Addressing congestion and transport-related air pollution in Saharanpur, India

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ABSTRACT Rapid growth in the use of private motor vehicles in high-income nations has created serious problems of congestion in most cities, and has also contributed to a high dependence on oil, to air pollution and to high levels of greenhouse gas emissions per person. But rapid growth in the use of motor vehicles, and congestion and air pollution are also evident in cities in low-income nations – where transport infrastructure and management has been unable to cope with this upsurge in traffic. This paper considers the problems faced by a relatively small city in India, Saharanpur, where rapid growth in private motor vehicle use combines with limited local investment capacity and a high use of non-motorized vehicles, including bullock carts. It presents the findings of field surveys for the city's five main roads, and highlights the high levels of congestion and air pollution. The paper also presents an alternative scenario, emphasizing the promotion of public transport.

KEYWORDS air pollution / congestion / transport

I. INTRODUCTION

India's urban population is growing rapidly and now represents around one-third of the country's total population. Cities with more than 100,000 people (what are termed Class I cities in the Indian census) have over 65 per cent of India's urban population, and India now has the second largest urban population of any country (China having the largest).(1) Rapid increase in the population of any city brings with it significant changes in land use, including transformation of land for residential, commercial and industrial activities, and increased demand for transport.(2)

Over the last few decades, in India, as in most other nations, increasing use of motor vehicles has been inextricably linked to urbanization. Mobility in urban areas is of particular interest because limited space and high densities of land-intensive individual modes of transport (cars, motorbikes/ scooters and three-wheeled motor vehicles including auto-rickshaws) often result in congestion.(3) The basic causes of congestion and its consequences are similar in all cities. However, when compared to cities in high-income nations, cities in India are characterized by:

- much lower levels of motorized transport and travel requirements, with a higher proportion of trips made on foot or by non-motorized transport;

1. United Nations (2004), *World Urbanization Prospects: The 2003 Revision*, Population Division, Department for Economic and Social Affairs, ESA/P/WP190, New York, 323 pages.

2. Vasconcellos, E A (2001), *Urban Transport, Environment and Equity: The Case for Developing Countries*, Earthscan Publications, London.

3. TERI (2000), *Cleaner Air and Better Transport: Making Informed Choices*, TERI Press, New Delhi.

Vol 18(1): 141–154. DOI: 10.1177/0956247806063970 www.sagepublications.com

- more rapid rates of economic growth, population growth and growth in the number of motor vehicles;
- higher population densities;
- much lower per capita energy consumption and per capita emissions of carbon dioxide; and
- reduced access to capital and to advanced environmental technologies.

Despite cities in India having much lower levels of vehicle ownership, lower rates of trip generation and less fossil fuel consumption per person, most suffer from growing traffic congestion, overcrowded public transport, poor conditions for pedestrians and cyclists, and many have high levels of motor vehicle-generated air pollution and accidents.[4] This relates not only to the rapid growth in the number of motor vehicles, which increased from 21 to 43 million between 1990 and 2000, but also to the lack of investment in transport infrastructure.[5]

Traffic congestion means reduced vehicle travel speeds, longer travel times and increased fuel consumption, air pollution and discomfort for road users. To provide an efficient and environmentally sound transportation system is now a matter of great urgency for cities in India, both to improve the quality of urban life for the inhabitants and to sustain economic growth.[6] Of course, the pattern of transport differs in different urban centres, as it is influenced by factors such as size, form and structure of the city, employment characteristics, industrialization, commercial growth and topography.[7] But many cities have experienced rapid increases in the number of motor vehicles, combined with inadequate provision of public transport services and poorly managed city expansion. Without better management, problems of congestion and air pollution are likely to increase.

This paper considers these issues in the context of the small city of Saharanpur. It describes the findings from a traffic survey of the city's five main roads, and considers an alternative scenario for dealing with congestion and pollution.

4. CPCB (1999), "Central Pollution Control Board – auto emissions", *Parivesh Newsletter* Vol 6, No 1, New Delhi, June.

5. TERI (1998), *Air Pollution with Special Reference to Vehicular Pollution in Urban Cities*, TERI Press, New Delhi.

6. CSE (1989), "The environmental problems associated with India's major cities", *Environment and Urbanization* Vol 1, No 1, April, IIED, London, pages 7–15.

7. Bhattacharya, M (1977), "Role of municipal government in pollution control", *Environmental Pollution and Urban Administration*, New Delhi, pages 62–65.

II. THE CASE OF SAHARANPUR CITY

a. Introduction to Saharanpur

Saharanpur City is situated in the west of India's most populous state, Uttar Pradesh, between the hilly state of Uttaranchal (in the north) and the plains of Uttar Pradesh (to the south). It is a district headquarters and the second largest city in its division. According to the 2001 census, the city had 455,000 inhabitants within municipal boundaries (a population density of 239 persons per hectare), and the city's Town and Country Planning Department projects a population of 600,000 by 2005. Lying in the fertile land between two of India's most important rivers, the Ganga and the Yamuna, the city has a well-developed market for agro-based products. It is also a service centre for nearby towns and for the inhabitants of the hilly region of Uttaranchal. Over the last 25 years, several industries have developed in Saharanpur, and this has changed the fabric of the city's economy. The city has paper, strawboard, tobacco and cigarette industries as well as several medium-level agro-based, motor transport and hosiery industries that are flourishing. The city also has a reputation for wood sculptures, which are exported to several countries. This economic success helps explain why the city and its surroundings have experienced rapid change.[8]

Saharanpur is connected to other parts of the country by five main roads that converge on Ghanta Ghar, almost in the centre of the city (Figure 1):

- *Delhi Road*: This is the national highway, and connects the city with India's national capital. It bears a heavy flow of traffic because most traffic in and out of the city is along this road. It enters from the southwest.
- *Ambala Road*: This is another important road, which connects the city with the states of Punjab, Haryana and Jammu–Kashmir. It enters the city from the west, and much of the movement of agricultural goods, inputs and implements is along this road.
- *Chilkana Road*: Entering from the north, this connects the city to the town of Chilkana and several rural settlements. It serves as the transport route for agricultural commodities from nearby regions.
- *Chakrata Road*: Entering from the northeast, this connects the city to the city of Chakrata and many villages. Agricultural commodities and construction materials from nearby areas enter the city along this route.
- *Dehradun Road*: Entering from the west, this connects the city with the hill state of Uttaranchal, and commodities and tourists pass along this road to the hill stations of Massourie and Dehradun.

8. Fazal, S (2000), "Urban expansion and loss of agricultural land. A GIS-based study of Saharanpur city, India", *Environment and Urbanization* Vol 12, No 2, October, IIED, London, pages 133–149.

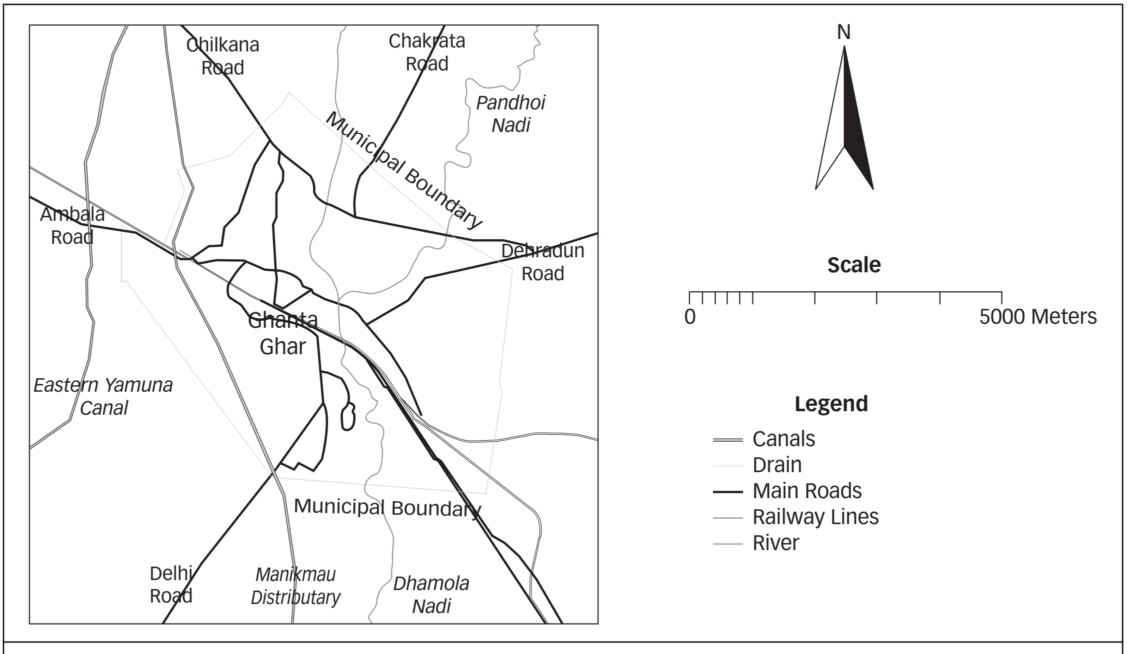

FIGURE 1
Saharanpur City surveyed roads

TABLE 1
Volume of vehicles on important roads of Saharanpur, 2003

Roads/vehicles		Heavy vehicle	Light motor vehicle	Two-wheeler	Three-wheeler	Cycle	Cycle rickshaw	Bullock-driven cart	Total motorized vehicles	Total non-motorized vehicles	Total
Delhi Road	Vehicles/hour	6	21.3	65.3	15	105	31	1.9	107.6	137.9	245.5
	Vehicles/day	145	513	1567	361	2518	745	46	2,586	3,309	5,892
Ambala Road	Vehicles/hour	5	14.2	57.8	10	126	30	1.8	87	157.8	244.8
	Vehicles/day	121	342	1,388	241	3,024	722	41	2,092	3,787	5,879
Chilkana Road	Vehicles/hour	2	9.1	53.5	8	88	23	1.1	72.6	112.1	184.7
	Vehicles/day	47	217	1,284	192	2,112	551	26	1,740	2,689	4,429
Chakrata Road	Vehicles/hour	3	6.9	41.1	6	74	18	0.5	57	92.5	149.5
	Vehicles/day	71	167	986	145	1,776	432	12	1,369	2,220	3,589
Dehradun Road	Vehicles/hour	5.2	20.5	60	12	97	34	1.2	97.7	132.2	229.9
	Vehicles/day	124	492	1,442	289	2,328	815	29	2,347	3,172	5,519

SOURCE: Based on field survey, 2003.

b. Data and methodology

This paper draws primarily on field surveys for the city's five main roads, which were conducted in September 2003 and which measure traffic congestion, traffic volume, traffic mobility and traffic pollution. This was supplemented by secondary data, drawn mainly from the records of government agencies. The vehicular traffic data were collected on three normal working days for a period of one hour at four-hourly intervals, i.e. at 00:00 hours, 04:00 hours, 08:00 hours, 12:00 hours, 16:00 hours and 20:00 hours. On the basis of these data, average vehicle flow was estimated for the entire day. The vehicular emissions were calculated taking into the account the average vehicle emissions suggested by TERI (The Energy and Resources Institute).(9)

9. See http://www.teriin.org/

c. Features of vehicular traffic in Saharanpur

The number of motor vehicles in Saharanpur has increased four-fold in 30 years, from an estimated 16,000 in 1971 to 64,000 in 2001,(10) as a result of increases in income level, inadequate provision of public transport services and unconstrained expansion of the urban limits. During 2001 alone, 82,371 motorized vehicles were registered at Saharanpur Road Transport Office, of which 76.5 per cent were two-wheelers and 16.1 per cent were tractors. Despite increasing numbers of vehicles in the city, there has been little upgrading of the road infrastructure.

10. Enumerating vehicles in any urban centre is difficult because the Road Transport Office registers vehicles for the entire district, and many vehicles are used outside the urban centres.

Vehicular traffic on the important roads of Saharanpur was categorized as:

- motorized vehicles: which included heavy diesel-engined vehicles (including buses and trucks), light-heavy vehicles, private four-wheeled vehicles (cars, jeep etc.), three-wheeled and two-wheeled vehicles and tractors; and
- non-motorized vehicles, which category included cycles, cycle rickshaws and bullock-driven carts.

The survey revealed that the important roads of Saharanpur had a heavy flow of traffic (an estimated 25,308 vehicles per day) but, importantly, there were more non-motorized vehicles than motorized vehicles. The Delhi Road had the highest traffic flow, with an average of 5,892 vehicles per day, followed by Ambala Road (5,879 vehicles per day), Dehradun Road (5,519 vehicles per day), Chilkana Road (4,429 vehicles per day) and Chakrata Road (3,589 vehicles per day). The share of non-motorized vehicles (70 per cent) was higher than of motorized vehicles on all the roads (Table 1). Delhi, Dehradun and Ambala roads had higher numbers of heavier vehicles – linked to their function of connecting the city to important resource areas. Chilkana and Chakrata roads connect the city to rural settlements, and have a higher proportion of non-motorized vehicles. Among the motorized vehicles, the high proportion of two- and three-wheelers was notable; among the non-motorized vehicles, the share of bicycles and rickshaws was equally high.

d. Traffic congestion in Saharanpur

To measure the level of congestion on the roads of Saharanpur, different modes of transport were converted into Passenger Car Units (PCU) based

TABLE 2
Passenger Car Unit (PCU) equivalents for different vehicles

Vehicle	Equivalent PCU factor	Type of vehicle
Bus/truck	3	Motorized
Light motor vehicle	1	Motorized
Auto rickshaw	1	Motorized
Two-wheeler	0.5	Motorized
Cycle rickshaw	1.5	Non-motorized
Bicycle	0.5	Non-motorized
Bullock cart	6	Non-motorized

on their size, speed and turning radius (Table 2). The non-motorized vehicles were assigned a higher PCU factor because of their slower speeds and slower acceleration. Bullock carts, for instance, were assigned a maximum PCU factor because of their slow speed, poor acceleration, higher braking margin and greater turning radius.

The survey showed that there were heavy motorized and non-motorized traffic flows on the important roads of Saharanpur during the day but little traffic during night hours. Road congestion is most notable during peak business hours, with the Delhi Road being the most congested (Table 3). This road recorded 4,837 PCU per day, followed by Ambala Road (4,563 PCU per day), Dehradun Road (3,329 PCU per day), Chilkana Road (3,282 PCU per day) and Chakrata Road (2,450 PCU per day). The high share of non-motorized vehicles on all the roads was the main factor in congestion. The maximum congestion recorded was 987 PCU per hour at midday on the Delhi Road, and the minimum was six PCU per hour at 00:400 hours on the Chakrata Road.

e. Trip length in Saharanpur

The survey also measured average trip length, and this showed high temporal and spatial variation. The morning and evening hours showed longer trip lengths, with midday showing shorter trip lengths. Chakrata and Chilkana roads had longer trip lengths, while Delhi Road had the highest share of shorter trips (Table 4). The trip lengths were longer on Chakrata and Chilkana roads because of a large number of rural dwellers coming to the city for employment and marketing. Trip lengths were shorter during the daytime, as much of the movement was by the city population moving within the city.

f. Emission levels in Saharanpur

Motor vehicles are the major source of air pollution in Saharanpur. Motor vehicles emit carbon monoxide, hydrocarbons, oxides of nitrogen, sulphur dioxide, suspended particulates and, for vehicles using leaded petrol, lead. Emissions of carbon monoxide and hydrocarbons are most pronounced when engines are idling, and total suspended particulates and nitrogen dioxide emissions are higher when vehicles accelerate. All

TABLE 3
Traffic congestion on the important roads of Saharanpur, 2003

Roads/vehicles	Passenger Car Units (PCU)	Heavy vehicle	Light motor vehicle	Two-wheeler	Three-wheeler	Cycle	Cycle rickshaw	Bullock-driven cart	Total motorized vehicles	Total non-motorized vehicles	Total
Delhi Road	PCU/hour	18	21.3	32.7	15	52.5	46.5	15.3	87	114.3	201.3
	PCU/day	435	513	783.5	361	1,259	1,117.5	368	2,092.5	2744.5	4837
Ambala Road	PCU/hour	15	14.3	28.9	10	63	45	14	68.2	122	190.2
	PCU/day	363	342	694	241	1,512	1,083	328	1,640	2,923	4,563
Chilkana Road	PCU/hour	6	9	26.8	8	44	34.5	8.6	49.8	87.1	136.9
	PCU/day	141	217	642	192	1,056	826.5	208	1,192	2,090.5	3,282.5
Chakrata Road	PCU/hour	9	6.9	20.5	6	37	27	4	42.4	68	110.4
	PCU/day	213	167	493	145	688	648	96	1,018	1,432	2,450
Dehradun Road	PCU/hour	15.5	20.5	30	12	48.5	51	9.7	78	109.2	187.2
	PCU/day	372	429	721	289	1,164	122.5	232	1,811	1,518.5	3,329.5

TABLE 4
Average trip lengths on important roads in Saharanpur, 2003

Roads	<15 km	10–15 km	5–10 km	2.5–5 km	>2.5 km
Delhi	12	11	20	17	40
Ambala	8	15	22	30	25
Chilkana	35	20	10	15	20
Chakrata	40	22	17	8	13
Dehradun	15	17	24	20	24

these emissions are to varying degrees deleterious not only to human health but also to the environment. Vehicular emissions are of particular concern as they are generated at ground level, and as a large number of people live, move and operate along the roads, they are thus exposed to automotive pollutants. These emissions also contribute to wider environmental problems – for instance, oxides of nitrogen and hydrocarbons contribute to photochemical oxidant pollution, and sulphur dioxide and oxides of nitrogen to acid rain.[11]

Traffic pollution in Indian cities is greatly influenced by the higher proportion of older and poorly maintained motor vehicles (which have higher emission levels) (Table 5). Also by the higher number of motor vehicles with two-stroke engines (motorbikes and scooters), which emit 10 times more hydrocarbons and smoke, and by the use of adulterated oil.[12]

Carbon monoxide. The important roads of Saharanpur receive an average of 197,626 gm/day of carbon monoxide (Table 6). Emission levels for this pollutant are higher from two-wheelers, three-wheelers (petrol-driven auto rickshaw) and older models of cars and jeeps, which are all the most commonly used vehicles. Among the important roads, Delhi Road receives the highest emission of carbon monoxide, an average of 51,528 gm/day followed by Dehradun Road (47,792 gm/day), Ambala Road (40,500 gm/day), Chilkana Road (32,449 gm/day) and Chakrata Road (25,359 gm/day).

Hydrocarbons. Hydrocarbon emissions derive from fuel evaporation as well as from incomplete combustion. Emission levels are higher from

11. Evteev, S A (editor) (1989), "Environmental problems in cities of developing countries", UNEP/USSR/IGU, Moscow.

12. Biswas, D K and S A Dutta (1994), "Vehicular pollution – combating the smog and noise in cities", *The Hindu*, Survey of the Environment, Chennai, pages 41–45.

TABLE 5
Pollutant emissions (gm/km) in Indian vehicles

Type of vehicle	SO_2	NO_2	PM	HC	CO
Two-wheeler	0.02	0.07	0.2	10.0	17.0
Light motor vehicle	1.0	3.2	0.33	6.0	40.0
Auto rickshaw	0.25	0.60	1.3	14	7
Heavy vehicle (diesel-operated)	1.5	21.0	3.0	2.1	12.7

SOURCE: Based on Central Pollution Control Board specifications. See CPCB (1999), "Central Pollution Control Board – auto emissions", *Parivesh Newsletter* Vol 6, No 1, June, New Delhi.

two-wheelers, three-wheelers (petrol-driven auto rickshaw) and older models of cars and jeeps. The important roads of Saharanpur receive an average of 73,893 gm/day of hydrocarbons. Among the important roads, Delhi Road receives the highest emissions, an average of 26,847 gm/day followed by Dehradun Road (21,675 gm/day), Ambala Road (19,560 gm/day), Chilkana Road (16,929 gm/day) and Chakrata Road (13,041 gm/day).

Particulate matter. Emission levels are higher from heavier diesel-engined vehicles. The important roads of Saharanpur receive an average of 5,025 gm/day daily. Among the important roads, Delhi Road receives the highest emissions of particulate matter because of a higher number of heavy vehicles (an average of 1,387 gm/day) followed by Dehradun Road (1,198 gm/day), Ambala Road (1,067 gm/day), Chilkana Road (718 gm/day) and Chakrata Road (654 gm/day).

Sulphur dioxide. Ambient concentrations of sulphur dioxide, a respiratory irritant, come mainly from the use of fuel with a high sulphur content. Heavy vehicles have higher emission levels and the main roads of Saharanpur receive an average of 2,933 gm/day of sulphur dioxide from vehicular emissions alone. Among the important roads, Delhi Road receives highest emissions (an average of 852 gm/day), followed by Dehradun Road (779 gm/day), Ambala Road (612 gm/day), Chilkana Road (362 gm/day) and Chakrata Road (329 gm/day).

Nitrogen dioxide. Transport is the principal contributor to nitrogen dioxide pollution in urban areas. Heavy vehicles have higher emission levels and the main roads of Saharanpur receive an average of 17,411 gm/day from vehicular emissions. Among the important roads, Delhi Road receives highest emissions (an average of 5,013 gm/day), followed by Dehradun Road (4,453 gm/day), Ambala Road (3,877 gm/day), Chakrata Road (2,181 gm/day) and Chilkana Road (1,886 gm/day).

TABLE 6
Emission of vehicular pollutants on important roads of Saharanpur City, 2003

Pollutants	Emission	Delhi Road	Ambala Road	Chilkana Road	Chakrata Road	Dehradun Road	Total roads
Sulphur dioxide	gm/hour	35.4	25.7	15.2	13.7	29.9	119.9
(SO_2)	gm/day	852.1	611.5	361.2	329.5	779.1	2,933.4
Nitrogen dioxide	gm/hour	207.7	160.6	79.6	91.6	84.7	624.2
(NO_2)	gm/day	5,012.9	3,877.2	1,886.5	2,181.4	4,452.7	17,410.7
Particulate matter	gm/hour	57.6	44.3	30.1	27.3	142.7	302
(PM)	gm/day	1,387	1,066.8	718.5	653.8	1,198.5	5,024.6
Hydrocarbons	gm/hour	1,003.4	813.5	705.7	548.6	918.5	3,989.7
(HC)	gm/day	2,684.7	19,560.1	16,928.7	13,041.1	21,678.4	73,893
Carbon monoxide	gm/hour	9,811.7	1,685.3	1,354.1	1,054.9	1,934.8	15,840.8
(CO)	gm/day	51,527.5	40,499.7	32,448.9	25,358.7	47,791.8	197,626.6

SOURCE: Based on Field Survey, 2003.

III. MITIGATION STRATEGIES FOR STRESSED ROADS IN SAHARANPUR CITY

Growing Indian cities such as Saharanpur are on the threshold of an environmental crisis due to growing air pollution. Although greenhouse gas emissions per person remain low by international standards, rapid growth in cities such as Saharanpur, and increasing amounts of road traffic, help make India one of the largest contributors to greenhouse gas emissions. At present, there is no focused approach or cohesive strategy to address the problems of congestion and pollution in smaller cities. There have been some efforts to address vehicular pollution (Box 1), especially after the intervention of the Supreme Court of India, but in a haphazard and piecemeal manner – and this has not helped to obtain the maximum benefit possible or make a discernible impact on mobility demand and vehicular emissions.

There are two basic approaches to reducing vehicular emissions: reducing emissions per vehicle kilometre travelled and reducing the total number of kilometres travelled. In other words, reduction and control of pollutant emissions from motor vehicles, along with more efficient utilization of motor vehicles, should be the aim of air pollution and greenhouse gas abatement policies. At the same time, more efficient vehicle use helps to control congestion. An emissions tax has been suggested as the most effective means of reducing pollution because it would provide consumers with an incentive to choose the least-cost option of the two approaches. But, in practice, such a tax would need to be accompanied by effective emission monitoring, which is difficult to implement in India. A more practical strategy would be to reduce both emissions and congestion, using a mix of "command and control" and market-based instruments.(13) These include:

- taxes on fuels, vehicles and parking;
- incentives and regulations affecting vehicle ownership, usage and movement;
- traffic management; and
- the provision of public transport alternatives.

Thus, there are a number of ways to meet the first objective of reducing emissions per vehicle kilometre travelled, such as enforcing higher maintenance standards on existing vehicles, in order to keep emissions closer to the design standards of the vehicles; introducing vehicles designed to meet stricter emission standards; and retrofitting motor vehicles to use other kinds of fuel modifications or fuels, such as compressed natural gas and propane.

The second objective is to reduce total vehicle kilometres travelled. This can be accomplished either by reducing the total demand for travel or by altering the mix of vehicles used to carry travellers. The first option may be achieved in part by increasing the cost of travel. More important, however, is to reduce the total demand for travel. Altering the mix of vehicles used to carry travellers requires policies to move people away from the use of private automobiles towards public transport. In the Indian context, a two-prong approach is required. The first is to raise the cost of private vehicle use. Options include traffic management (for example, one-way systems, closing streets, exclusively pedestrian zones downtown, and the provision of lanes exclusively for buses) and demand

13. TERI (1998), *Vehicle Emission Control Strategies to Protect the Local and Global Environment: Challenges and Opportunities in India*, TERI Press, New Delhi.

BOX 1
Measures to improve vehicle emission standards in India

Fuel requirements

Tighter new vehicle standards have been made possible through the widespread availability of unleaded petrol.

With regard to in-use vehicles, all four-wheeled petrol-fuelled vehicles are required to meet a standard of 3 per cent carbon monoxide when measured at idle; two and three-wheeled vehicles must meet a standard of 4.5 per cent carbon monoxide. With regard to diesel vehicles, all but agricultural tractors must meet a smoke density requirement of no more than 75 Hartridge Smoke Units (l-ISU) when tested at full load, 70 per cent maximum revolutions per minute (RPM) or 65 HSU when tested by the free acceleration test.

Recent steps to reduce vehicle emissions include the following:

Unleaded petrol: as of September 1998, only unleaded gasoline has been sold in Delhi with the result that there has already been a reduction of lead in the air by more than 60 per cent. Industry has also been asked to ensure that benzene emissions do not increase and to constrain the benzene content in unleaded fuel to 5 per cent, the level proposed for leaded gasoline in 1996. By 2000 the level was reduced to 3 per cent in Delhi only. Leaded petrol was banned throughout the country by' April 2000.

Other fuel parameters: the Supreme Court directed the Ministry of Petroleum and Natural Gas to ensure that the region of Delhi (which includes the national capital itself and bordering districts of adjoining states) be supplied with petrol with a maximum sulphur content of 0.05 per cent by 31 May 2000, petrol with a maximum benzene-content of 1 per cent by 31 March 2001 and diesel with a maximum sulphur content of 0.05 per cent by 30 June 2001.

CNG conversions: another debate focused on introducing compressed natural gas (CNG) on the existing fleet of buses, since the Supreme Court ordered that all buses more than eight years old were to be run on CNG in Delhi from April1 2000. From 2001 the entire fleet was expected to run on CNG.

Emissions standards for new vehicles: the National Ministry of Surface Transport has extended the Bharat Stage II emissions standards (equivalent to Euro II) for passenger cars to the other metropolitan cities. Euro II equivalent emissions standards for passenger cars were enforced in Delhi under an order of the Supreme Court from April1 2000. According to the notification, the dates of enforcement were to be January 1 2001 in Mumbai and July 1 2001 in Kolkata and Chennai. The date of enforcement for Mumbai was in keeping with the order of the Mumbai High Court. However, for Kolkata, the Department of Environment of the West Bengal government issued an order bringing the date of implementation of the Bharat Stage II standard forward to November 1 2000. Since the availability' of fuels of desired quality was a prerequisite for complying with the new standards, the West Bengal notification confirmed that both petrol and diesel with a maximum sulphur content of 0.05 per cent would be available in Kolkata from November 1, 2000.

Oil for two-stroke (2T) engines: pre-mixed oil dispensers have been installed in all the petrol filling stations of Delhi and the sale of loose 2T oil has been banned since December 1998. The Ministry of Environment and Forests has required the use of low smoke 2T oil since April1 1999.

Phase-out of old vehicles: Since December 1998, commercial vehicles older than 15 years have been phased out.

Steps taken to date have begun to reduce pollution in Delhi although, with the exception of ambient lead, the reductions have been very modest. Therefore additional control measures are under discussion, including:

- Improvement of public transport.
- Optimization of traffic flows and improved traffic management.
- Upgraded inspection and maintenance system.

continued

BOX 1
Continued

- Phase-out of gross polluters.
- Additional fuel quality improvements including lower benzene and aromatics in gasoline reformulated gasoline and lower sulphur in diesel fuel.
- Euro 4 standards by 2005.
- Restrictions on two-stroke engines, introduction of onboard diagnostics.
- Stopping fuel adulteration.
- Stage 1 vapour recovery systems.
- SIAM road map (the Society of Indian Automobile Manufacturers (SIAM) has submitted to the government a road map for a progressive reduction in emissions).
- Bharat Stage II-compliant four-wheeled non-commercial vehicles, light commercial vehicles and city buses in nine principal cities within six months of notification if fuel with 0.05 per cent sulphur is made available.
- Passenger cars meeting Euro III equivalent standards from April 1 2004 and Euro IV equivalent standards from 2007. This would be subject to the availability of petrol with a maximum sulphur content of 150 ppm and diesel with a maximum sulphur content of 350ppm.
- For commercial vehicles, SIAM has offered to comply with Bharat Stage II standards from April 1 2003 over the whole country, subject to the availability of diesel with 0.05 per cent sulphur. It has proposed to skip the Euro III stage and go directly to Euro IV by 2008 provided that diesel with a maximum of 50 ppm sulphur is available.
- For two-wheelers, SIAM has proposed emissions standards of 1.5 grammes per kilometre (g/km) for carbon monoxide and 1.5 g/km for hydrocarbons plus oxides of nitrogen from 2005 (a 25 per cent reduction from the current 2000 standards). It has suggested targets of 1.25 g/km for both of the pollutants in 2005 but wants a review of these standards in 2005. Similar levels of reduction are proposed for three-wheelers.
- In July 1998, the Supreme Court ordered the replacement of all three-wheeled auto-rickshaws registered in Delhi before 1990 with new ones running on CNG. The auto-rickshaw is a popular form of public transport and is used as a taxi in most Indian cities.
- The Indian Motor Vehicles Act prohibits the use of liquefied petroleum gas (LPG) as an automotive fuel. The main reason for this is that, it is sold at a subsidized price primarily as a kitchen fuel by the government-controlled oil industry. Since LPG is considered an environmentally cleaner fuel, the Indian parliament has recently passed a bill seeking to remove any restrictions on use of LPG as an automotive fuel. The government is now expected to issue the necessary notifications and safety standards.

SOURCE: Walsh, M P (2003), "Vehicle emissions and health in developing countries", in G McGranahan and F Murray (editors), *Air Pollution and Health in Rapidly Developing Countries*, Earthscan Publications, London; also TERI (1998), *Vehicle Emission Control Strategies to Protect the Local and Global Environment: Challenges and Opportunities in India*, TERI Press, New Delhi.

management (such as increased parking fees, road tolls, fuel taxes and car-pooling programmes). The second is to provide alternatives to private automobiles that can favour either larger vehicles (vans, buses or mass transit) or non-motorized options, primarily bicycles. Without viable transit alternatives, the higher road user fees would lead to higher financial costs of travel with relatively little decrease in actual travel.

In the case of Saharanpur, with its current total travel demand of 40,526 passenger kilometres per day of road traffic, an alternative traffic scenario is proposed here. This scenario would emphasize public transport, which could curb the present trend towards the increasing use of personalized transportation, and assumes no change in the use of non-motorized vehicles – in part because of the economic circumstances of the population using these.

Available literature suggests that to meet each kilometre of passenger travel demand, a car consumes nearly five times more energy than a 52-seat bus with 82 per cent average load factor, while two-wheelers consume about 2.6 times and three–wheelers three times more energy. A car occupies over 38 times more road space in comparison to a bus; the corresponding figures for two- and three-wheelers are 54 and 15, respectively. The fuel cost per kilometre of passenger travel for a two-wheeler, a three-wheeler and a car, when compared to a bus, is 6.8 times, seven times and 11.8 times higher, respectively. And the total cost of operation per kilometre of passenger travel for two- and three-wheelers is more than three times higher than for a bus, and for a car, 9.5 times higher than for a bus.(14)

14. TERI (1996), *CO_2 Mitigation and the Indian Transport Sector*, TERI Press, New Delhi.

The alternative scenario for Saharanpur was developed based on the survey findings.

- *Existing demand on the surveyed roads*: There was a high degree of variation in the volume of vehicles on surveyed roads. During daytime rush hours, the volume of vehicles was high and here, it would be possible to substitute personalized modes of transport with mass transport.
- *Trip length*: The survey highlighted the variation in trip lengths on different roads. The alternative scenario would give priority to public transport where trip lengths were longer, although even people making shorter trips could also be provided with the option of public transport by identifying stops at main junctions of important roads.
- *Congestion*: The survey highlighted the high contribution to congestion as a result of the increasing use of personal transport modes (especially two-wheelers – which can be maneuvered easily in heavy traffic). The alternative scenario would promote public transport aimed at reducing traffic congestion at peak traffic hours.
- *Carrying capacity of roads*: All the roads surveyed had long periods when the traffic volume was beyond their capacity. The reduction in volume would be the only solution for smooth movement of traffic.
- *Emission levels*: Greater use of public transport vehicles with lower emission levels could further reduce the amount of pollutants on roads.

The alternative scenario suggests that strengthening public transport, which would involve an increase in heavy vehicles of 179 to the present strength of 508, would result in a reduction of 53 per cent of total vehicles used on the surveyed roads (Table 7). There would be a 62 per cent decrease in light motor vehicles, a 57 per cent decrease in two-wheelers and a 68 per cent decrease in three-wheelers. This would reduce traffic congestion by 40 per cent, and a substantial reduction in emission levels from vehicles would also be expected, including a 30–36 per cent reduction in sulphur dioxide and particulate matter emissions, and a 66 per cent reduction in hydrocarbons and carbon monoxide emissions.

But improved provision of public transport is not enough to attract commuters away from their cars or motorbikes and onto public transport. Disincentives for private vehicle use are required to achieve a higher ridership for public transport. Similarly, the provision of public transport

TABLE 7
Saharanpur: implications of promoting public transport in place of individual mode of transportation

	As per present trends					As per alternative scenario				
	HV	**LMV**	**2-wh**	**3-wh**	**Total**	**HV**	**LMV**	**2-wh**	**3-wh**	**Total**
Total travel demand (in passenger km/day)	25,400	6,924	6,667	1,535	40,526	34,350	2,636	2,889	651	40,526
Modal split	5%	17.1%	65.8%	12.1%	100%	14.4%	13.9%	60.7%	11%	100%
Number of vehicles	508	1,731	6,667	1,228	10,134	687	659	2,889	521	4,756
Passenger Car Units	1,524	1,731	3,333	1,228	7,816	2,061	659	1,444	521	4,685
Composite air pollution loading (all vehicles)	**SO_2**	**NO_2**	**PM**	**HC**	**CO**	**SO_2**	**NO_2**	**PM**	**HC**	**CO**
Emission per day – gm/km	2,933.3	17,410.7	5,025	95,314.8	198,126	1877.5	17050.6	3533.6	41328.7	87844.9

alternatives is not sufficient to achieve reduced congestion or emissions. As motorists switch to public transit, others will start driving, upon seeing the congestion slightly reduced. Thus, it is always essential to attack urban congestion through comprehensive measures – both traffic management and pricing – that also restrict automobile use.

IV. CONCLUSION

The urbanization process in Saharanpur is characterized by an infrastructure that is under severe stress as a result of rapid growth in population and in the number of road vehicles, and by a lack of planning and coordination among various government authorities for developing infrastructure facilities. Road transport, which is characterized by congestion and high levels of air pollution, is the most important mode of transport in the city, and is likely to remain so. A survey of traffic on Saharanpur's major roads leads to the conclusion that the promotion of public transport could be the most effective measure to reduce both pollution and congestion in the city. This is proposed, however, with the recognition that no single measure can be sufficient in addressing this complex issue, and that more comprehensive management approaches will also be needed.