 thousand kgs. In contrast, the technology of emission reduction corresponding to EURO II norms provides for the reduction of PM emissions of cars to 0.00001 kgs per km traveled. That means if all the cars operating on roads in India comply with the EURO II norms, the pollution load of PM reduces from 62.25 thousands to 9.27 thousand kgs per day. Similar estimates for other pollutants are reported in Table-1. The physical accounts of air pollution loads from the transport sector in India could be estimated as loads with and without emission reduction technologies. Table 1 provides these estimates for different pollutants and for different vehicle types in India.

[1] See Table 1 for information about other vehicles.
[2] See Masheker Committee Report.

Table 1: Vehicular Traffic and Air Pollution Loads in India

	TW	CAR	BUS	TRUCK	Others
No. of Veh(1000)	41478	7571	669	3045	6100
Avg. Dist/day km	30.99	34.99	37.76	32.675	36.19
Dist km(1000)	1285403.2	264909.29	25261.44	99495.375	220759
Load Per Day	**1000 kgs**				
CO	5141.61	675.52	113.68	497.48	1523.24
HC	4241.83	154.97	30.31	99.50	61.81
NO_x	77.12	237.09	424.39	795.96	549.69
PM	128.54	62.25	40.42	79.60	110.38
Load Per Day as Per Euro II					
CO	1799.56	260.94	70.73	278.59	141.29
HC	1696.73	26.49	19.45	76.61	12.36
NO_X	51.42	75.50	252.61	497.48	110.38
PM	51.42	9.27	5.81	9.95	11.04
Load Reduction Required as per **Euro II Norms**	**1000 kgs**				
CO	3342.05	414.58	42.94	218.89	1381.95
HC	2545.10	128.48	10.86	22.88	49.45
NO_X	25.71	161.59	171.78	298.49	439.31
PM	77.12	52.98	34.61	69.65	99.34
Concentration	**kg/km**				
	Bus	**Trucks**	**PCG**	**2W**	**Others**
Pre Euro (1996-00)					
CO	0.0045	0.0050	0.0026	0.0040	0.0069
HC	0.0012	0.0010	0.0006	0.0033	0.0003
NOX	0.0168	0.0080	0.0009	0.0001	0.0025
PM	0.0016	0.0008	0.0002	0.0001	0.0005
Euro 3					
CO	0.0028	0.0028	0.0010	0.0014	0.0006
HC	0.0008	0.0008	0.0001	0.0013	0.0001
NOX	0.0100	0.0050	0.0003	0.0000	0.0005
PM	0.0002	0.0001	0.0000	0.0000	0.0001

Monetary accounts of air pollution abatement from the transport sector in India could be developed given the physical accounts described above if there are estimates of cost of pollution abatement per km traveled for different vehicles.

II Emissions and Air Pollution Abatement Technologies

Vehicular Technologies in India have seen improvement only in the recent years. Vehicles with old technologies (Pre Euro) constitute a large number, though the vehicle age in major cities is reducing. There is an urgent need to reduce vehicular emissions. In this context, the Expert Committee on Auto Fuel Policy (Mashlekar, 2002) has recommended an Auto Fuel Policy to address the issues of vehicular emissions, vehicular technologies, and auto fuel quality in a cost efficient manner. It recognizes that efficient transport is an essential service and it is also conscious of the health implications and social costs of automobile emissions and the need to neutralize the costs to the extent it is feasible. The Committee puts forth that the primary requirement of the Auto fuel policy is to formulate measures that will help reduce auto emissions and improve air quality. Upgrading auto fuel quality and vehicular technology to levels that are compatible with the emission norms are crucial components in any strategy that aims at reducing auto emissions and improving air quality. Particularly, investments are needed to enable the automobile industry to produce vehicles that are compatible with the recommended emission norms. In this context, the report provides estimates of investments that are needed by the automobile industry and oil producing companies in India. In the past two decades, investments have been made in the infrastructure, design and development of vehicles. With the commencement of the formal emission standards for vehicles in 1991, a number of steps have been taken to improve the energy efficiency of vehicles and reduce their environmental effects.

Some emission norms were there in India before the year 2000 which are known as pre Euro norms. Bharat Stage I norms or Euro I norms were introduced in April 2000 for all new vehicles. Bharat Stage II norms or Euro II were introduced in Delhi in the year 2000 and were extended to other metro cities in the year 2001. Bharat Stage III or Euro III norms are currently being considered for all the vehicles. Table 2 provides information about these norms. The Society of Indian Automobile Manufacturers (SIAM) has provided estimates of incremental costs for the manufacture of vehicles that are compatible with Bharat Stage II/Euro II and Euro III equivalent fuel quality which are given in Table 3. The Energy Research Institute (TERI), which undertook a study on

`Incentives for Cleaner Automobiles' has also estimated the incremental costs to be incurred by the manufacturers for producing Bharat Stage II and Euro III equivalent emission compatible vehicles, which are given in Table 4. Tables 5 and 6 provide estimates of incremental production costs to refineries of different vintages in India for producing petrol and diesel of improved quality compatible with the Euro norms.

Table 2: Emission coefficients of various pollutants (CO, NO_X, HC AND PM) corresponding to different emission technologies

Pre Euro (1991-95)	Buses	Trucks	PCG	PCD	2W	LCV (Tractor, water carrier)
CO	0.0055	0.006	0.0098	0.0073	0.0065	0.0087
HC	0.0018	0.002	0.0017	0.00037	0.0039	0.00034
NOX	0.019	0.01	0.0018	0.00277	0.00003	0.00315
PM	0.003	0.002	0.00006	0.00084	0.00023	0.0008
Pre Euro (1996-00)						
CO	0.0045	0.005	0.0039	0.0012	0.004	0.0069
HC	0.0012	0.001	0.0008	0.00037	0.0033	0.00028
NOX	0.0168	0.008	0.0011	0.00069	0.00006	0.00249
PM	0.0016	8E-04	0.00005	0.00042	0.0001	0.0005

Emission Coefficients (Kg/Km)						
Euro 1/India stage 2000	**Buses**	**Trucks**	**PCG**	**PCD**	**2W**	**LCV (Tractor, water carrier)**
CO	0.0036	0.0036	0.0024	0.0011	0.0022	0.0051
HC	0.00097	0.00097	0.00048	0.00025	0.00213	0.00014
NOX	0.0126	0.0063	0.00039	0.00059	0.00006	0.00128
PM	0.00056	0.00028	0.00004	0.00014	0.00005	0.0002
Euro 2/Bharat Stage 2I						
CO	0.0032	0.0032	0.0022	0.001	0.0015	0.00072
HC	0.00087	0.00087	0.00035	0.00014	0.001425	0.000063
NOX	0.011	0.0055	0.00015	0.00056	0.000075	0.00059
PM	0.00024	0.00012	0.00003	0.00008	0.00005	0.00007

Emission Coefficients (Kg/Km)					
Euro 3/ Bharat Stage 3	**Buses**	**Trucks**	**PCG**	**PCD**	**LCV(Tractor, water carrier)**
CO	0.0028	0.0028	0.00139	0.00058	0.00064
HC	0.00077	0.00077	0.00015	0.00005	0.000056
NOX	0.01	0.005	0.00012	0.00045	0.0005
PM	0.00023	0.0001	0.00002	0.00005	0.00005

Source: Transport Fuel Quality, 2005, CPCB, Delhi

Table 3: Incremental cost of Bharat Stage II and Euro III equivalent vehicles

VEHICLE CATEGORY	CONVERSION	INCREMENTAL COST/VEHICLE (Rs. Lakh)
Passenger car	Bharat II to Euro III	0.5
Trucks	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	1.25 2.25
Buses	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	1.25 2.25
Two and Three Wheelers	Bharat 2000 to Euro III	0.05-0.10

Source: SIAM.

Table 4: Incremental Cost of Bharat Stage II and Euro III Equivalent Vehicles

VEHICLE CATEGORY	CONVERSION	INCREMENTAL COST/VEHICLE Rs.Lakh)
Passenger car	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	0.3 0.5
Trucks	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	0.61 1.62
Buses	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	0.61 1.62
Two Wheelers	Bharat 2000 to Euro III	0.35-0.52
Three Wheelers	Bharat 2000 to Euro III	0.55

Source: TERI

Table 5: Incremental production cost for petrol

Sl. No.	Refineries	BIS-2000 to *Bharat Stage II* Rs./litre	BIS-2000 to *Euro III* Rs./litre
1	IOCL, Digboi	1.38	4.03
2	IOCL, Barauni	1.71	3.20
3	IOCL, Halda	0.60	1.45
4	IOCL, Gujarat	1.00	2.35
5	IOCL, Mathura	1.11	1.94
6	ICOL, Panipat	0.80	1.71
7	HPCL, Mumbai	2.80	3.95
8	HPCL, Vaiskh	1.50	4.00
9	BPCL, Mumbai	0.50	2.10
10	KRL. Kochi	0.98	3.17
11	CPCL, Chennai	1.50	1.80
12	BRPL, Bongaigaon	Nil*	3.90
13	RPL, Jamnagar	Nil*	0.60
14	MRPL, Managalore	Nil*	2.50

*Have set up Facilities for *Euro II* equivalent

Source : Ministry of Petroleum and Natural Gas

Table 6: Incremental production cost for diesel

Sl. No.	Refineries	BIS-2000 to *Bharat Stage II* Rs./litre	BIS-2000 to *Euro III* Rs./litre
1	IOCL, Digboi	3.35	4.11
2	IOCL, Guwahati	2.50	2.70
3	IOCL, Barauni	1.60	2.10
4	IOCL, Gujarat	0.84	1.03
5	IOCL, Halda	1.16	1.24
6	IOCL, Mathura	1.23	1.41
7	ICOL, Panipat	0.83	0.93
8	HPCL, Mumbai	1.40	2.00
9	HPCL, Vaiskh	1.50	2.00
10	BPCL, Mumbai	1.50	2.40
11	KRL. Kochi	0.73	2.15
12	CPCL, Chennai	1.30	1.60
13	BRPL, Bongaigaon	1.90	2.20
14	NRL, Numaligarh	0.51	0.98
15	RPL, Jamnagar	0.25	0.90
16	MRPL, Managalore	1.00	1.10

(I) Import parity premium differential between BIS-2000 and Bharat Stage II petrol and diesel, inclusive of 20% customs duty, is 20 paise per litre and 40 paise per liter (approx.)

(ii) Import parity premium differential between BIS-2000 *and Euro III equivalent petrol and diesel, inclusive of* 20% customs duty, is Rs. 1.35 & Rs. 1.50 per litre (approximately)

Source: Ministry of Petroleum and Natural Gas

III Physical Accounts of Air Pollution from Road Transport for Andhra Pradesh and Himachal Pradesh States

Physical accounts of air pollution from the road transport in the two States corresponding to various norms described above could be developed. In fact, using the data on number of vehicles in a state, emission coefficients and distance traveled by each vehicle, one can compute the physical load of each of the pollutants (CO_2, Hydro Carbon, NO_x, and SO_2). It is important to note that emission coefficients are prescribed for CO (carbon monoxide), and hence using the atomic weight of carbon (=12) and oxygen (=16), one can calculate the equivalent load of CO_2 from the pollution load of CO.

Andhra Pradesh:

The data on the number of vehicles plying on the road in each district is obtained from Statistical Abstract of Andhra Pradesh, which gives district-wise number of motor vehicles of different classes and categories registered and on road in the state. Also, average distance traveled per day by each type of vehicle is obtained from Urban Road Traffic and Air Pollution report on Hyderabad. The report gives figures as per outer cordon surveys and fuel station surveys[3]. For district Hyderabad, the study uses the latter whereas for all other 22 districts, outer cordon survey figures have been used. Since the classification of vehicles into different categories is different in the Statistical Abstract Report and the Traffic and Air Pollution Report, certain assumptions have been made in this regard. For calculating the distance traveled by Goods vehicles, a weighted average of the distance traveled by LCV, HCV and MAV has been taken, with the weights being the number of observations for each category of vehicle. Tractors have been assumed to be in the LCV category, taxicabs as OBC (old brand cars) and motorcars and jeeps as a mix of OBC and NBC, thus taking a weighted average of the distance traveled by an OBC and a NBC.

[3] In Outer Cordon Surveys, a total of 7 outer cordon points were selected around Hyderabad and classified traffic volume counts along with road side interviews were conducted on sampling basis for 24 hours at each of these locations.
In Fuel Station Surveys, a total of 15 fuel stations out of 150 stations located in Hyderabad have been selected to conduct interviews of the owners/drivers of vehicles visiting the fuel stations for collecting the fuel. The survey has been conducted round the clock at stations, which were in peripheral areas because the traffic passing through this area is likely to fill fuel at these stations during night hours. In the city, the survey has been conducted for a period of 12 hours.

Data on emission factors for different categories of vehicles for each of the pollutants, CO, NO_X, HC and PM is obtained from Transport Fuel Quality Report, CPCB. However, since the emission factors are available for a few broad heads namely, two-wheelers, three wheelers, PCD, PCG, LCV, buses and trucks, the present study has assumed the emission factors of all Goods vehicles and certain non-transport vehicles (as classified in the Statistical Abstract) such as rigs, cranes, road-rollers, fire engines etc. to be the same as that of trucks. Also, for motorcars, emission factors for PCG and for jeeps, emission factors for PCD have been used.

As regards the methodology, to arrive at the emission of a specific pollutant from a particular category of vehicle, say trucks, one can multiply the emission factor for trucks with the total distance traveled by trucks in a day in each district. Also, an estimate of the total distance traveled is obtained by multiplying the number of trucks plying in each district with the average distance traveled per day by a truck. It is thus possible to arrive at emissions from each category of vehicle for each district and for the state as a whole as also the estimate of total emission of a pollutant for each district and for the entire state.

Similarly, using emission factors corresponding to Bharat Stage II norms, total emissions of various pollutants according to the norms can be generated. The difference between the actual emissions and the emissions according to the norms gives us an estimate of the pollution load to be reduced as per the given norm. Table 7 provides estimates of pollution loads from the vehicular traffic in Andhra Pradesh state during the year 2001-02. The estimates of detailed district wise physical accounts of pollutants for three years during the period 1997-2002 are given in Appendix A2.

Himachal Pradesh:

Data on number of vehicles has been obtained from the Transport Commissioner's Office in Shimla, and the information on distance traveled by different vehicles has been obtained from the primary survey of vehicles conducted in Shimla[4]. Taking the average distance from a sample of 100 vehicles of each category, and multiplying by the emission coefficient of say, CO_2, gives us the per day emissions of CO_2 from a vehicle, which can then be extrapolated for obtaining total emissions of CO_2 by further multiplying by the

[4] For details of vehicular survey in Himachal Pradesh see Section V.

total number of vehicles in the state. Table 8 provides estimates of pollution loads by vehicular traffic in Himachal Pradesh during the year 2002-2003. Tables in Appendix A3 provide detailed physical accounts of air pollution from the road transport in Himachal Pradesh.

Table 7: Pollution loads by vehicular traffic in Andhra Pradesh

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Tones /Year)	*Pre Euro*	369463.9	148887.7	45556.2	9285.2
	Euro II / Bharat II	147389.8	70309.7	30402.7	3157.9
Load Reduced/ Physical Accounts (Tones /Year)	*Pre Euro to Euro II*	222074.1	78578	15153.6	6127.3

Table 8: Pollution loads by vehicular traffic in Himachal Pradesh

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Tones Kg/Year)	*Pre Euro*	49626.5	9220	24248	2920
	Euro I / Bharat 2000	22829.2	5822	16150	940
	Euro II/ Bharat II	17967	4181	13651	452
Load Reduced/ Physical Accounts (Tones /Year)	*Pre Euro to Euro I*	26793	3396	8097	1977
	Pre Euro to Euro II	31657.2	5038	10596	2.47
	Euro I to Euro II	4862	1640	2497	4872

IV Monetary Accounts of Air Pollution

The cost of pollution abatement or the cost of vehicles complying with the emission norms (Euro norms) consists as explained in Chapter II the cost of change of vehicle technology and the cost of improving the fuel quality. The estimates of capital cost of air pollution abatement of different vehicles complying with Euro norms given by TERI and SIAM studies could be used to estimate the per vehicle annual cost of air pollution abatement from the change in vehicular technology. The capital cost of changing vehicle technology could be annualized using the interest rate at which the commercial banks in India are lending currently which is about 10.625 percent during the year 2003-2004.

Table 9 provides these estimates for different types of vehicles. Estimation of the second component of air pollution abatement cost of a vehicle, the cost of improving the fuel quality compatible with the Euro norms, requires data about the incremental production cost of improving the quality of fuels, distance traveled by the vehicle per litre of fuel, and the distance traveled by the vehicle per day. Report of Expert Committee on Auto Fuel Policy (Mashelkar Committee, 2002) provides estimates of incremental production cost of improving the quality of petrol and diesel that is compatible with the Euro norms for refineries of different vintages in India as given in Tables 5 and 6 in Section II. These estimates form a range of Rs. 0.50-2.80 and Rs.0.60-4.03 per litre petrol respectively for Bharat Stage II and Stage III technologies. Similarly, for diesel they form ranges of Rs. 0.25-3.35 and Rs. 0.90-4.11 for these technologies. The vehicular survey in Shimla described in Section V provides estimates of kms traveled per a litre of fuel used, an the average distance per day traveled by different vehicles. Also Mashelkar Committee provides estimates of an estimate of distance traveled per day by different vehicles in Andhra Pradesh. These estimates are used to estimate the incremental fuel cost consumed per day by different vehicles in AP and HP as given in Tables 12 and 13. Tables 14 and 15 provide estimates of incremental annual cost of different vehicles in AP and HP due to the increased cost of fuel from the improvement of fuel quality as per the Euro norms.

Table 9: Annualized incremental cost of investment per vehicle for improving vehicular technology as per Euro norms based on TERI estimates of investment cost

VEHICLE CATEGORY	CONVERSION	ANNUALISED COST/VEHICLE (Rs.)
Passenger car	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	3187.5 5312.5
Trucks	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	6481.25 17212.5
Buses	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	6481.25 17212.5
Two Wheelers	Bharat 2000 to Euro III	4621.87
Three Wheelers	Bharat 2000 to Euro III	5843.75

With the help of information on number of vehicles operating on road in a year for each of the above vehicle categories, one can estimate the total annualized cost of conversion (from one technology to another) of different vehicles operating in a state. Tables 10 and 11 provide the estimates of annualized cost of investment for converting the vehicular technology as per Euro norms respectively in AP and HP.

Table10: Total annualized cost of conversion of technology of different vehicles operating in Andhra Pradesh

Vehicle Category	CONVERSION	Annualized Cost/Vehicle (Rs.)	No. Of Vehicles on road 2001-02	Total Annualized Cost 2001-02 (Rs.)
Passenger car	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	3187.5 5312.5	370398	1180643625 1967739375
Trucks	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	6481.25 17212.5	160185	1038199031 2757184313
Buses	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	6481.25 17212.5	215769	1398452831 3713923913
Two Wheelers	Bharat 2000 to Euro III	4621.87	3609373	16682052788
Three Wheelers	Bharat 2000 to Euro III	5843.75	171834	1004154938

Table11: Total annualized cost of conversion of technology of different vehicles operating in Himachal Pradesh

Vehicle Category	CONVERSION	Annualized Cost/Vehicle (Rs.)	No. Of Vehicles on road 2002-03	Total Annualized Cost 2002-03 (Rs.)
Passenger car	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	3187.5 5312.5	63249	201606187.5 336010312.5
Trucks	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	6481.25 17212.5	37805	245023656.3 650718562.5
Buses	Bharat 2000 to Bharat Stage II Bharat 2000 to Euro III	6481.25 17212.5	4417	28627681.25 76027612.5
Two Wheelers	Bharat 2000 to Euro III	4621.87	149286	689980484.8
Three Wheelers	Bharat 2000 to Euro III	5843.75	2611	15258031.25

Table 12: Incremental production cost of fuel for different vehicles (Rs/day in AP)

Vehicle Category		*Pre Euro to Bharat Stage II / Euro II*	*Pre Euro to Bharat Stage III / Euro III*
PC	High	6.22	8.95
	Low	1.11	1.33
Bus	High	33.03	40.52
	Low	2.46	8.87
Truck	High	36.72	45.05
	Low	2.74	9.87
Jeep	High	11.78	14.46
	Low	0.88	3.17
Two Wheeler	High	2.70	3.89
	Low	0.48	0.58
Commercial Vehicles	High	16.38	20.10
	Low	1.22	4.40

Table 13: Incremental production cost of fuel for different vehicles (Rs/day in HP)

Vehicle Category		*Pre Euro to Bharat Stage II / Euro II*	*Pre Euro to Bharat Stage III / Euro III*
PC	High	6.10	8.77
	Low	1.09	1.31
Bus	High	154.69	189.79
	Low	11.54	41.56
Truck	High	147.81	181.34
	Low	11.03	39.71
Jeep	High	34.70	42.57
	Low	2.59	9.32
Two Wheeler	High	2.40	3.45
	Low	0.43	0.51
Commercial Vehicles	High	62.34	76.48
	Low	4.65	16.75

Table 14: Annualized cost of vehicles for using fuels compatible with Euro norms in AP

VehicleCategory	Pre Euro to Euro II		Pre Euro to Euro III	
	Per Vehicle Cost	Total Cost	Per Vehicle Cost	Total Cost
PC	1337.764	495505110.1	1876.923	695208525.4
Bus	6477.368	1397615216	9014.337	1945014480
Truck	7201.993	1153651249	10022.77	1605497412
Two Wheeler	581.1387	2097546333	815.3552	2942921044

Table 15: Annualized cost of vehicles for using fuels compatible with Euro norms in HP

VehicleCategory	Pre Euro to Euro II		Pre Euro to Euro III	
	Per Vehicle Cost	Total Cost	Per Vehicle Cost	Total Cost
PC	1311.13	82927661.37	1839.55	116349698
Bus	30338.65	134005817.1	42221.28	186491393.8
Truck	28987.57	1095875084	40341.03	1525092639
Two Wheeler	515.88	77013661.68	723.8	108053206.8

V Vehicular Survey in Himachal Pradesh and Estimation of Air Pollution Abatement Cost of Vehicles

5.1 Vehicular Survey

Estimates of cost of air pollution abatement for different vehicles are also obtained using data collected through a primary survey of vehicles in Shimla. As explained in the earlier sections data on distance traveled and fuel consumed per day by different vehicles used in preparing physical and monetary accounts of air pollution from the transport sector in HP are obtained from this survey. The survey of vehicles conducted in Shimla covers a sample of 700 vehicles pertaining to different vehicle categories, namely, buses, trucks, private cars, jeeps, taxicabs, two wheelers and other commercial vehicles. For all these vehicle categories, focus has been on HP registered vehicles. For instance, for the 'bus' category, the survey has been conducted for State Transport buses and HP registered tourist buses. Information has been obtained on the per day distance traveled by the vehicles, model and age of the vehicle, characteristic features such as size of the vehicle, type of fuel used, mileage, cost related information such as fuel cost, maintenance cost and insurance cost, and purchase and current price of the vehicle. Information has also

been obtained on whether the vehicle has undergone any conversion in technology or if it is complying with any particular emission technology such as Pre Euro norm, Bharat Stage 2000 or Euro II. The questionnaire used for the survey is provided in the Appendix A4.

5.2. Estimation of Hedonic Travel Cost Function

The hedonic travel cost function which is a function of various characteristics of the vehicle: size of vehicle, distance traveled per day, and the emission coefficients is estimated for the passenger cars.

$$C = f(Size, Dist, EF)$$

where C: Total per day Cost to the owner of the vehicle

Size: Size of the vehicle. This variable takes a value of 1 for big vehicles and 0 otherwise.

Dist: Distance traveled per day by the vehicle

EF: Emission Factor or coefficient of the pollutant (CO_2, HC, NO_X, PM, as the case may be)

Variables in the Hedonic Cost Function:

Cost : This variable has been constructed using the annualized current price of the vehicle plus other costs like fuel cost, maintenance cost and insurance cost. The current price, which the private car owners stated, is the price, which they perceive to obtain if they sell the vehicle. This price has been annualized using the current bank-lending rate, which is 10.625% in the year 2003-04. The annualized cost thus obtained has been converted to per day cost.

Size: This is a dummy variable, which takes a value 1 for a big vehicle and 0 for a small vehicle.

Distance: Data on distance is expressed in kilometers traveled per day.

Emission coefficients: expressed in Kgs/Km.

Table 16 provides the descriptive statistics of variables used in the estimation.

Table 16: Descriptive statistics of the variables

Variables	Mean	Std. Dev.
Cost (C)	163.63	82.47
Dist	28.89	19.67
CO2	0.00774	0.00509
HC	0.00089	0.00056
NOX	0.00092	0.00068
PM	0.00005	0.00001

Table 17: Correlation matrix of emission variables

	CO2	NOX	HC	PM
CO2	1.00	0.93	0.99	0.88
NOX	0.93	1.00	0.97	0.99
HC	0.99	0.97	1.00	0.93
PM	0.88	0.99	0.93	1.00

The parametric estimates of hedonic travel cost function are given in Table 18. Separate estimates of cost function are made for three pollutants because correlation matrix of the emission factors as shown in Table 17 reveals very high pair-wise correlation coefficients, which are of the order of 0.8 and above. This implies that all the emission factors cannot be used as explanatory variables in the estimation of cost function because it would lead to biased estimates. Hence the cost variable has been regressed separately on each of the emission factors, with size and distance traveled per day as the other two explanatory variables. The standard diagnostic tests of heteroscedasticity have been performed on these models and the models are free from any such problem. Results indicate that the coefficients are highly significant (at the 1% level of significance) and have the expected signs.

Table 18: Parametric estimates of hedonic travel cost function dependent variable: Cost (C)

Variables (Expected Signs)	Log-Log Model		
	Coefficients (t-statistics)		
	Reg. 1	Reg. 2	Reg.3
Constant	2.05** (7.546)	2.17** (8.306)	1.47** (4.208)
Size (+)	0.30** (3.956)	0.33** (4.244)	0.32** (4.139)
Dist (+)	0.48** (10.056)	0.51** (10.524)	0.49** (10.316)
CO2 (-)	-0.26** (-5.700)		
HC (-)			-0.26** (-5.828)
NOX (-)		-0.15** (-5.446)	
Uncentered R^2	0.62	0.61	0.62
Adjusted R^2	0.60	0.59	0.61

Note: ** denotes 1% level of significance, * denotes 5% level of significance

5.3. Estimates of Abatement Cost of Vehicular Pollution

Using the estimated hedonic cost functions, the annual abatement cost of vehicular pollution could be calculated for each of the pollutants namely, CO_2, NO_X, and HC. The derivative of cost function with respect to emissions gives us an estimate of increase in travel cost per day due to reduction of one kg of emissions per kilometer.

$$\frac{dC}{dCO2} = \frac{C}{CO2} * \beta = -0.264747 * 163.69/0.00774 = (-)5599.02$$

$$\frac{dC}{dHC} = \frac{C}{HC} * \beta = -0.260463 * 163.69/0.00085 = (-)50159.04$$

$$\frac{dC}{dNOX} = \frac{C}{NOX} * \beta = -0.151446 * 163.69/0.000922 = (-)26887.4$$

For instance the incremental cost for CO_2 is computed as Rs. 5599.02. Switching from pre Euro to Euro I vehicle technology requires an emission coefficient of 0.0013 kgs per kilometer for CO_2. Therefore the per day abatement cost of a small car is estimated as

Rs. 7.28 which makes the annual abatement cost equivalent to Rs. 2729.72. Table 19 provides similar estimates for NO_x, and HC. The data shows that there is a very high degree of correlation among emission variables as shown in Table 17 above implying that the switching of vehicles to emission reduction technologies results in the simultaneous reduction of all the emissions. Therefore the estimate of annual abatement cost for a passenger car is obtained as the maximum of the abatement cost estimates for CO_2 , NO_X, and HC given in Table 19.

Table 19: Estimates annual abatement cost per vehicle

PRIVATE CAR	Reduction of the Emission Kg/Km			Estimates of annual Abatement Cost		
	CO2	HC	Nox	CO2	HC	NOX
	(Due to change in Technology)			**Abatement cost per kg of emission**		
				5599.02	50159.04	26887.4
				Annual Abatement Cost (Rs./Veh)		
Pre euro 1996-00 to E1	0.0013	0.0002	0.0004	2729.72	4027.77	3974.63
Pre euro 1996-00 to E2	0.0015	0.0003	0.0005	3050.87	6224.74	5299.51
Pre euro 1996-00 to E3	0.0025	0.0005	0.0006	5025.9	8879.4	5986.48
E1 to E2	0.0002	0.0001	0.0001	321.144	2196.97	1324.88
E1 to E3	0.0011	0.0003	0.0002	2296.18	4851.63	2011.85

VI Conclusion

Air pollution from the road transport is non-point source of pollution as it is the case with water pollution from agriculture. In the absence of clearer methods in the literature on environmental pollution to measure the pollution loads and the cost of pollution abatement from the road transport, this paper outlines a method and provides case studies of road transport in AP and HP states in India. The suggested method as shown in this paper requires lot of data about the road transport. Vehicular transport creates demand for the waste disposal services from the atmosphere and there is a supply constraint on these services imposed by the environmental regulation in the form of emission norms (for example Euro norms as discussed in the paper). There is a problem of air pollution from the transport sector if the pollution load from vehicles exceed the load corresponding to emission norms. The cost of air pollution abatement is the cost to vehicles for complying with the emission norms.

Vehicular pollution could be reduced by changing the vehicular technologies and by improving the fuel quality. The Government of India has been recently introducing Euro norms, which are different for different vehicles. As explained in this paper the vehicular technologies and the fuel quality are different for different norms (Euro I, II, III, and IV). Estimates of air pollution loads in excess of loads compatible with norms for each type of vehicle are obtained. Estimates of pollution abatement cost for each type of vehicle in terms of cost of changing the vehicular technologies and the cost of using the improved fuels to comply with the emission norms are made.

Table 20 shows the total abatement cost for complying with Euro II and Euro III emission norms for road transport sectors in AP and HP. The estimate of air pollution abatement for each type of vehicle (passenger cars, trucks, buses, two-wheelers) is obtained by summing up the estimates of cost for the change in vehicular technology and improving the fuel quality. The estimates of aggregate pollution abatement cost for the road transport in AP and HP are obtained by adding up costs for all the above vehicle categories.

Table 20: Monetary accounts of air pollution abatement in the transport sectors of AP and HP states (Rs. million)

	Andhra Pradesh		Himachal Pradesh	
Technology	Euro II	Euro III	Euro II	Euro III
1. Cost of upgrading Vehicular Technology	3617.295487	25120.900389	475.2575251	1752.736972
2. Cost of Change in Fuel	5144.317908	7188.641462	1389.822224	1935.986938
3. Total Cost (1+2)	8761.613395	32309.541851	1865.079749	3688.723910

Note:
It is to be noted that regarding the cost of technology upgradation, TERI provides estimates of investment costs of technology upgradation per vehicle for different vehicles from Euro I to Euro II and Euro III whereas the information on cost of fuel quality conversion is available for conversion from Pre Euro to Euro II and Euro III. This essentially implies that the total cost of abatement figures (for complying with Euro II and Euro III) at which the present study arrives by summing up the cost of technology upgradation and change in fuel quality, are in fact less than what it would have been, in case the conversion cost of upgrading vehicular technology was available for Pre Euro to Euro II and Pre Euro to Euro III.

The estimates of air pollution abatement cost for the transport sector reported in Table 20 are made taking into account the number of vehicles on roads in the year 2001-2002 for AP and the year 2002-2003 for HP. The estimates of air pollution abatement cost of road transport required for complying with Euro III norms constitute 2.134 and 5.880 per cent of the State Domestic Product (SDP) respectively in AP and HP. Similar estimates for complying with Euro II norms are obtained as 0.578 and 1.169 per cent.

Appendix A1
Table A1.1: Growth of Vehicles in India

Ear	No of vehicles	Two wheelers		Car, jeep, taxi		Buses		Goods vehicles		Others	
	(thousands)	(thousands)	Percentage	(thousands)	Percentage	(thousands)	Percentage	(thousands)	Percentage	(thousands)	Percentage
1951	306	27	8.82	159	51.96	34	11.11	82	26.8	4	1.31
1961	665	88	13.23	310	46.62	57	8.57	168	25.26	42	6.32
1971	1865	576	30.88	682	36.57	94	5.04	343	18.39	170	9.12
1981	5391	2618	48.56	1160	21.52	162	3.01	554	10.28	897	16.64
1991	21374	14200	66.44	2954	13.82	331	1.55	1356	6.34	2533	11.85
1996	33783	23252	68.83	4204	12.44	449	1.33	2031	6.01	3850	11.39
1997	37231	25729	69.01	4672	12.52	484	1.31	2343	6.07	4104	11.09
1998	41,369	28642	69.23	5138	12.35	538	1.31	2536	6.18	4514	10.94
1999	44,875	31328	72.04	5556	12.38	540	1.20	2554	5.69	4897	10.91
2000	48857	34118	70.08	6143	12.49	562	1.16	2715	5.54	5319	10.74
2001	54991	38556	70.11	7058	12.83	634	1.15	2948	5.36	5795	10.54
2002	58863	41478	70.47	7571	12.86	669	1.14	3045	5.17	6100	10.36

Source: Department of Road Transport and Highways, GOI

Appendix A2: Physical Accounts for AP

Table A2.1: Physical Accounts for CO2: 1997-98

Unit: Tons

	CO EMISSIONS			CO2 EMISSIONS
District	Actual (Pre Euro 1991-95)	Proposed (B-II)	Physical Accounts	Physical Accounts
			(Load to be reduced)	(Load to be reduced)
Srikakulam	2060.57	498.90	1561.66	2454.04
Vizianagaram	2438.79	597.99	1840.80	2892.68
Visakhapatnam	20443.09	4867.80	15575.28	24475.45
East Godavari	19179.29	4581.04	14598.25	22940.10
West Godavari	12619.74	2950.69	9669.05	15194.22
Krishna	20807.44	5402.90	15404.54	24207.13
Guntur	9565.18	2367.88	7197.31	11310.05
Prakasam	3495.99	847.23	2648.77	4162.35
Nellore	4398.22	1135.06	3263.15	5127.81
Coastal Andhra	95008.30	23249.49	71758.81	112763.84
Kurnool	6104.25	1525.51	4578.75	7195.17
Anantapur	7010.71	1841.78	5168.93	8122.60
Cuddapah	4178.82	1057.33	3121.49	4905.20
Chitoor	7462.88	1864.14	5598.74	8798.01
Rayalaseema	24756.66	6288.76	18467.90	29020.99
Ranga Reddy	11763.94	2910.48	8853.46	13912.58
Hyderabad	85758.43	20100.69	65657.74	103176.45
Nizamabad	5520.26	1333.27	4187.00	6579.56
Medak	3300.55	795.77	2504.78	3936.08
Mahbubnagar	3404.89	834.84	2570.05	4038.65
Nalgonda	4602.13	1034.12	3568.01	5606.88
Warangal	7705.94	1782.52	5923.42	9308.23
Khammam	5745.57	1295.13	4450.44	6993.55
Karimnager	8305.67	1913.51	6392.16	10044.82
Adilabad	1959.07	492.03	1467.04	2305.36
Telangana	138066.44	32492.34	105574.11	165902.17
Andhra Pradesh	257831.41	62030.59	195800.81	307686.99

Table A2.2: Physical Accounts for HC: 1997-98

Units: Tons

HC EMISSIONS			
District	Actual (Pre Euro 1991-95)	Proposed (B-II)	Physical accounts
			(Pollution Load to be reduced)
Srikakulam	1060.33	376.45	683.87
Vizianagaram	1298.17	461.69	836.48
Visakhapatnam	11067.46	3847.28	7220.18
East Godavari	10469.14	3807.32	6661.82
West Godavari	6628.73	2426.49	4202.25
Krishna	10428.67	3803.17	6625.50
Guntur	4809.02	1735.48	3073.53
Prakasam	1670.98		1056.18
Nellore	2252.87	818.80	1434.07
Coastal Andhra	49685.37	17891.49	31793.88
Kurnool	3156.07	1070.72	2085.36
Anantapur	3782.27	1350.36	2431.91
Cuddapah	2002.26	727.96	1274.30
Chitoor	3967.65	1409.09	2558.56
Rayalaseema	12908.25	4558.12	8350.13
Ranga Reddy	6376.21	2287.78	4088.43
Hyderabad	45965.06	15207.51	30757.55
Nizamabad	2877.36	1052.87	1824.49
Medak	1592.51	571.16	1021.35
Mahbubnagar	1855.58	642.51	1213.08
Nalgonda	2221.21	792.14	1429.07
Warangal	4069.30	1406.51	2662.79
Khammam	2953.64	986.24	1967.41
Karimnager	4342.30	1523.86	2818.45
Adilabad	1068.98	365.42	703.56
Telangana	73322.15	24835.98	48486.18
Andhra Pradesh	135915.78	47285.59	88630.19

Table A2.3: Physical Accounts for NOX: 1997-98

Units: Tons			
NOX EMISSIONS			
District	Actual (Pre Euro 1991-95)	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	400.88	192.00	208.88
Vizianagaram	391.24	206.38	184.86
Visakhapatnam	2004.74	1204.66	800.08
East Godavari	1885.61	1103.83	781.78
West Godavari	1366.42	703.24	663.18
Krishna	4142.96	2456.42	1686.55
Guntur	1714.42	909.10	805.32
Prakasam	768.79	353.82	414.98
Nellore	930.45	501.06	429.38
Coastal Andhra	13605.52	7630.51	5975.01
Kurnool	1256.11	699.02	557.10
Anantapur	1474.38	866.75	607.63
Cuddapah	1138.39	543.50	594.89
Chitoor	1421.53	737.26	684.27
Rayalaseema	5290.41	2846.53	2443.89
Ranga Reddy	1417.45	844.60	572.86
Hyderabad	9371.99	5270.40	4101.59
Nizamabad	807.61	414.52	393.09
Medak	687.51	346.08	341.43
Mahbubnagar	587.33	313.21	274.11
Nalgonda	747.83	329.91	417.92
Warangal	902.98	476.09	426.89
Khammam	747.55	385.03	362.52
Karimnager	1055.69	536.07	519.62
Adilabad	433.23	220.38	212.85
Telangana	16759.18	9136.29	7622.89
Andhra Pradesh	35655.11	19613.33	16041.79

Table A2.4: Physical Accounts for PM: 1997-98

Unit: Tons			
PM EMISSIONS			
District	Actual (Pre Euro 1991-95)	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	127.31	18.05	109.25
Vizianagaram	135.64	20.83	114.81
Visakhapatnam	898.12	161.31	736.80
East Godavari	910.10	158.67	751.43
West Godavari	623.12	104.87	518.26
Krishna	1215.68	185.73	1029.95
Guntur	548.47	83.04	465.43
Prakasam	228.39	31.42	196.97
Nellore	270.42	39.26	231.16
Coastal Andhra	4957.25	803.19	4154.06
Kurnool	365.47	53.08	312.38
Anantapur	435.00	63.62	371.38
Cuddapah	304.97	39.21	265.76
Chitoor	446.70	65.17	381.53
Rayalaseema	1552.13	221.08	1331.05
Ranga Reddy	559.67	96.46	463.21
Hyderabad	3738.54	655.03	3083.50
Nizamabad	300.20	47.21	252.98
Medak	208.52	29.55	178.96
Mahbubnagar	197.03	29.30	167.74
Nalgonda	266.26	39.32	226.94
Warangal	377.99	62.51	315.48
Khammam	291.13	46.51	244.62
Karimnager	433.47	69.20	364.27
Adilabad	126.73	17.32	109.42
Telangana	6499.54	1092.41	5407.12
Andhra Pradesh	13008.92	2116.68	10892.24

Table A2.5: Physical Accounts for CO2: 1998-99

Units: Tons

	CO EMISSIONS			CO2 EMISSIONS
	Actual (Pre Euro 1996-2000)	Proposed (B-II)	Load to be reduced	Load to be reduced (CO2)
Srikakulam	1443.72	560.92	882.80	1387.26
Vizianagaram	1661.91	663.19	998.72	1569.41
Visakhapatnam	13239.88	5266.98	7972.90	12528.84
East Godavari	12861.29	4964.01	7897.29	12410.02
West Godavari	8711.25	3273.72	5437.53	8544.69
Krishna	13649.12	5764.50	7884.61	12390.11
Guntur	6464.72	2649.34	3815.37	5995.59
Prakasam	2330.95	899.79	1431.16	2248.97
Nellore	2999.56	1263.17	1736.39	2728.61
Chittoor	5129.18	2047.04	3082.15	4843.38
Cuddapah	2813.56	1145.61	1667.95	2621.06
Anantapur	4670.30	1909.13	2761.17	4338.97
Kurnool	3277.57	1305.76	1971.81	3098.56
Mahbubnagar	2447.42	915.37	1532.05	2407.51
Ranga Reddy	8121.81	3319.81	4801.99	7545.99
Hyderabad	54663.65	21694.53	32969.11	51808.61
Medak	2275.50	852.12	1423.38	2236.74
Nizamabad	3556.75	1444.02	2112.73	3320.00
Adilabad	1353.01	540.25	812.76	1277.20
Karimnagar	5656.89	2098.18	3558.71	5592.26
Warangal	5240.38	1962.06	3278.32	5151.65
Khammam	4017.14	1454.31	2562.83	4027.30
Nalgonda	2919.39	1108.29	1811.09	2846.01
Andhra Pradesh	169504.95	67102.12	102402.83	160918.73

Table A2.6: Physical Accounts for HC: 1998-99

Units: Tons

HC EMISSIONS			
	Actual (Pre Euro 1996-2000)	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	912.67	424.74	487.93
Vizianagaram	1115.66	513.31	602.35
Visakhapatnam	9111.21	4164.15	4947.05
East Godavari	9280.15	4130.32	5149.84
West Godavari	6098.48	2700.60	3397.88
Krishna	8856.17	4088.62	4767.55
Guntur	4263.68	1952.61	2311.07
Prakasam	1438.28	659.17	779.11
Nellore	1965.90	907.72	1058.19
Chittoor	3340.27	1558.51	1781.76
Cuddapah	1718.56	806.32	912.24
Anantapur	3104.39	1454.32	1650.07
Kurnool	2010.93	961.87	1049.06
Mahbubnagar	1408.16	680.71	727.46
Ranga Reddy	5817.27	2616.94	3200.32
Hyderabad	34194.67	16286.88	17907.79
Medak	1377.46	634.71	742.74
Nizamabad	2550.75	1152.49	1398.26
Adilabad	826.25	402.38	423.87
Karimnagar	3619.71	1678.16	1941.54
Warangal	3293.19	1537.31	1755.88
Khammam	2296.85	1099.44	1197.41
Nalgonda	1901.88	878.80	1023.08
Andhra Pradesh	110502.54	51290.07	59212.47

Table A2.7: Physical Accounts for NOX: 1998-99

Units: Tons			
NOX EMISSIONS			
District	Actual (Pre Euro 1996-2000)	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	374.99	212.91	162.07
Vizianagaram	359.34	224.88	134.46
Visakhapatnam	1856.18	1296.60	559.58
East Godavari	1714.63	1164.68	549.95
West Godavari	1235.16	759.49	475.67
Krishna	3645.67	2539.32	1106.36
Guntur	1539.32	983.40	555.92
Prakasam	659.91	366.59	293.32
Nellore	860.84	544.36	316.48
Chittoor	1316.84	782.33	534.51
Cuddapah	974.04	557.13	416.91
Anantapur	1153.27	744.04	409.23
Kurnool	789.33	479.15	310.18
Mahbubnagar	591.57	349.13	242.44
Ranga Reddy	1358.24	935.07	423.17
Hyderabad	8888.81	5852.12	3036.69
Medak	585.50	316.67	268.83
Nizamabad	700.51	459.77	240.74
Adilabad	419.70	242.44	177.27
Karimnagar	908.16	558.71	349.45
Warangal	820.75	522.97	297.78
Khammam	724.88	440.93	283.95
Nalgonda	576.52	351.45	225.07
Andhra Pradesh	32054.18	20684.15	11370.03

Table A2.8: Physical Accounts for PM: 1998-99

Units: Tons			
PM EMISSIONS			
	Actual (Pre Euro 1996-2000)	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	70.43	20.26	50.17
Vizianagaram	72.82	23.16	49.66
Visakhapatnam	459.34	174.31	285.03
East Godavari	466.76	171.88	294.88
West Godavari	331.86	116.10	215.76
Krishna	639.76	198.27	441.49
Guntur	299.35	92.58	206.77
Prakasam	119.90	33.04	86.86
Nellore	144.46	43.10	101.37
Chittoor	238.23	71.41	166.82
Cuddapah	161.83	42.04	119.79
Anantapur	209.16	65.51	143.65
Kurnool	143.75	44.53	99.22
Mahbubnagar	114.32	33.39	80.93
Ranga Reddy	301.48	109.98	191.50
Hyderabad	1929.96	705.60	1224.35
Medak	111.05	31.31	79.74
Nizamabad	148.42	49.73	98.69
Adilabad	67.78	18.88	48.89
Karimnagar	227.02	75.50	151.52
Warangal	203.21	69.28	133.93
Khammam	166.27	52.86	113.42
Nalgonda	123.87	39.56	84.31
Andhra Pradesh	6751.03	2282.27	4468.75

Table A2.9: Physical Accounts for CO2: 2001-02

Units: Tons

	CO EMISSIONS			CO2 EMISSIONS
District	Actual (Pre Euro 1996-2000)	Proposed (B-II)	Load to be reduced	Load to be reduced (CO2)
Srikakulam	2183.96	822.98	1360.99	2138.69
Vizianagaram	2415.03	943.55	1471.47	2312.32
Visakhapatnam	17466.20	6866.49	10599.71	16656.68
East Godavari	17442.15	6712.24	10729.91	16861.29
West Godavari	11734.53	4585.60	7148.93	11234.04
Krishna	18211.73	7766.33	10445.40	16414.20
Guntur	8814.01	3650.83	5163.19	8113.58
Prakasam	3548.36	1545.81	2002.54	3146.85
Nellore	4360.09	1864.90	2495.19	3921.02
Chittoor	6938.07	2829.43	4108.65	6456.44
Cuddapah	2825.24	1278.29	1546.96	2430.93
Anantapur	7536.00	3074.74	4461.26	7010.55
Kurnool	5491.70	2217.77	3273.93	5144.75
Mahbubnagar	3212.17	1314.89	1897.28	2981.43
Ranga Reddy	13128.75	5391.50	7737.24	12158.52
Hyderabad	72221.05	28689.58	43531.47	68406.60
Medak	3379.30	1347.57	2031.73	3192.72
Nizamabad	5412.14	2194.76	3217.38	5055.88
Adilabad	4212.37	1568.03	2644.34	4155.39
Karimnagar	7494.14	2770.58	4723.55	7422.73
Warangal	7219.79	2706.18	4513.61	7092.82
Khammam	6007.80	2131.91	3875.88	6090.67
Nalgonda	3858.84	1519.57	2339.28	3676.00
Andhra Pradesh	235113.42	93793.53	141319.89	222074.11

Table A2.10: Physical Accounts for HC: 2001-02

			Units: Tons
HC EMISSIONS			
District	Actual (Pre Euro 1996-2000)	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	1352.09	634.76	717.33
Vizianagaram	1558.32	727.73	830.59
Visakhapatnam	11735.81	5411.06	6324.74
East Godavari	12180.98	5515.13	6665.84
West Godavari	8329.06	3728.26	4600.80
Krishna	11809.00	5542.62	6266.37
Guntur	5774.33	2695.88	3078.45
Prakasam	2204.93	1060.12	1144.81
Nellore	2790.72	1327.56	1463.15
Chittoor	4522.60	2138.09	2384.51
Cuddapah	1628.30	815.17	813.12
Anantapur	4997.51	2346.33	2651.18
Kurnool	3190.65	1564.93	1625.72
Mahbubnagar	1776.63	892.10	884.53
Ranga Reddy	9464.24	4224.64	5239.60
Hyderabad	42661.19	20703.04	21958.14
Medak	2097.84	1009.35	1088.48
Nizamabad	3545.35	1669.39	1875.96
Adilabad	2207.82	1151.42	1056.40
Karimnagar	4929.25	2264.80	2664.45
Warangal	4222.44	2062.88	2159.56
Khammam	3304.57	1628.30	1676.26
Nalgonda	2604.10	1196.15	1407.94
Andhra Pradesh	148887.70	70309.72	78577.97

Table A2.11: Physical Accounts for NOX: 2001-02

Units: Tons			
NOX EMISSIONS			
District	Actual	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	464.89	270.72	194.17
Vizianagaram	472.68	307.57	165.11
Visakhapatnam	2252.83	1584.04	668.79
East Godavari	2272.69	1641.98	630.71
West Godavari	1836.35	1282.71	553.64
Krishna	4684.36	3470.46	1213.90
Guntur	1985.88	1393.02	592.86
Prakasam	1297.28	908.26	389.03
Nellore	1237.47	868.46	369.01
Chittoor	1770.93	1152.08	618.85
Cuddapah	1324.34	854.47	469.88
Anantapur	1814.16	1210.94	603.23
Kurnool	1554.31	1010.21	544.10
Mahbubnagar	1147.57	757.33	390.24
Ranga Reddy	2078.02	1328.83	749.19
Hyderabad	12561.39	7806.62	4754.77
Medak	813.74	535.24	278.50
Nizamabad	1141.65	823.63	318.02
Adilabad	998.96	641.02	357.94
Karimnagar	1023.07	634.74	388.33
Warangal	1155.41	820.68	334.73
Khammam	870.66	583.33	287.34
Nalgonda	797.55	516.33	281.22
Andhra Pradesh	45556.21	30402.66	15153.55

Table A2.12: Physical Accounts for PM: 2001-02

Units: Tons

PM EMISSIONS			
District	Actual	Proposed (B-II)	Physical Accounts
			(Pollution Load to be reduced)
Srikakulam	97.32	29.73	67.59
Vizianagaram	101.52	33.13	68.39
Visakhapatnam	582.31	226.05	356.26
East Godavari	618.87	231.43	387.44
West Godavari	449.22	159.64	289.59
Krishna	820.03	263.75	556.28
Guntur	386.48	125.49	261.00
Prakasam	197.90	54.82	143.09
Nellore	203.37	62.97	140.39
Chittoor	316.42	97.71	218.72
Cuddapah	186.38	45.81	140.56
Anantapur	332.12	105.59	226.53
Kurnool	265.19	77.66	187.52
Mahbubnagar	178.75	47.76	130.99
Ranga Reddy	466.57	174.29	292.28
Hyderabad	2574.10	920.14	1653.96
Medak	148.93	46.62	102.31
Nizamabad	225.74	75.42	150.32
Adilabad	182.51	55.46	127.05
Karimnagar	284.03	98.88	185.15
Warangal	273.83	94.79	179.04
Khammam	225.23	76.82	148.42
Nalgonda	168.36	53.95	114.41
Andhra Pradesh	9285.19	3157.90	6127.29

Appendix A3: Physical Accounts for Himachal Pradesh

Table A3.1 Passenger cars (Private cars, taxi cabs, jeeps)

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Million Kg/Year)	*Pre Euro*	22.196	1.709	3.774	0.743
	Euro I/ Bharat 2000	4.413	0.602	0.809	0.148
	Euro II/ Bharat II	4.153	0.404	0.586	0.090
	Euro III/ Bharat III	2.557	0.165	0.470	0.057
Load Reduced/ Physical Accounts (Million Kg/Year)	*Pre Euro to Euro I*	17.782	1.106	2.965	0.594
	Pre Euro to Euro II	18.0422	1.305	3.188	0.652
	Pre Euro to Euro III	19.639	1.544	3.304	0.685
	Euro I to Euro II	0.259	0.198	0.223	0.057
	Euro I to Euro III	1.856	0.437	0.338	0.090

Table A3.2 Buses

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Million Kg/Year)	*Pre Euro*	2.0165	0.345	4.790	0.456
	Euro I/ Bharat 2000	1.6132	0.276	3.593	0.159
	Euro II/ Bharat II	1.434	0.248	3.136	0.068
	Euro III/ Bharat III	1.254	0.219	2.851	0.065
Load Reduced/ Physical Accounts (Million Kg/Year)	*Pre Euro to Euro I*	0.403	0.068	1.197	0.296
	Pre Euro to Euro II	0.582	0.096	1.654	0.387
	Pre Euro to Euro III	0.761	0.125	1.939	0.390
	Euro I to Euro II	0.179	0.028	0.456	0.0912
	Euro I to Euro III	0.358	0.0570	0.741	0.094

Table A3.3 Trucks

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Million Kg/Year)	*Pre Euro*	12.441	2.128	14.778	1.407
	Euro I/ Bharat 2000	9.952	1.706	11.083	0.492
	Euro II/ Bharat II	8.847	1.530	9.676	0.211
	Euro III/ Bharat III	7.741	1.3546	8.796	0.175
Load Reduced/ Physical Accounts (Million Kg/Year)	*Pre Euro to Euro I*	2.488	0.422	3.694	0.914
	Pre Euro to Euro II	3.594	0.598	5.102	1.196
	Pre Euro to Euro III	4.699	0.774	5.981	1.231
	Euro I to Euro II	1.105	0.175	1.407	0.281
	Euro I to Euro III	2.211	0.351	2.287	0.316

Table A3.4 Two Wheelers

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Million Kg/Year)	*Pre Euro*	9.421	4.946	0.090	0.150
	Euro I/ Bharat 2000	5.181	3.192	0.075	0.075
	Euro II/ Bharat II	3.297	1.978	0.060	0.060
Load Reduced/ Physical Accounts (Million Kg/Year)	*Pre Euro to Euro I*	4.239	1.754	0.015	0.075
	Pre Euro to Euro II	6.123	2.968	0.030	0.090
	Euro I to Euro II	1.884	1.214	0.015	0.015

Table A3.5 Commercial Vehicles

		CO2	*HC*	*NOX*	*PM*
Pollution Load (Million Kg/Year)	*Pre Euro*	3.552	0.092	0.816	0.164
	Euro I/ Bharat 2000	1.670	0.046	0.590	0.066
	Euro II/ Bharat II	0.236	0.021	0.193	0.023
	Euro III/ Bharat III	0.210	0.018	0.164	0.016
Load Reduced/ Physical Accounts (Million Kg/Year)	*Pre Euro to Euro I*	1.881	0.046	0.226	0.098
	Pre Euro to Euro II	3.316	0.071	0.622	0.141
	Pre Euro to Euro III	3.342	0.073	0.652	0.147
	Euro I to Euro II	1.435	0.025	0.396	0.043
	Euro I to Euro III	1.461	0.028	0.426	0.049

Appendix A4: Questionnaires

A4.1: Transport Sector Survey, November 2004

1. Put a tick below the correct option.

   ☐ Himachal Pradesh Registered

   or

   ☐ Tourist vehicle registered outside Himachal Pradesh

2. If it is a Tourist vehicle, then state the following.
   - Number of trips to HP in a year: _____
   - Average distance traveled in HP in each trip: _____
   - How many days are spent in HP per trip: _____

3. Vehicle Category (Put a Tick below)

   a. Bus b. Truck c. Pvt. Car d. Jeep e. Taxi Cab

   g. Any other Commercial (Tractor, water carrier, any other)

4. Model and age of the vehicle:
   _____

5. Year of Purchase:
   _____

Leave question number 6 and 7 if it is a tourist vehicle.

6. Total distance traveled (as displayed by the speedometer): _____
   _____

7. Average distance traveled per day: _____

8. Does your vehicle already have any one of the following technologies when you bought it or have you converted/shifted to any of the following after you bought it?

   ☐ Euro III/ Bharat Stage III technology

   ☐ Euro II/ Bharat Stage II technology

   ☐ Euro I/ India Stage 2000 technology

   ☐ Pre Euro Norm (1996-2000) technology

☐ Pre Euro Norm (up to 1995) technology

☐ CNG Engine

☐ LPG cylinder

☐ Any other. Mention it. _____

If **No Conversion**, then

(a) What is the type of fuel used? a. Petrol b. Diesel c. CNG d. LPG

(b) What is the mileage (Km. per litre of petrol or diesel or per cylinder of CNG or LPG) in your vehicle?

_____

(c) What is the maintenance or running cost of your vehicle (Rs.)

a. Fuel Cost	
b. Cost of repair and replacement	
c. Insurance Cost	

If **Vehicle Has Undergone A Conversion**, then

(a) What is the Installation/Investment Cost undertaken for conversion?

Rs. _____

(b) Fill table below.

	Before Conversion	**After Conversion**
1. **Fuel Used**		
2. **Mileage**		
3. **Maintenance/Running Cost**		
a. Fuel Cost		
b. Cost of repair and replacement		
c. Insurance Cost		

9. Have you bought a new vehicle or is it a second hand? ☐ New

☐ Second Hand

10. What is the purchase price of the vehicle?

_____

11. What is the current price of the vehicle if you sell it?
_____

12. Any other technology/cost information_____
_____
_____

A4.2 Questionnaire for Two Wheelers

1. Model and age of the vehicle: _____
2. Year of Purchase: _____
3. Tick the relevant option : ☐ Two Stroke ☐ Four Stroke
4. Total distance traveled (as displayed by the speedometer): _____
   _____
5. Average distance traveled per day: _____
6. What is the mileage (Km. per litre of petrol) in your vehicle? _____
7. What is the maintenance or running cost of your vehicle? (Rs.)

a. Fuel Cost	
b. Cost of repair and replacement	
c. Insurance Cost	

8. Have you bought a new vehicle or is it a second hand? ☐ New
   ☐ Second hand
9. What is the purchase price of the vehicle? _____
10. What is the current price of the vehicle if you sell it? _____

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