Emissions from India's Intercity and Intracity Road Transport

Consultation Draft

Sudhir Gota and Bert Fabian

Clean Air Initiative for Asian Cities (CAI-Asia) Center

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About CAI-Asia

The **Clean Air Initiative for Asian Cities (CAI-Asia**) promotes innovative ways to improve air quality in Asian cities by sharing experiences and building partnerships. CAI-Asia was established in 2001 by the Asian Development Bank, the World Bank, and USAID, and is part of a global initiative that includes CAI-LAC (Latin American Cities) and CAI-SSA (Sub-Saharan Africa).

CAI-Asia brings together stakeholders to build knowledge and capacity, develop policies and implement on-the-ground measures for improved air quality and simultaneously addressing health, climate change, energy and transport issues. Since 2007, this multi-stakeholder initiative consists of three parts:

- **CAI-Asia Center**, a regional, Manila-based non-profit organization that is the implementing arm of CAI-Asia
- **CAI-Asia Partnership**, a United Nations Type II partnership, with over 120 members representing cities, governments, academia, NGOs, private sector, and development agencies
- **Country Networks** in China, India, Indonesia, Pakistan, Philippines, Nepal, Sri Lanka, and Viet Nam

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LIST OF ABBREVIATIONS

ADB	–	Asian Development Bank
ARAI	–	Automobile Research Association of India
ASIF	–	Activity-Structure-Intensity-Fuel
BMTC	–	Bangalore Metropolitan Transport Cooperation
CAI-Asia Center	–	Clean Air Initiatives for Asian Cities - Center
CDP	–	City Development Plans (India)
CIRT	–	Central Institute of Road Transport
CO_2	–	Carbon dioxide
CTTS	–	Comprehensive Traffic and Transportation Study
DSV	–	Design Service Volume
GDP	–	Gross domestic product
GHG	–	Greenhouse Gases
HCV	–	Heavy commercial vehicle)
IEA	–	International Energy Agency
IEA	–	International Energy Agency
JNNURM	–	Jawaharlal Nehru National Urban Renewal Mission (India)
JNNURM	–	Jawahar Lal Nehru National Urban Renewal Mission
KM	–	Kilometer
LDV	–	Light Duty vehicle
LOS	–	Level of service
MOSRTH	–	Ministry of Shipping, Road Transport and Highways
MOUD	–	Ministry of Urban Development
NHAI	–	National Highway authority of India
NHDP	–	National Highway Development Programme
NMT	–	Non-motorized Transport
NO_X	–	Nitrogen Oxides
PCU	–	Passenger car unit
PM	–	Particulate Matter
SIAM	–	Society of Indian Automobile Manufacturers
UMTA	–	Unified Metropolitan Transport Authority
USD	–	US Dollars
V/C	–	Volume capacity ratio
VKT	–	Vehicle Kilometer Travel

1. EXECUTIVE SUMMARY

1.1 Introduction

This paper aims to stimulate debate on the quantification and mitigation of greenhouse gas (GHG) and air pollutant emissions from transport infrastructure, policies and projects and to highlight the need to intensify efforts to reduce emissions from both intra and intercity movement of people and goods.

Developing countries are at a crossroads as current decisions and investments in the transport sector are set to lock-in GHG (CO_2) and air pollutant emissions for the next decades. There is reason for concern as sustainable transport policies that incorporate air quality and climate change are being developed and implemented at a slow pace, risking irreversible damage to the environment and people's welfare. This is further aggravated by the global economic recession, which has lead to economic stimulus packages in developed countries for roads, the automotive industry, and related transport infrastructure. If developing countries follow this lead by prioritizing vehicles instead of people, it is certain that CO_2 emissions, air pollution, congestion, and other transport related problems will worsen.

The CAI-Asia Center has analyzed the impact of increased urbanization and motorization on CO_2, particulate matter (PM), and NOx emissions, by comparing emission estimates from the transport sector in India at the national and city level. India is used as a case study because relatively robust national and city information on travel activity and vehicle numbers is available from different sources. Emissions in Indian cities were forecasted up to 2025 based on available data for mode shares, number of trips and trip lengths, combined with assumptions on vehicle occupancy, vehicle type, and emission factors.[1]

1.2 Key Findings

Based on a business-as-usual scenario for motorization in India (without taking into consideration new circumstances that may yet arise out of the current global financial crisis) the main trends from 2005 to 2025 are:

- The number of total vehicles would grow at 8.70% per year, an increase from 49 million to 246 million between 2005 and 2025.
- CO_2 emissions from road transport would increase at 7.75% per year, which is higher than many other Asian countries, from 203 million tons in 2005 to 905 million tons by 2025. Passenger transport represents 45% and freight transport represents 55% of total CO_2 emissions from road transport in 2005; this ratio would remain approximately the same in 2025.
- PM emissions from road transport would decline until 2025 by 1.88% per year due to the adoption of stricter fuel and vehicle emission standards, while NO_x emissions would increase at

[1] The main limitation of the study is that many of the aspects of transport (such as activity, age of vehicles, fuel mix, occupancies, emission factors, etc.) are not collected and updated by the official agencies. Emissions generally refer to CO2 but some places PM and NOx estimates have been provided for discussions. It is very difficult to estimate PM and NOX without the availability of information on vehicle standards of vehicles in use. Some of the data on intercity transport had to be extracted from several sources including the National highways authority of India (NHAI) website and estimates were based on a hypothetical 4-lane corridor having traffic with Level of Service (LOS) B and vehicle/ capacity (V/C) ratio of 0.5.

a rate of 2.37% per year. However, PM emissions would subsequently rise again due to the continued rapid vehicle growth, especially if emissions standards are not further tightened (Euro IV and above).

An analysis of CO2 and PM emissions from road transport for 29 major Indian cities in different Indian states showed that:

- Only about 22% of total CO_2 emissions from land passenger transport in India are attributed to intracity movement in these 29 cities. It is probable that the remaining 78% of CO_2 emissions come from other 498 cities (India has a total of 527 cities with over 100,000 people but limited data are available) and movement of passengers and freight from one city to another (intercity transport).
- If the current trip mode share is retained, CO_2 emissions would increase 2- or 3-fold between 2008 and 2025, due to a rapid growth in urban population and in the number of trips.
- If the cities are able to increase the current non-motorized transport (NMT) and public transport trip shares by 5% each with a reduction in motorized transport share, the CO_2 emissions in 2008 would reduce by 9.16% and 6.21%.

To analyze the contribution of intercity transport to India's total CO_2 emissions from road transport, the study analyzed the CO_2 emissions of motorized traffic on national highways (India has approx 66900 km of National Highway) and compared these to city passenger CO_2 emissions in Bangalore and Delhi. In the absence of data for intercity transport or national highways, a back-calculation of CO_2 emissions was carried out based on a 4-lane national highway carrying vehicle traffic volume equivalent to LOS "B" and V/C ratio of 0.5 and vehicle mode share typical to these kinds of roads. Estimated emissions showed that a 442 km stretch of 4-lane national highway with the characteristics described above corresponds to the total passenger transport emissions from intracity movement in Bangalore. Similarly, CO_2 emissions from intracity passenger transport in Delhi are comparable to a 772 km stretch of highway. The high emission from traffic in National Highways needs to be tackled by the government to reduce the environmental impact.

The reason for relatively high emissions from national highways is that freight transport dominates the highways (52% of the vehicle mode share) whereas 2- and 3-wheelers are more present on typical urban roads (about 40% of vehicle mode share). Because 2- and 3-wheelers are more fuel efficient and emit less CO2 than larger vehicles, emissions from urban road transport are relatively lower compared to highways. A second reason could be high empty truck movements due to inefficiencies in freight logistics.

1.3 Recommendations

The main conclusion is that the projected growth of vehicles and road trips and the resulting CO_2 and air pollutant emissions until 2025 (continued growth is expected after 2025) is leading Indian road transport on an unsustainable path. While the Indian government and stakeholders are already taken steps to manage transport and emissions growth, these efforts must be stepped up immediately and significantly to reverse these trends. Key recommendations for government and stakeholders are as follows:

The projected growth of vehicles, road trips, and the resulting CO_2 and air pollutant emissions until 2025 (continued growth is expected after 2025) is leading Indian road transport on an unsustainable path. While the Indian government and stakeholders have already taken steps to manage transport and emissions growth, these efforts must be stepped up immediately and significantly to reverse these trends. Key recommendations for government and stakeholders are as follows:

1. Policies and projects should have a stronger focus on making cities livable and accessible for **people,** rather than on just improving the flow of **vehicles** in cities, by integrating transport demand management (i.e. reducing the number of trips made and distances traveled), public transport, and non-motorized transport into urban development and transport policies.

2. Policies and projects should aim to reduce CO_2 and air pollutant emissions from the outset, thus creating a low carbon and emission transport system, rather than adding emission mitigating measures to transport policies and projects after they have been designed. Land use and urban planning is critical in influencing transport demand and behavior thereby reducing the emissions thus improving the health.

3. In addition to the 29 prime cities, more analysis is needed for the remaining 498 cities, as well as intercity movements for which limited data is available but which contribute to about 78% of road transport emissions. Such analysis would enhance understanding of these sources of CO_2 emissions, and enable the formulation of more tailored and effective policies. By concentrating on smaller cities, the government can prevent these cities from making the same urban development mistakes found in larger cities. it is important to develop a mechanism to scale up activities from the 63 JNNURM cities to other Indian cities and modify the current strategy of promoting intercity movement by roads using the national highway development program.

4. Indian cities are not maximizing the density influence to reduce the emissions. Many cities which are dense are showing high emissions because of insufficient public transport and high influx of private vehicles. Many Transit oriented development initiatives are being taken by city governments, but much remains to be done on land use-transport-environment integration.

5. The National Highways carry a huge amount of traffic. Considering high emissions from road based mode of transportation, the government needs to revise feasibility and environmental impact assessment (EIA) guidelines to include emission quantification and mitigation measures in the selection of projects.

6. Urgent attention is needed for freight transport, which currently contributes to 55% of road transport CO_2 emissions. Most freight vehicles use diesel fuel which contributes to relatively high PM emissions and black carbon ("soot"), which in addition to being an air pollutant is considered a major contributor to global warming. Both urban transport and freight transport should receive equal attention.

2. URBANIZATION AND TRANSPORT INFRASTRUCTURE

In the past decade, developing countries invested huge resources in transportation infrastructure in the urban and rural areas, focusing mostly on expansion of road space to boost economic growth. Such action had an enormous impact on the vehicle ownership patterns and created a demand for private mobility. Consequently, public transport and non-motorized transport (NMT) started showing decrease in patronage with roads getting heavily populated by motorcycles and cars. Governments further increased investment in roads to improve traffic flow which in turn stimulated vehicle growth. This created a vicious cycle, and the environment and climate suffered from these actions.

In India, the Planning Commission was one of the foremost initial transport initiatives which set up the Study Team on Metropolitan Transport in 1965. The study's aim was to assess the adequacy and limitation of existing transport facilities in the cities of Kolkata, Mumbai, Chennai, and Delhi, and to determine the feasibility of different modes of transport. The study recommended the implementation of phased programmes for the development of transport facilities in Indian cities.[2] The Motor Vehicle Act of 1988 advanced the liberalization and harmonization of government regulations across the different states of India, but much needed to be done to streamline administration, improve enforcement and reduce corruption.[3] In 1996 the government finally issued a first series of more stringent norms for the tail-pipe emissions control.

In the decade that followed, the realization grew that vehicle standards and fuel quality needed to be supplemented with stronger transport demand focused actions. With increasing focus on climate change and air pollution, sustainable urban transport projects in mega cities is steadily growing under the rationale that rapid urbanization and increase in economic activity results in increased urban transport with high emissions. It is expected that India's urban population will increase from 230 million in 2001 to 402 million in 2025. It is also expected that share of economic activity in urban areas would increase from 56% of GDP in 1990 to about 75% in 2020 and most of the growth is expected to take place in the nine mega cities of the country. [4]

The transport sector accounts for a 6.4% share in India's GDP with the road sector accounting for 4.5% of GDP.[5] The approved outlay for the 10th Five year Plan (2002-2007) for the Central Road Transport Sector was Rs. 2100 million (approx USD 47 million) of which Rs. 1,530 million (nearly 73% of approved outlay) was for road safety. The Rakesh Mohan Committee estimated that the cost of urban transport infrastructure is about Rs. 124770 million (approx USD 2.700 billion, 1996 prices) over a 10-year period up to 2006. The 11th Five Year Plan (2008-2012) Steering Committee estimates suggest a requirement of Rs. 132.59 billion (USD 2.9 billion).

Major investment is currently limited to national highways and urban transportation in few mega cities; it is doubtful whether these investments will lead to sustainable transport as envisioned. India is currently at a crossroads as current decisions and investments in the transport sector are set to lock-in

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[2] See http://www.cag.gov.in/reports/railways/2006_5/chap_3.pdf

[3] See World Bank - *India Road Transport Service Efficiency Study 2005-* *http://siteresources.worldbank.org/INTSARREGTOPTRANSPORT/PublicationsandReports/20747263/Final_version03NOV2005.pdf*

[4] 2008. Ravinder. K. Urban Road Traffic and Air Pollution in Indian Cities & Impact of Traffic Management Measures. Central Road Resources Institute

[5] Planning Commission

greenhouse gas and air pollutant emissions for the next decades. There is reason for concern as sustainable transport policies that incorporate air quality and climate change are being developed and implemented at a slow pace, risking irreversible damage to the environment and people's welfare. This is further aggravated by the global economic recession, which has lead to economic stimulus packages in developed countries for roads, the automotive industry, and related transport infrastructure. If developing countries follow this lead by prioritizing vehicles instead of people, it is certain that CO_2 emissions, air pollution, congestion, and other transport related problems will worsen.

3. MOTORIZATION TRENDS

India has undergone multiple surges in the vehicle growth and ownership rates in the past three decades. The vehicle registrations increased from 1.8 million in 1971 to 62.7 million in 2003.[6] Even though in 2005 the total number of vehicles was high, ownership levels (measured as motorization levels) were low (43 vehicles for 1,000 people). Some experts expect an acceleration in the increase in vehicle ownership levels in the coming decades with the growth nearly twice as fast as per-capita income in India. [7]

3.1 Passenger cars

In order to estimate the future motorization levels at the country level, the authors used vehicle parc[8] data from the ADB Study on Energy Efficiency for On-Road Transport in Asia.[9] Market research and economic growth were used to predict the growth of total vehicle ownership in the future (170 vehicles per 1,000 population by 2025). It is estimated that people with higher income would opt for more powerful vehicles with more number of vehicles per household. It is predicted that maximum growth would be seen in the passenger car segment with motorization levels increasing from 5 to 29 cars per 1000 people by 2025. Estimates from Dargay et al. (2007), IEA[10] and Schipper et al (2007)[11] suggests 110 vehicles per 1000 people in 2030, 30 LDV's per 1000 people in 2025 and 38 cars per 1000 people in 2025 respectively. The increased motorization will lead to greater fuel demand for the transport sector, which in 2004-05, accounted for 28% of total petroleum products consumption in India[12].

3.2 2- and 3-Wheelers

The motorization trend towards powerful vehicles is a cause of concern (powerful motorcycles of 150-250 cc are slowly replacing the less powerful motorcycles) as this may result in downward trend in the fuel efficiencies of the fleet. A study by Society of Indian Automobile Manufacturers (SIAM) (2008), see figure 1, shows that the scooter (including mopeds - 50 cc) to motorcycle ratio which used to around 3.5

[6] 2008. MOSRTH. Ministry of Shipping, Road Transport and Highways Website (See http://morth.nic.in/)
[7] 2007. Dargay et. al. Vehicle Ownership and Income Growth, Worldwide: 1960-2030. (See http://www.econ.nyu.edu/dept/courses/gately/DGS_Vehicle%20Ownership_2007.pdf)
[8] Vehicle parc details the total number of vehicles on the road. It takes into account vehicles scrappage over the years due to accidents, old age, lack of parts, etc.
[9] ADB. 2006. Energy Efficiency and Climate Change Considerations for On-Road Transport in Asia. See http://www.adb.org/Documents/Reports/Energy-Efficiency-Transport/default.asp
[10] IEA/SMP Transport Model
[11] Schipper et al. (2007) CO_2 Emissions from Land Transport in India
[12] Integrated Energy Policy, Planning Commission 2006

in 1985 has changed to 0.2 by 2006.[13] The SIAM study also shows change in the vehicle production ratio of 2- and 3- wheelers from 25 in 1986 to 15 in 2006. This indicates the increasing role of intermediate public transport vehicles in growing cities. The autorickshaws are slowly replacing the cycle rickshaws as public transport vehicles like buses are yet to fill the void.

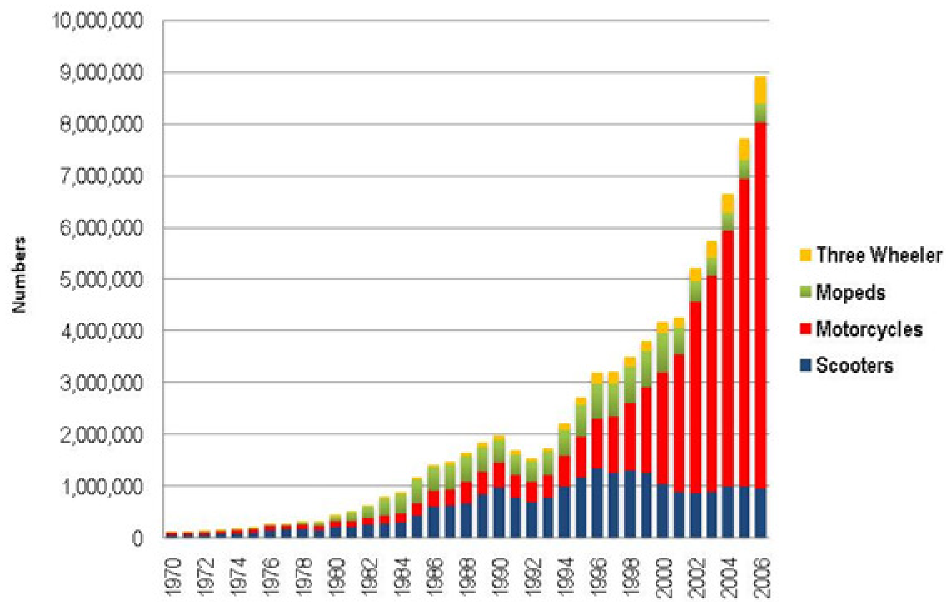

Figure 1. Production of Vehicles in India
Source: SIAM, 2007

3.3 Buses

The International Energy Agency (IEA) forecasts suggest 0.5 bus per 1000 people by 2025 in India. The estimates from Schipper et.al and the CAI-Asia center are more optimistic with numbers of 1 and 0.75 bus per 1000 people. Central Institute of Road Transport (CIRT)[14] recommends at-least 0.4 buses for 1000 people for Indian conditions to match the demand. However, the challenge is not only to increase the number of buses but also to increase the ridership and the vehicle kilometer travelled (VKT). Moreover, the CIRT's recommendations do not consider the required number of buses and ridership to keep traffic congestion and transport emissions low.

[13] SIAM – Statistical Profile 2007-2008
[14] See http://www.cirtindia.com/

Table 1. NMT mode share in Indian cities (Source: CAI-Asia, 2009, compiled from various sources)

	OLD Modeshare		NEW Modeshare	
CITY	Year	NMT %	Year	NMT%
Ahmedabad	1994	64	2008	36
Kanpur	1994	62	2008	48
Varanasi	1994	52	2008	41
Vijayawada	1994	50	2007	40
Pune	1994	42	2008	33
Nagpur	1994	54	2008	49
Jaipur	2005	44	2008	39
Hubli Dharwad	1994	46	2008	42
Bhopal	1994	39	2008	43
Shimla	1994	50	2008	59
Kochi	2001	10.51	2008	21
Guwahati	1994	28	2008	42

3.4 Change in behavior

The increase in number of private vehicles has affected people's intracity travel behavior. The biggest change is the decline of the cyclists and public transport users, both in terms of total users and number of trips in many cities. Interestingly, some cities have shown improvement in the total non motorized transport (NMT) (walking and cycling) share such as Bhopal, Shimla, Kochi, and Guwahati (see Table 1). The public transport share in most cities is gradually deteriorating except for three cities, Jaipur, Nagpur, and Hyderabad. It is also interesting to see that while Shimla and Guwahati had the highest decline in public transport share, the NMT share increased in these cities between 1994 and 2008. This may perhaps be due to the proliferation of mixed land use areas, environmental concerns, and rising fuel prices.

Table 2. Public Transport Mode share in Indian cities
(Source: CAI-Asia, 2009, compiled from various sources)

	OLD Modeshare		NEW Modeshare	
CITY	Year	Public Transport %	Year	Public Transport %
Shimla	1994	86	2008	16
Guwahati	1994	47	2008	8
Kolkata	1994	89	2008	54

	OLD Modeshare		NEW Modeshare	
Hubli Dharwad	1994	50	2008	22
Kochi	2001	72	2008	51
Pune	1994	29	2008	12
Bhopal	1994	30	2008	15
Bangalore	2002	49	2008	35
Ahmedabad	1994	29	2008	16
Vijayawada	1994	34	2007	22
Varanasi	1994	9	2008	0
Kanpur	1994	18	2008	9
Mumbai	2005	52	2008	45
Jaipur	2005	17	2008	22
Nagpur	1994	5	2008	12
Hyderabad	2003	28	2008	35

The statistics of mode share should be noted with caution considering the issues with enumeration and modeling.

4. FORECASTING EMISSIONS FOR INDIA ROAD TRANSPORT

Estimating national transport emissions is complex because developing countries often find it difficult to measure trip characteristics at the country level. The methodology consists of estimating the vehicle numbers in-use and surveying and assuming the travel behavior. The vehicle registration data provided on the Ministry of Shipping, Roads and Highway website neither segregates vehicles by fuel type nor suggests the number in active use. The reason for the latter is that vehicles are not registered periodically and migration to another city not monitored.

In 2008, the ADB project "Transport Sector Greenhouse Gas Contributions in Asia" updated the ADB Study "Energy Efficiency and Climate Change Consideration for On-road Transport in Asia" (2006) and generated new emission forecasts. The main objective of this ADB project was to collect existing country information estimate future energy use and CO_2 emissions in Asia and the Pacific. To derive the travel characteristics, the authors tried to understand the behavior patterns by studying various research reports and national highway studies. Using the trip lengths, emission factors and energy intensity values, emissions were calculated for current and future scenarios.

Box 1. ASIF Philosophy

The transport sector consists of a diverse set of activities, connected by their common purpose of moving people and goods. Broadly speaking emissions (G) in the transport sector are dependent on the level of travel activity (A) in passenger kilometers (or ton-km for freight), across all modes; the mode structure (S); the fuel intensity of each mode (I), in liters per passenger-km; and the carbon content of the fuel or emission factor (F), in grams of carbon or pollutant per liter of fuel consumed.

G = A * S * I *F

This study assumes VKT of cars is on the slightly higher side when compared with other studies from India (Table 3). The main reason for this was that the estimates from some recent origin-destination surveys conducted by various consultants in NHDP projects showed high usage of vehicles and distortion in registration vis-à-vis private and commercial usages.[15] International experience suggests that average car usage for countries similar to India like China is nearly 24000 km/year[16]. To generate the best estimates, it would be better to segregate the vehicles based on age and to use the reduction factors in the distances traveled as older vehicles are used less because of the higher maintenance and operation costs. Since the activity data is not collected nationally, this was not considered. Using the fuel consumption assumptions and emission factors derived from IEA and Automobile Research Association of India (ARAI), emissions were forecasted in the ADB Study (2008) for 2005, 2008, 2015, 2025, and 2035.

Box 2. Transport Emissions - India's initial National Communication to the UN Framework Convention on Climate Change (UNFCCC), 2004

The total CO_2 emissions from transport sector in 1994 were 79,880 Gg. Among transport sub-sectors, road transport is the main source of CO_2 emissions and accounted for nearly 90 per cent of the total transport sector emissions in 1994. Road transport is characterized by heterogeneous gasoline-fuelled light vehicles and diesel-fuelled heavier vehicles. According to the survey by the Indian Market Research Bureau on behalf of the Ministry of Petroleum and Natural Gas (MoPNG, 1998), the transport sector consumed nearly all (98.3 per cent) of gasoline and 61.8 per cent of the diesel sold through the network in the country

[15] NHAI reports suggest average trip length of 100-217km, indicating high intercity usages (NHAI, 2008). See http://www.nhai.org/
[16] Projection of Chinese Motor Vehicle Growth,Oil Demand, and CO2 Emissions through 2050. See http://www.transportation.anl.gov/pdfs/TA/398.pdf

Table 3. Annual VKT (km) considered in selected studies in India

Description/Year of Forecast	IEA (2005)	Schipper et. al (2005)	India Vision 2020 Transport (1995)	Bose and Chary (1993)	Planning Commission (2001)	ADB/ CAI-Asia (2008)
2-Wheelers	7500	9000	3500	25 km / Day - approx		7500
3-Wheelers	40000	30000	-	-	29 200 km/year (in 1980 with increase of 80 km/year-Energy Map)	19000
Cars/LDV	8000	10000	7000 (in 1995 and increasing 100km every year)	26 Km/Day	-	28100
Light Commercial Vehicles	20000 (medium trucks)	-	-	-	23 000 km (in 1995 with 200 km every year)	28100
Heavy Commercial Vehicles (includes Bus)	60000 (Heavy Trucks) and 40,000 (Bus)	-	40,000 km (in 1995 and increasing 400 km every year)	46355 (Bus)	40 000 km (in 1995 with increase of 400km/year)	60000

Some interesting results from national level emissions estimates are shown below:

- PM emissions from road transport [17]would decline until 2025 by 1.9% per year due to the adoption of stricter fuel and vehicle emission standards, while NOx emissions would increase at a rate of 2.4% per year. However, PM emissions would subsequently rise again due to the continued rapid vehicle growth, especially if emissions standards are not further tightened (Euro IV and above). NOx emissions would increase at a rate of 2.4% (2005-2025).
- CO_2 emissions (see Figure 3) from road transport would increase at 7.8% per year, which is higher than many other Asian countries and results in an increase from 203 million tons to 905 million tons between 2005 and 2025. Passenger transport represents 45% and freight transport represents 55% of total CO_2 emissions from road transport in 2005 and the ratio would remain approximately the same in 2025.
- The share in fuel consumption between gasoline and diesel is 29% and 71% respectively.
- Within a decade (2005-2015), the VKT would increase at a rate of 6.7%, which suggests near doubling of transport-activity in the next decade.
- Dieselization of fleet would continue with diesel vehicles increasing from 12% in 2005 to 17% in 2025. For cars and SUVs, diesel vehicles show an increase from 19% to 44% in 2005 to 2025. This is due to the lower price of diesel in India compared to gasoline

[17] PM emissions are through the vehicle tail pipe and does not include the road dust which in India is a major contributor to PM emissions

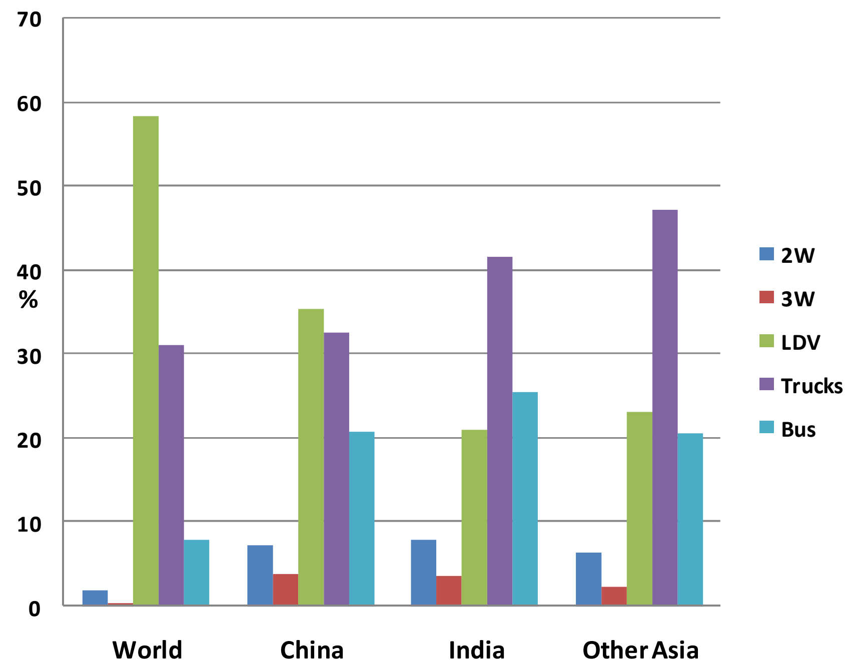

Figure 2. IEA-SMP Estimates for 2005 - World Transport Vehicle CO_2 Emissions
Source: IEA (2004)

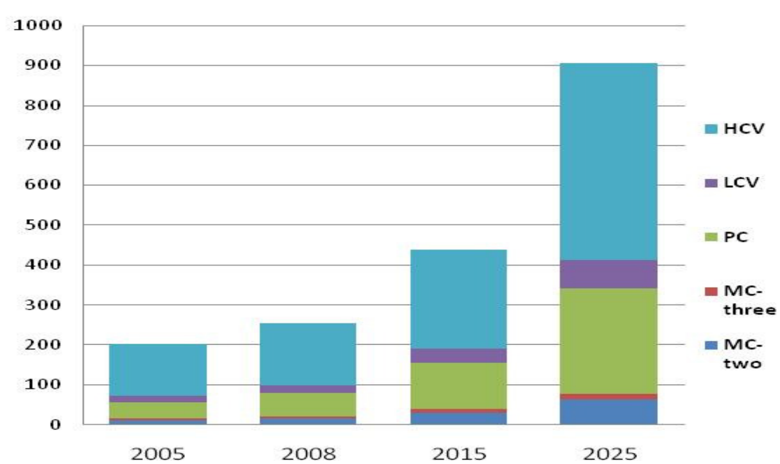

Figure 3. CO_2 Emissions in India (million tons)
Source: ADB/ CAI-Asia (2008)

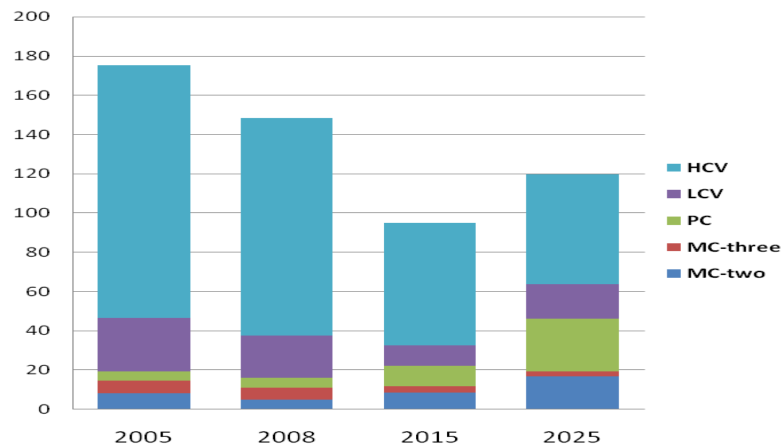

Figure 4. PM Emissions in India (Kilotons)
Source: ADB/ CAI-Asia (2008)

5. QUANTIFICATION OF EMISSIONS AT CITY LEVEL

The 2001 census of India indicates that out of the total population of 1.027 billion, about 742 million (72.2%) live in rural areas and 285 million (27.8%) in urban areas. Also, it is expected that urban population is set to reach 540 million (37%) by 2021. By 2021, number of cities having populations greater than 1 million would be around 51.[18] While India's top 20 cities account for 10% of the population, they generate 30% of the country's income.[19] The impact of transport on people's lives is apparent in the booming cities of India: people spend more on transport (21.3%) than on health (7.6%), education (5.2%) and housing (8%) combined.

With growing urbanization and rising income levels in cities, majority of vehicles are found in urban areas (in 1994, nearly 33% of India's vehicles are in the 23 top metropolitan cities).[20] There is a high probability that vehicles are being registered in cities then transported to the suburban and rural areas due to lack of sales and registration bureaus in the rural areas. Also there is high probability of people migrating to bigger cities bringing their vehicles with them. Due to insufficient data, more detailed analysis could not be done. However, high concentration of vehicles in cities and subsequent engendered traffic would generate a variety of social costs such as air pollution, accidents, and climate impacts.

Earlier research from ADB stated the importance of quantification of emissions at country and city levels and its backcasting method for developing policy packages. The study indicated that rapid mobility growth, including rise in vehicle ownership and use, are the primary cause of increase in emissions.[21]

To estimate the impact of cities on total emissions, 29 cities geographically scattered across India were selected. Currently, about 10% of India's total population lives in these cities and the Ministry of Urban

[18] Ministry of Housing and Urban Poverty Alleviation
[19] future capital research-National Council of Applied Economic Research-2008
[20] Rail India Technical and Economic Services Limited and Operations Research Group, 1994.
[21] Visioning and Backcasting for Transport in India & Delhi - ADB

Development (MOUD) projections suggest that by 2025, the figure would reach nearly 12%. It is to be noted that these 29 cities could represent nearly 38% of India's total *urban* population (considering the urban share as 27.8%).

Among the 29 cities, 27 are part of Jawaharlal Nehru National Urban Renewal Mission (JNNURM) cities and 24 have populations greater than 1 million. The selection of these cities was based on the cities selected for detailed study by the MOUD conducted in 2007-2008.[22] The MOUD study [23]provides the baseline data by conducting limited household interview survey, cordon survey, terminal survey, speed studies, parking studies, and collating some primary data. MOUD data was supplemented by city data from comprehensive traffic and transportation studies, comprehensive development plans, and traffic studies.

The emission calculations in this paper were quantified based on ASIF approach using the online tool "CART." [24] The trip data which is essentially the number of person trips were converted into vehicular trips considering typical occupancy ratios for various modes.[25] Using the average trip lengths from different reports (MOUD/CTTS/CDP) and supplemented with logical assumptions, vehicular mode wise trip lengths were calculated. Since the data is never collated on average age and vehicular fuel mix by governmental agencies, again further assumptions were made to fill the gaps. The emission factors and energy intensity values were based on IEA and ARAI.

The city analysis and subsequent comparison with national estimates generated some surprising results as shown below:

- The 29 major cities contribute only 22% of total CO_2 emissions from road passenger transport of India (see Figure 5 and 6). Per capita passenger transport CO_2 emissions in cities are high when compared with passenger emissions from India. Although the cities selected for the study constitute 10% of total population and 38% of total urban population, they accommodate only 23% of total national passenger travel (VKT – excluding the freight), indicating that the majority of VKT is happening outside these 29 cities. (This study highlights the 1998 MOUD findings - "urban transport is a major consumer of energy accounting for about 20% of the total energy used in transport sector").

[22] Study on Traffic and Transportation Policies and Strategies in Urban Areas in India-MOUD
[23] Administrative boundaries of many cities are regularly changed to include the suburban areas and this study is based on study area selected by MOUD study
[24] www.urbanemissions.info, Smart Carbon Analysis for Road Transport calculates carbon emission reductions for alternative transport interventions
[25] car = 1.8; 2-wheeler = 1; taxi = 2; buses = 33 assumption used where data not available

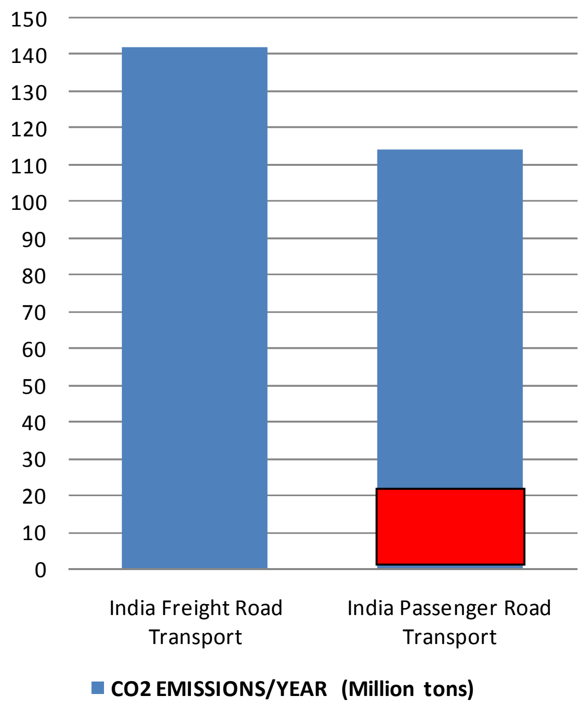

Figure 5. National and City Level Emissions
(the red color indicates passenger road transport emissions from 29 cities)

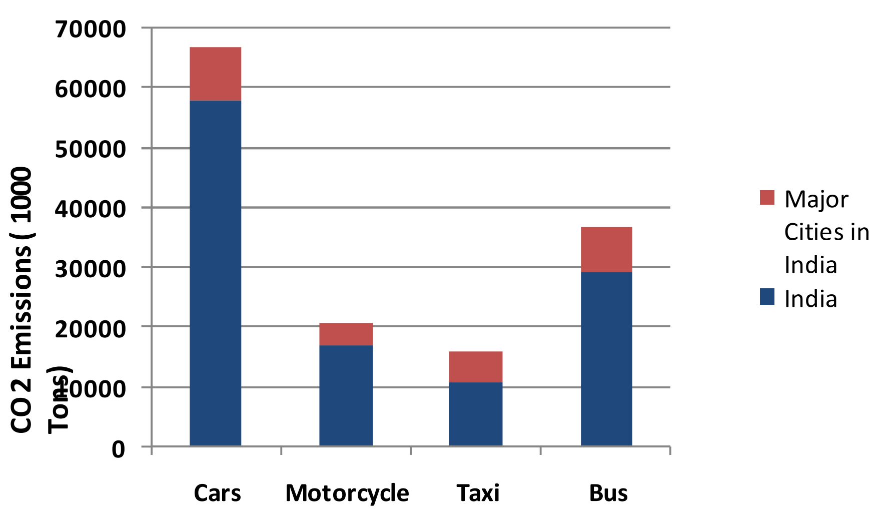

Figure 6. Comparison of passenger transport emissions from cities with total emissions from India

- The national estimate for individual travel is 2.1 km/day whereas an average urban individual travels approximately 4.4 km/day in the 29 cities. Current estimates suggest that there can be as many as 527 cities having population greater than 100,000.[26]

- India's national highways are the primary network and carries 40% of total traffic but accounts for only 2% of total road length.[27] This signifies the importance of intercity road transport on emissions. Since the impact of intercity transport and freight on emissions has never been explored in detail in India, the authors have tried to investigate this in a later section (Chapter 7).

- Indian cities are not maximizing the density influence to reduce the emissions. International research shows that the dense areas usually have fewer emissions. In India's case, many cities which are dense are showing high emissions because of insufficient public transport and high influx of private vehicles. For example Surat, Pune, Kochi and Madurai have approximately same area but different density. Kochi and Madurai have less density when compared to Surat and Pune but they also have less energy consumption. It may be logical to suggest that Surat and Pune have higher income. Then again, why do cities like Bhopal and Amritsar have higher per capita emissions than Chandigarh?[28] Why do cities like Hyderabad and Jaipur have high travel activity than a city like Kolkata? The Indian cities analysis shows that having public transport facilities (e.g., Mumbai and Kolkata) and land-use transport integration (e.g., Chandigarh) can not only better transport be provided but also emissions and economic activity can be decoupled. The travel behavior analysis also showed that Indian cities can be categorized into motorcycle cities, pedestrian cities and the transit cities. Each type of city presents different challenges and solutions. It is not logical to follow the "business as usual" approach, which is to establish the public transport and NMT improvements only after they grow in size. A better approach would be to re-orient the city growth to maximize the co-benefits agenda.

[26] http://www.world-gazetteer.com
[27] http://www.nhai.org/roadnetwork.htm
[28] Chandigarh is a mid-size, high-income, well designed city by Le Corbusier, a Swiss-French architect and urban planner in the 1950s. Many consider Chandigarh as the best designed and most livable city in India.

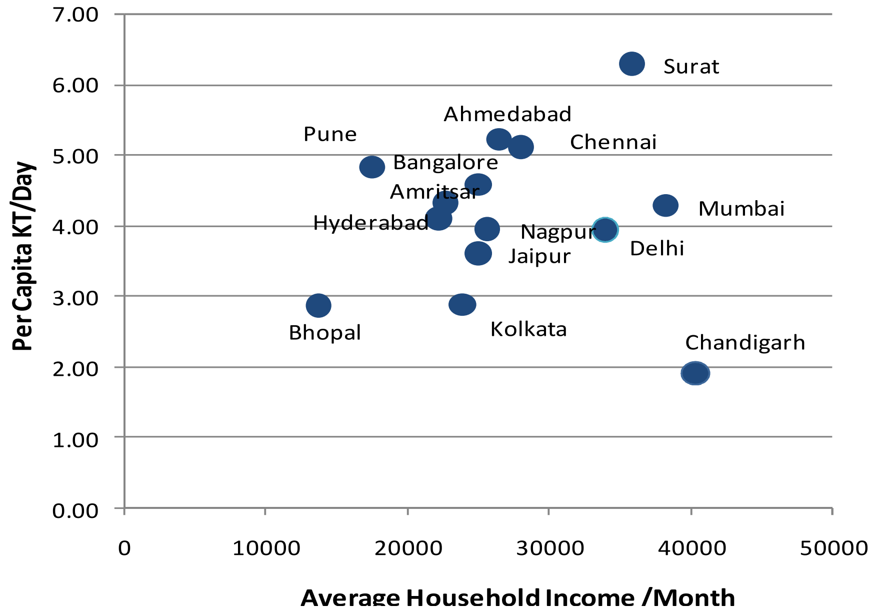

Figure 7. Variation of per capita kilometers travel / day with average household income

- When these results are compared with city estimates from other experts, differences exist as shown in Table 4. These differences may be due to inclusion of freight, inclusion of vehicles coming into study zone, different study area, differences in assumptions, mode share, and modeling.

Table 4. Comparison of CO2 Estimates from some studies

City	Research study	CAI Asia Center estimates (2008)
Bangalore	2.26 Million Tons in 2005-2006 [29]	2.54 Million Tons
Delhi	5.14 Million Tons (2004) [30]	4.14 Million Tons
Hyderabad	0.71 Million Tons (2006) [31]	1.58 Million Tons

- The estimates also show the importance of intercity bus transport. The CIRT[32] study had indicated the importance of improving the rural bus services and its importance (nearly 78% of total costs by state transport undertakings are borne by rural bus services). Not much attention has been paid by the government in pursing the agenda of increasing the occupancy of such rural services. This needs urgent attention in view of high intercity transport environmental impact.

[29] Co-benefits of controlling transport emissions in Bangalore city, India- Sarat Chandra et al.
[30] ADB. 2008. Visioning and Backcasting for Transport in India & Delhi
[31] http://www.urbanemissions.info/hyderabad/Index.html
[32] State Transport Undertakings : Profile and Performance', 1999-2000 Central Institute of Road Transport, Pune

Box 3. Bangalore Dilemma

Bangalore is one of the cities that continue to rely on bus-based public transport services, the Bangalore Metropolitan Transport Corporation (BMTC). BMTC has a fleet of 5,441 buses, which makes nearly 73,240 trips carrying 3.8 million passengers daily within a radius of 25 km from the city center, with 1.178 million service kilometers. The high pressure on the existing BMTC network is quite evident from the fact that the loading per trip is nearly 51 passengers. Each bus makes nearly 13 daily trips with an average trip length of 16km indicating high stress on drivers as they drive to congested traffic (210 km/day).

With an increase in area of Bangalore to 1,309 sq.kms due to the inclusion of adjacent suburban/rural areas, this added to the spiraling vehicle ownership (900 vehicles are added on roads daily). With the inclusion of metro light rail in 2011-2012, it remains to be seen if BMTC manages to retain its patronage.

The statistics show constant reduction in bus trips mode share: 60.19% in 1994 (ILFS); 48.91% in 2002 (RITES); and 35% in 2008 (MOUD). Meanwhile, the 2-wheeler ownership motorization levels (2-wheelers per 1000 people) increased from 124 in 1995 to 247 in 2005. To combat decrease in share, Bangalore doubled the number of buses in 7 years (2001-2007) but at the same time, owing to the growth in city size, the average trip length increased by 2.5km and per capita energy consumption increased from 3.59 Megajoules/Day (MJ/day) to 9.67 MJ/day. Thus, even if the mode share of Bangalore does not change, by 2025 the per capita energy consumption would increase to 15 MJ/day!

This shows that increasing the number of buses without improving the overall public transport system and integrating other modes is not enough. Public transport ridership will continue to decline unless city planners adopt innovative approach to retain the bus ridership.

6. IMPACT OF MODE SHARES ON CITY PASSENGER TRANSPORT EMISSIONS

6.1 Emissions Forecast In Cities For 2025

This study forecasted emissions for the 29 cities by considering the freeze-mode scenario (i.e., basic assumption being current mode share would remain same in 2025 without any technological improvements). Trip forecasting was done using the generic equations from the MOUD study on Indian Cities (2008). The population projections were also taken from MOUD study and normalized for year 2025. The following assumptions were made in this scenario:

- Shape factor (ratio of minimum spread and maximum spread) and structure of the city would remain the same in future.
- The same mode shares in the cities were used in generating the 2025 estimates
- Trip length = 0.0476 x population in 0.1 millions + 4.7726 x shape factor [33]
- Per capita trip rates were assumed based on current trends with regression. Population and trip lengths are dependent variables. These growth rates were compared with growth rates suggested by MOUD (1998 & 2008) and the logically consistent ones were selected. In fact many believe that the mobility rates would increase at the rate of 2-2.5% per annum.[34]

[33] MOUD (2008)
[34] MOUD(1998) and http://muepa.nic.in/pdf/annual-reports/1999-2000/English/6.pdf

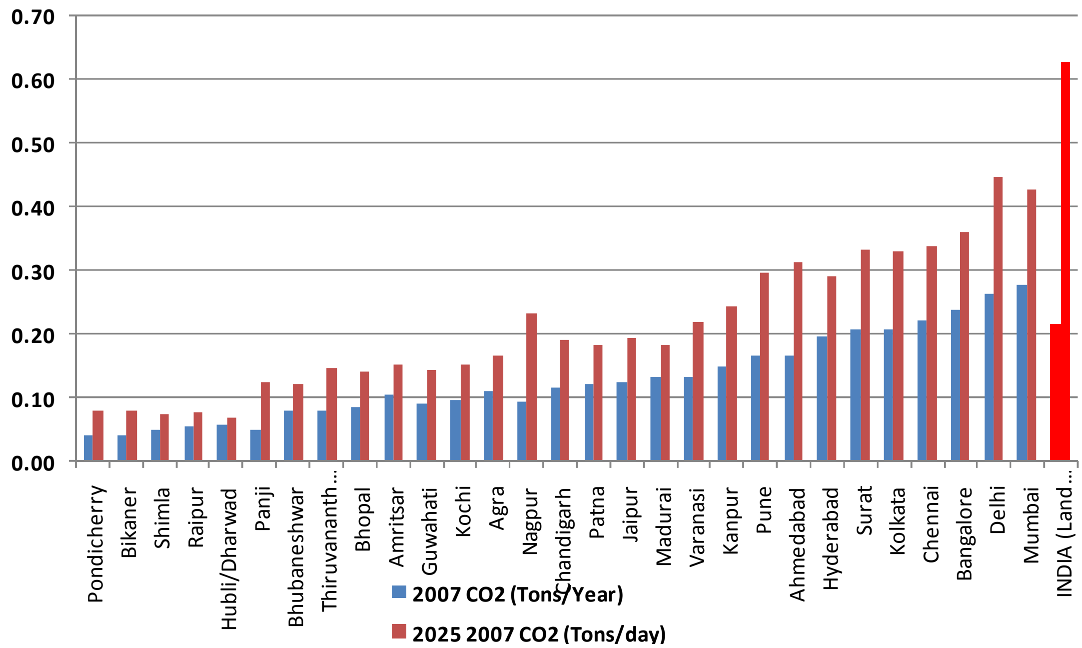

Figure 8. City Emissions in 2025 with current trip mode share

Even if the current trip mode share were fixed in favor of public transport and non-motorized transport, emissions are set to inflate by 2-3 times. Although current vehicle ownership is low, vehicle growth is four times population growth. The motorization of cities will happen over the next two decades as people become exposed to the variety of transport modes, while infrastructure for public and non-motorized transport deteriorates. In 2006, the government has initiated the National Urban Transport Policy which is funded by the JNNURM scheme to implement people friendly projects in 63 cities but implementation in the transport sector has been slow.

6.2 Impact of Non-Motorized Transport

In order to measure the influence of NMT on emissions, the authors decided to increase the NMT share by 5% and quantify the emissions based on average trip lengths. The 5% share was deducted in equal proportion from other motorized modes and the effects of such an action on emissions were calculated. Since the average per capita travel per day across cities is low (approximately 4.4km/day), and with mixed land-use prevailing across the cities, the administrators can easily implement NMT-oriented policies. NMT is one of the most cost-effective co-benefit strategies that can be quickly applied in many Indian cities. Quantifying such a scenario reveals that "on an average, approximately 9.16% reductions in CO_2 emissions can be expected from a typical Indian city."

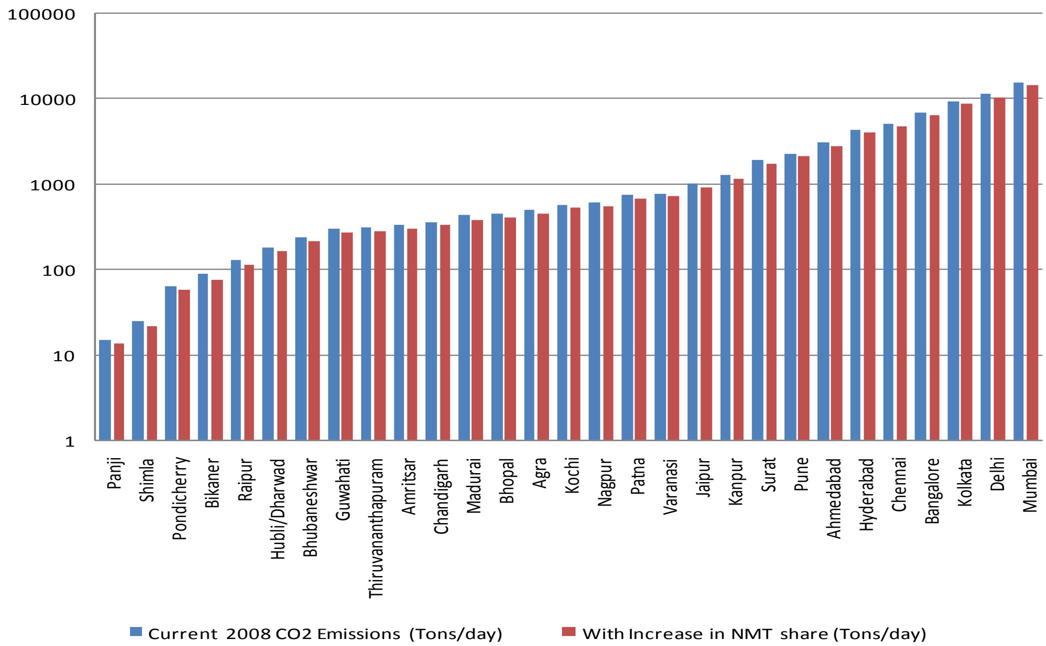

Figure 9. City Emissions in 2008 with increase in NMT share

6.3 Impact of Public Transport

In order to measure the influence of public transport on emissions, the authors decided to increase the public transport share by 5% and quantify the emissions based on average trip lengths. The 5% share was deducted in equal proportion from other motorized modes and the effects of such an action on emissions were calculated. If 5% of passengers shifted to public transport, nearly 6.21% of CO_2 emissions can be reduced in an average Indian city. Many smaller cities in India lack the basic public transport services and it is important to have the system in place so that the development is guided. Planners need to rethink the current philosophy that public transport services work only for the bigger cities. Indian cities should aim to shift the mode share from motorized transport to public transport.

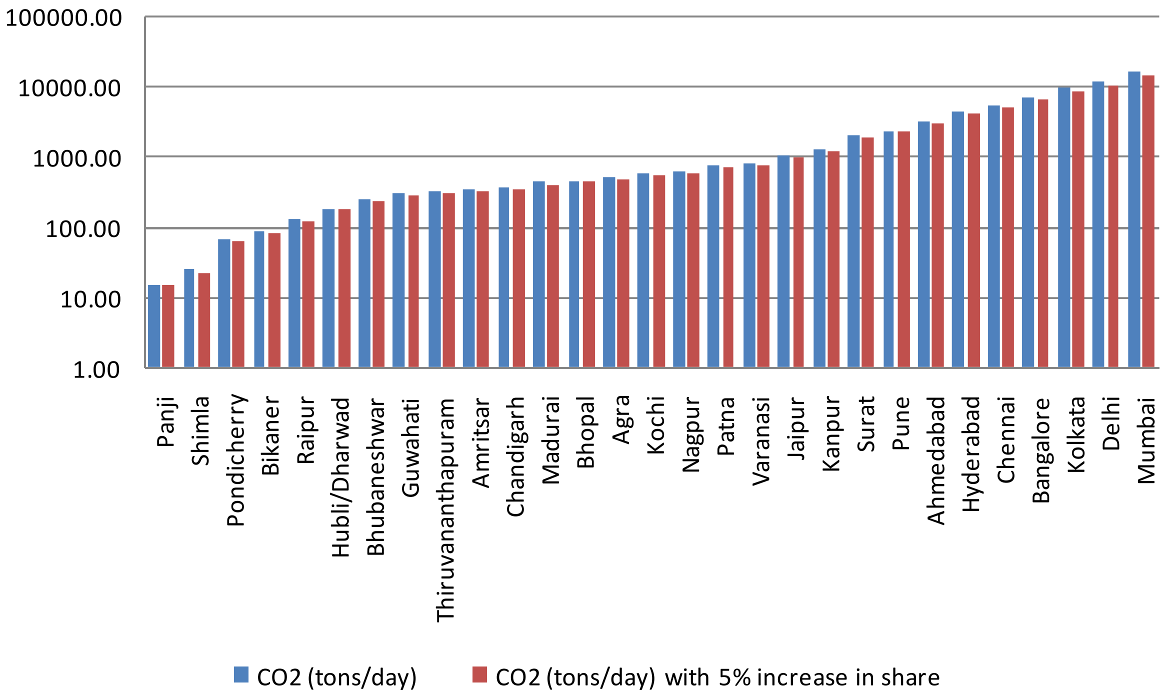

Figure 10. City Emissions in 2008 with increase in Public Transport share

7. EMISSIONS FROM TRAFFIC ON NATIONAL HIGHWAYS

National highways are designed for Level of Service (LOS) "B" by planners and consultants representing stable vehicle flow zone (LOS is the term used by traffic engineers to determine the quality of service of transport facility). The LOS "B" offer the drivers good freedom in terms of speed selection and to maneuver within the traffic stream. At this level, volume of traffic would be around 0.5 times the maximum capacity and is taken as the Design Service Volume (DSV). For a peak hour factor of 6%, the maximum capacity of a four lane road with paved shoulders on a plain terrain is 133,000 PCU/day with design service volume of 67,000 PCU/day.

Generally in rural road design due to increase in traffic growth, when the LOS drops down below "B", the road is widened (physical capacity is increased) to reach LOS B. Note that a newly constructed 4-lane road can offer LOS"B" for many years.

Using the philosophy of maintaining the LOS B by road widening, a typical section of a 4-lane road with paved shoulders with traffic equivalent to LOS B (V/C=0.5) was used to estimate the emissions and compare this to passenger emissions (only) from various cities. Fuel mileage was assumed (higher than city estimates) and corridor lengths were varied to equate the emissions (see Table 5 and Figure 11).

Table 5. Assumed Fuel consumption of vehicles in National highway

Vehicle	Assumed Fuel Consumption L/100KM in National Highways
Two wheeler	2.5
Three Wheeler	3.5
Car	8
Bus	30
Two Axle	30
Three Axle	30
Multi Axle	30
LCV	15
Tractor	10

Nearly 16 national highway corridors from various parts of India were studied to understand the rural highway traffic characteristics and to determine the average mode share. Using the DSV of 67,000, average number of vehicles at this LOS was determined. It is not correct to assume that this would be the exact amount of vehicles on all the 4-lane roads but it would be safe to assume that the corridor has been designed for this traffic (note that with the variations in mode share, the composition of traffic may change). The figure below shows the results of comparing national highway corridors operating at LOS "B" with city passenger transport emissions.

Results were surprising. Passenger transport emissions in cities like Bangalore and Delhi may corresponded to traffic emissions from 442km and 772km of 4-lane road length @ V/C = 0.5 (traffic of 33,360 vehicles/day or approx 2000 vehicles per hour in peak with 52% commercial vehicles and 7.7% buses). This shows that due to favorable trip mode shares of NMT and public transport, Indian cities are using the roads more effectively then rural roads (from emissions perspective). In a typical urban arterial road in Bangalore, 2-wheelers monitored constitute 40-50% of vehicles, 5-7% buses and 5% of commercial vehicles, indicating that the urban roads carry more fuel efficient vehicles than rural highways.[35]

[35] 2007 RITES -Comprehensive Traffic and Transportation study for Bangalore

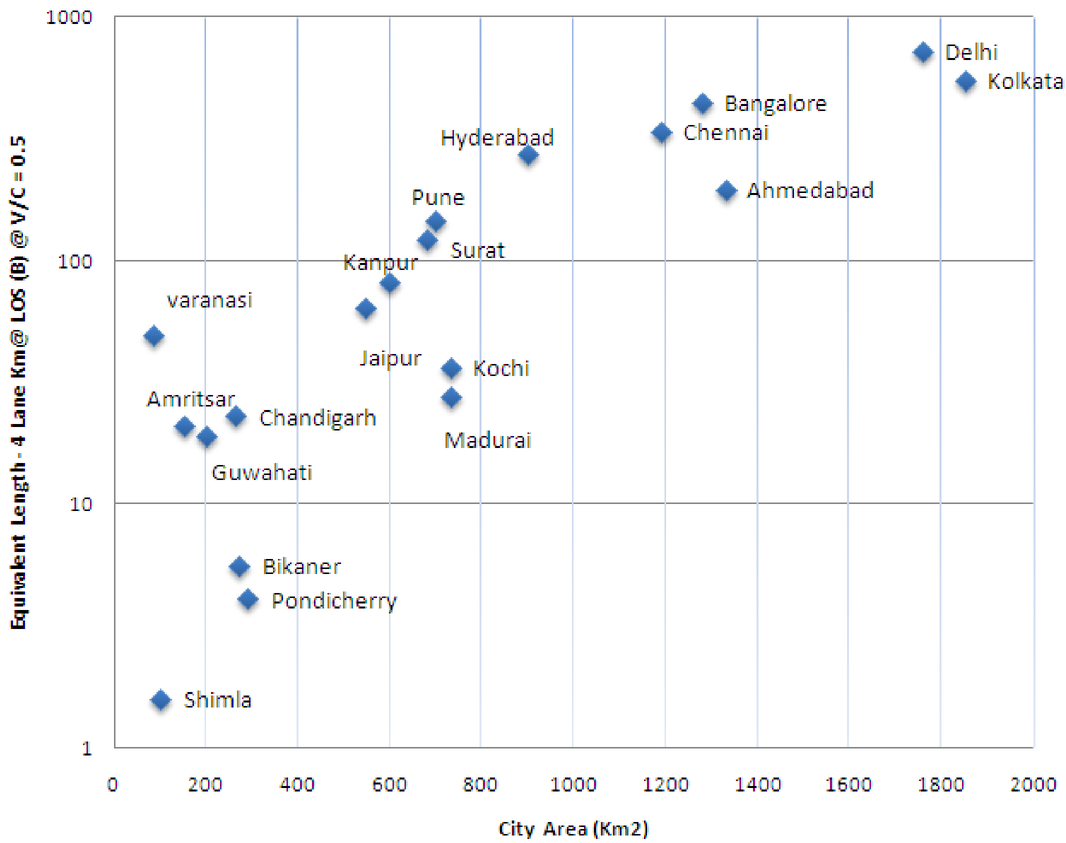

Figure 11. Comparison of City passenger transport emissions with equivalent length of a four lane road at V/C -0.5 and City area

In a research study,[36] China's transport CO_2 emissions were estimated at national, city and corridor level. The analysis showed some interesting results. The Shanghai-Wuhan highway of 827 km length with a traffic of 20483 vehicles (49%% freight and 51% passenger) had emissions nearing 2 Million tons. Passenger transport in Shanghai emitted nearly 7.7 million tons of CO_2 which is equivalent to 2.6% of total emissions from China's land transport.

Table 6. Country-City and Corridor level emissions in China

Description	Year	CO_2 Emissions
China	2004	297 Million Tons
Shanghai	2005	7.7 Million Tons
Shanghai-Wuhan-Highway (827 km)	2005	2 Million Tons

[36] Transport in China: Energy Consumption and Emissions of Different Transport Modes - ifeu – Institute for Energy and Environmental Research Heidelberg in cooperation with Institute of Comprehensive Transportation of National Development and Reform Commission of China (ICT) see http://www.ifeu.de/verkehrundumwelt/pdf/IFEU_et_al(2008)_Transport_in_China_GB.pdf

8. POLICY IMPLICATIONS AND RECOMMENDATIONS

Developing countries, like India, are currently at crossroads as current decisions and investments in the transport sector are set to lock-in GHG (CO_2) and air pollutant emissions for the next decades.

The National Urban Transport Policy of 2006 brought in a new direction and vision for the policy makers and has increasingly focused activities on the bigger cities for improving public transportation. In order to support the cities with the funding, the JNNURM[37] scheme was launched. The JNNURM offers carrot and stick policy incentives where the national government offers resources for improving the public transport (infrastructure and rolling stock) and asks city governments to reform the urban transport sector and take public transport improvement measures.

Some of the initiatives taken by the MOUD are:

- Setting up of a city-level Unified Metropolitan Transport Authority (UMTA)
- Setting up of a Dedicated Urban Transport Fund by tapping the fuel and vehicle registration taxes
- Integration of land-use and transport planning
- Setting up of a regulatory/ institutional mechanism to periodically revise fares for all public and intermediate public transport systems.
- Reforming the parking policy and tapping advertisement revenues
- Promoting multi-modal integration.

However, the cities are yet to become proactive in taking the initiatives suggested by the central government. Reports indicate that just about 10% of the amount sanctioned for JNNURM has been utilized in the last four years since the mission's launch in December 2005.[38] Also the JNNURM scheme is only applicable to 63 cities in India whereas there are a total of 527 cities with over 100,000 people. There needs to be a mechanism to scale up the activities in the remaining cities and modify the current strategy of promoting intercity movement by roads using the national highway development program.

Taking into consideration the findings of this research, national and local government agencies can consider the following recommendations:

1. Policies and projects should have a stronger focus on making cities livable and accessible for **people,** rather than on just improving the flow of **vehicles** in cities, by integrating transport demand management (i.e. reducing the number of trips made and distances traveled), public transport, and non-motorized transport into urban development and transport policies.

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[37] The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) is a project of the central government. Through this project, the central government funds cities in developing urban infrastructure and services. The cities will have to carry out mandated reforms in return. The mission will last for a period of seven years starting December 2005. The total central government funding will be Rs. 50,000 crores. Adding the contribution of states and municipalities, the amount will go upto to Rs. 1,25,000 crores over the seven year period.

[38] http://www.dnaindia.com/report.asp?newsid=1239703

2. Policies and projects should be developed with the aim to reduce CO_2 and air pollutant emissions from the outset, thus creating a low carbon and emission transport system, rather than adding emission mitigating measures to transport policies and projects after they have been designed. Land use and urban planning is critical in influencing transport demand and behavior.

3. In addition to the 29 prime cities, more analysis is needed for the remaining 498 cities, as well as intercity movements for which limited data is available but which contribute to about 78% of road transport emissions. Such analysis would enhance understanding of these sources of CO_2 emissions, and thus enable the formulation of more tailored and effective policies. By concentrating on smaller cities, the government can prevent that these cities make the same urban development mistakes as existing larger cities. Related to this, it is important to develop a mechanism to scale up activities from the 63 JNNURM cities to other Indian cities and modify the current strategy of promoting intercity movement by roads using the national highway development program.

4. Indian cities are not maximizing the density influence to reduce the emissions. Many cities which are dense are showing high emissions because of insufficient public transport and high influx of private vehicles. Many Transit oriented development initiatives are being taken by city governments, but much remains to be done on land use-transport-environment integration.

5. The National Highways carry a huge amount of traffic. Considering high emissions from road based mode of transportation, the government needs to revise feasibility and environmental impact assessment (EIA) guidelines to include emission quantification and mitigation measures in the selection of projects.

6. Urgent attention is needed for freight transport, which currently contributes to 55% of road transport CO_2 emissions. Most freight vehicles use diesel fuel which contributes to relatively high PM emissions and black carbon ("soot"), which in addition to being an air pollutant is considered a major contributor to global warming. However, this should not result in a reduced focus on urban transport.

ANNEX A

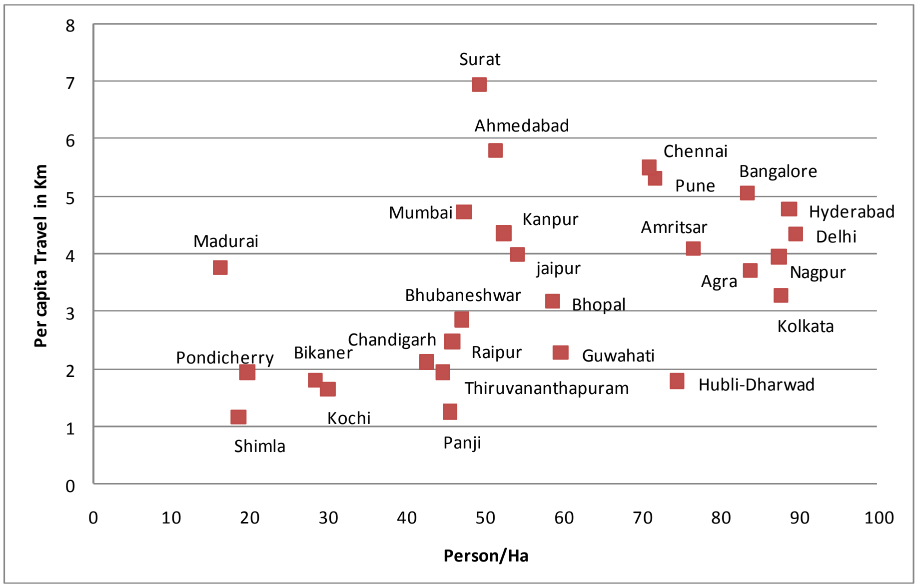

Figure 12. Density influence

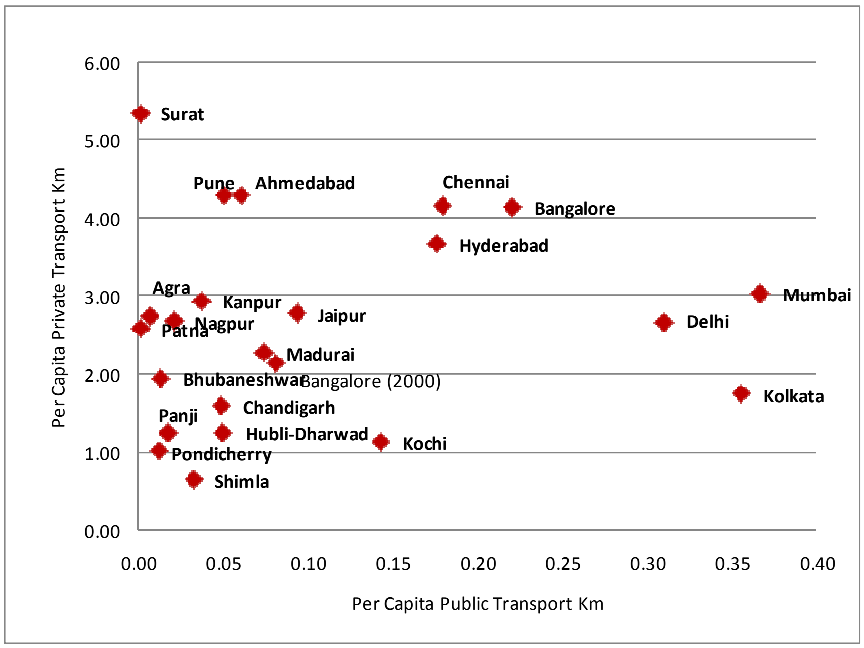

Figure 13 . Per capita Transport in Cities

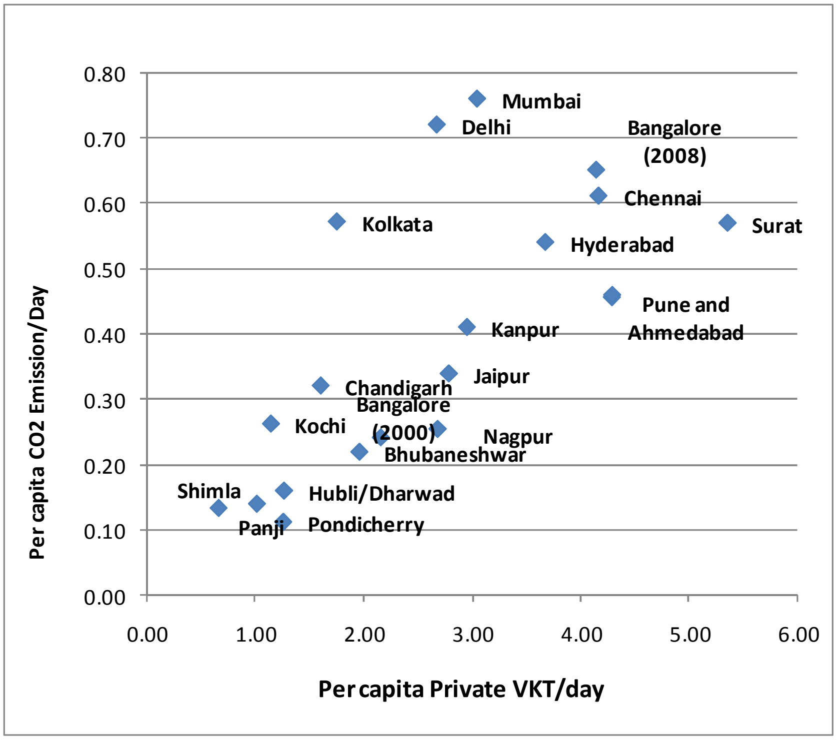

Figure 14. Per capita CO_2 Emissions in Cities

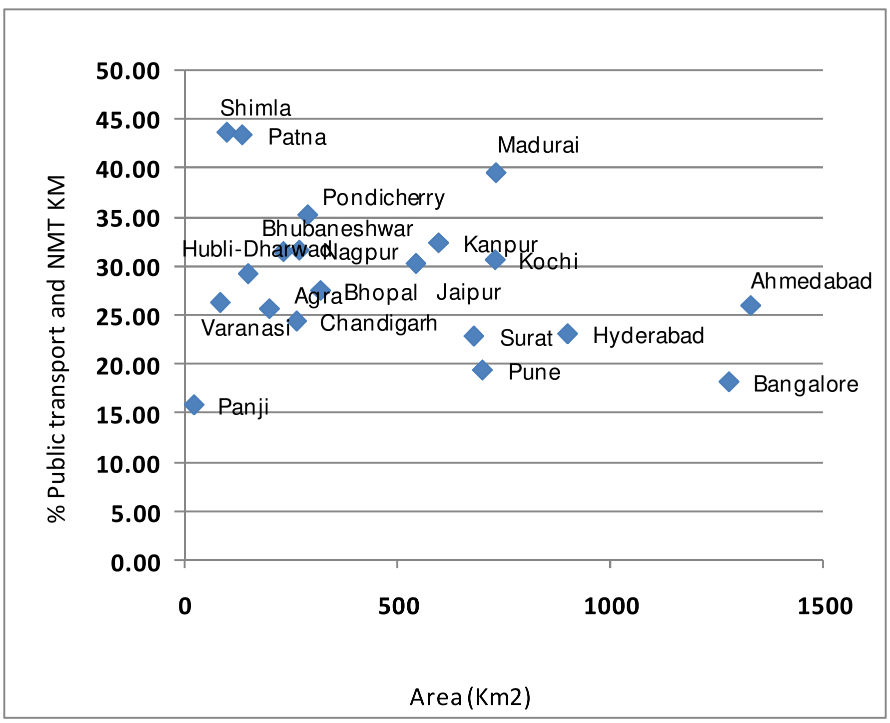

Figure 15. City Area vs Public transport and NMT travel

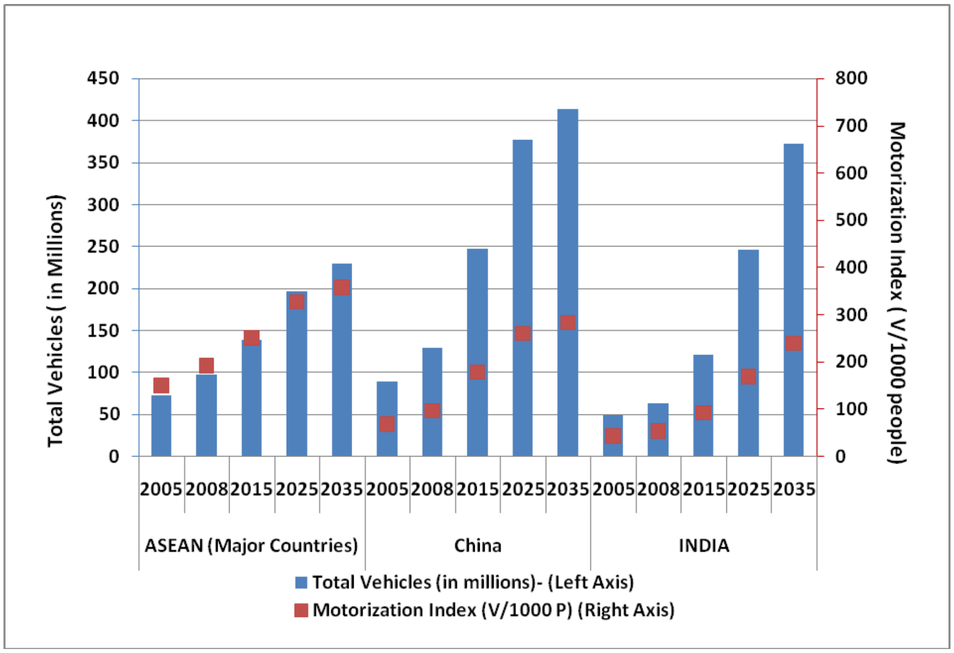

Figure 16. Motorization Index of ASEAN, CHINA and INDIA

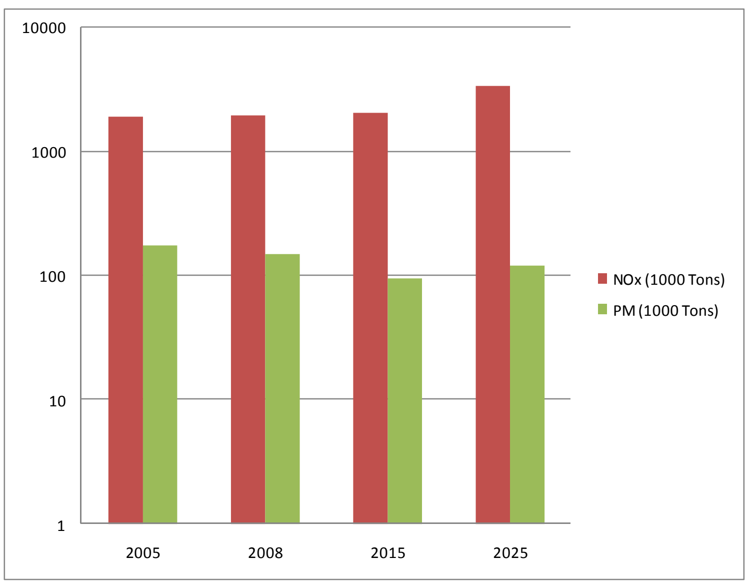

Figure 17. PM and NO_X emissions in INDIA

Table 7. Average Vehicle mode share in some National Highways in India

SI. NO	National Highways Corridor	Chainage	2W	3W	Car	Bus	2 Axle	3 Axle	Multi Axle	LCV	Tractor and Others	Year
1	NH-7 (Salem-Namakkal)	207+600-249+600	24.22	0.32	19.80	12.17	23.81	7.84	1.98	8.83	1.04	2003
2	NH14(Palanpur-Pindwara)	340+000-248+000	11.98	3.12	25.02	4.44	27.61	18.53	4.39	2.11	2.78	
3	NH47 (Salem-Coimbatore)	0+000-102+000	25.06	2.27	22.30	14.85	21.11	7.89	0.63	5.40	0.50	2004
4	NH-7(Farooq Nagar-Kottakota)	34+800-133+000	7.46	2.43	23.30	10.67	32.45	14.36	1.09	7.65	0.60	2004
5	NH1 Panipat Elevated Highway	86+000-96+500	14.25	5.50	32.50	6.50	23.00		7.50	7.25	3.50	2005
6	NH-7 Anantpur-AP/Karnatka	336+000-463+600	13.00		16.00	7.00	54.00			9.00	1.00	1999
7	NH-8A (Bamanbore to Garamore)	182+600-254+000	15.06		25.15	3.43	54.86				1.50	2002
8	NH- 28 (Gorakhpur Bypass)	0+000-32+469	22.36	1.00	18.79	18.42	23.45	6.38	0.88	4.97	3.76	2004
9	NH-31 (Siliguri to Islampur)	498+800 - 526+000	22.52	12.78	27.16	11.16	17.07	2.23	0.09	6.98		2002
10	NH-31 Nalbari to Bijni	983+000-1013+000	13.70	4.79	7.89	13.23	35.96	17.89		3.69	2.83	2002
11	Belgaum-Dharwad section of NH-4	KM 433-515	21.96	2.04	20.14	4.80	23.14	7.92	0.70	6.38	0.46	
12	Gonde-Nasik-Pimpalgaon-Section of NH-3	km 380km-426.000	15.00		22.00	7.00	18.00	9.00		10.00	13.00	2004
13	MP / Maharashtra Border Dhule (length 97.5 Km.)	168/500 to 265/000	16.33	4.33	12.67	3.33	33.67	11.00	3.33	9.00	6.34	2005
14	Namakkal - Karur - NH7	Km 258+600-292+600	32.54	0.87	14.97	9.42	21.49	7.97	1.09	6.27	5.38	2003
15	NH--2 from Varanasi to Aurangabad	Km 786-978.400	16.00		12.00	1.00	13.00	29.00	5.00	4.00	20.00	2007
16	NH-79A, NH-79 & NH-76 on Kishangarh – Udaipur Section	364.00 of NH-8 Junction - 113.800 of NH-76	15.25	1.42	18.75	2.67	16.50	20.75	16.08	4.42	4.16	2008