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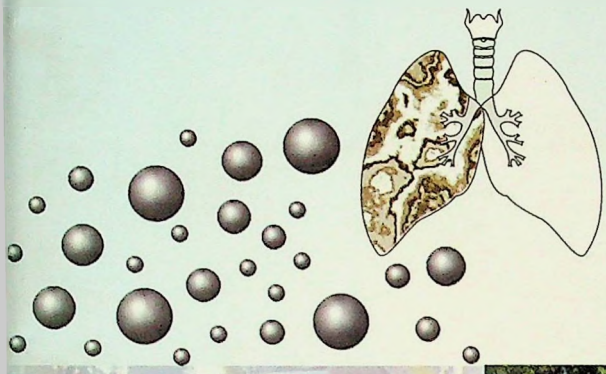
CHOICES FOR SUSTAINABILITY: 1

# Cleaner air and better transport

## making informed choices



# Cleaner air and better transport in cities

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TO TURN a clean sheet of white paper into a sheet of carbon paper within 8 hours, all you need to do is to filter ordinary air through it—air pollution will do the rest. If you find that hard to believe, here are the details of what researchers at TERI (Tata Energy Research Institute) observe virtually every week.

At a spot only a few metres away from Lodhi Road, one of the leafier roads of New Delhi, stands a strange-looking contraption (Figure 1). Twice every week, at 6 o'clock in the morning, a fresh, spotless, white sheet of paper is placed atop the device, resting flat on a supporting platform. The sheet is of the same size as that used in most photocopiers. Air is sucked through the sheet of paper at a steady rate. The paper is porous but the openings are so fine that only particles that are 1 micrometre or smaller can pass through. (A human body's in-built filter – the hair inside the nose and the moist lining of the air passage – can retain only those particles that are ten times as large.) Eight hours later, when the paper is removed, you can hardly distinguish it from carbon paper: it is thickly coated with dust and soot, some 160 milligrams of it on an average day (Figure 2). Over the 24-hour sampling period, the paper is changed every 8 hours, which means that we have a good sample of air as found in three periods: 6 o'clock in the morning to 2 o'clock in the afternoon; 2 in the afternoon to 10 in the evening, and 10 in the evening to 6 the next

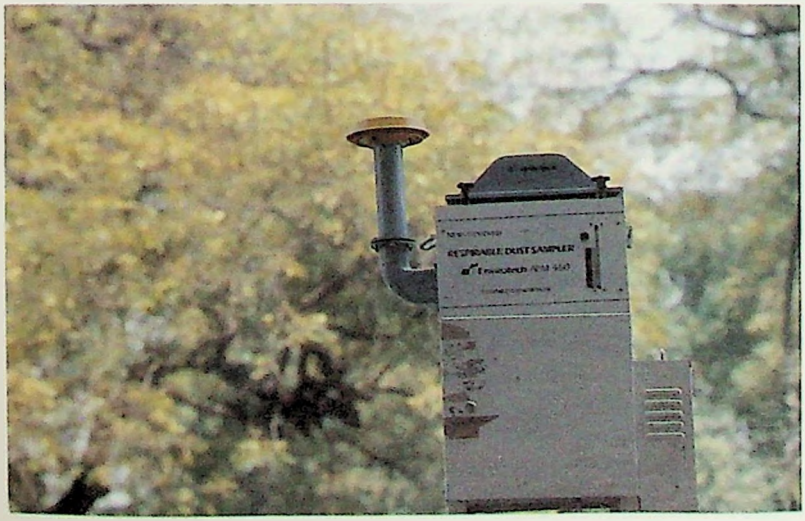


Figure 1 Air sampler to measure air pollution

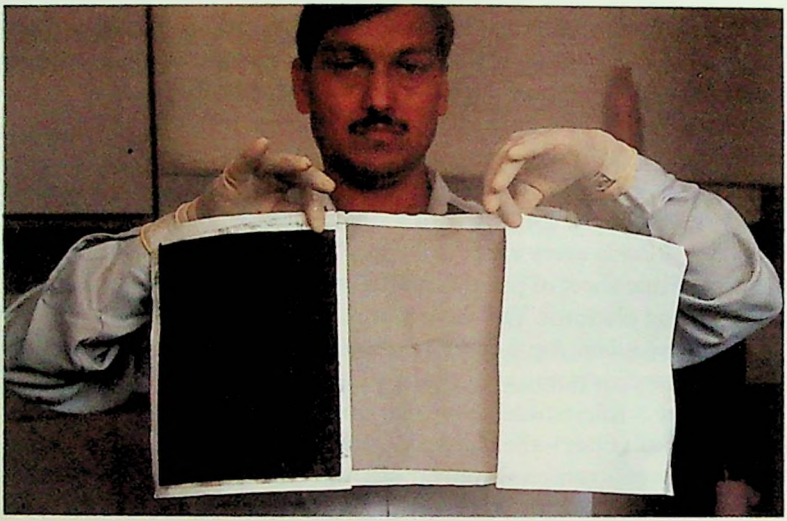

Figure 2 Pollutants turn a white filter paper to grey or black

morning. By analysing the substances retained on the filter paper, it is possible to guess their source in some cases: silica would indicate the sandy soil of the desert; lead points to traffic; ash means the thermal power stations that burn coal; and so on. The device is also used for sampling gases, namely nitrogen dioxide, sulphur dioxide, and ozone, that are serious pollutants.

## How does polluted air affect your health?

Severe air pollution can kill. The week that followed the infamous 'peasouper' fog in London in December 1952 left 4700 people dead. The elderly and those suffering from heart or lung diseases were the most common victims. Pregnant women, children, and the elderly are particularly susceptible to polluted air and so are those – traffic policemen, taxi- and autorickshaw-drivers, and garage attendants, for instance – who are exposed to polluted air for many hours a day at a stretch. The Central Road Research Institute in New Delhi carried out a study that compared such health problems as irritation of the eye and the throat among traffic policemen and those who work in offices. The study found that irritation of the eye was far more common (94%) among the policemen than among office workers (28%). Problems related to the throat were equally high in the policemen whereas the figure among office workers was less than 15%.

An active adult breathes in, on an average, about 15 000 litres of air each day but those engaged in hard manual labour or physical exercise inhale many times that amount during the physical activity. Children can be particularly susceptible to air pollution because they not only take in more air (if compared to adults on the basis of body weight) but their airways are narrower, their lungs are not fully developed, and they are more active than adults.

The most common air pollutants are (1) fine particles of soot, dust, etc., collectively known as SPM (suspended particulate matter) or TSP (total suspended particulates), (2) nitrogen dioxide and other oxides of nitrogen, (3) sulphur dioxide, (4) carbon monoxide, (5) hydrocarbons, and (6) ozone. Lead is also a serious pollutant in the developing world where the use of lead-free petrol is not yet common.

**Suspended particulate matter** (which includes fine soot, dust, pollen grains, and so on found floating in the air) consists of particles that are smaller than 100 micrometres (the diameter of a human hair is about 50 micrometres). The larger of such particles (greater than 10 micrometres across) are filtered out before they can reach the air passage but the smaller ones collect in the middle of the respiratory tract—particles smaller than a micrometre penetrate as far as the remotest parts of the lungs, namely the alveoli or the air sacs. It is through walls of the alveoli that oxygen taken in with breath is exchanged for carbon dioxide, which is expelled as we breathe out. A study carried out by the Vallabhbhai Patel Chest Institute in Delhi that compared the residents of two areas – one had a much higher concentration of suspended particles in the air than the other – showed that the lungs of those who lived in the more polluted locality clearly performed worse than of those from the less polluted locality.

Literature on pollution talks of two grades of particulate matter, PM10 and PM2.5, which tell us the size of particles: PM10 includes all particles with a diameter of up to 10 micrometres; PM2.5 refers to even finer particles, namely those that are 2.5 micrometres or smaller. The finer the particles, the deeper they penetrate and the longer the remain airborne.

**Nitrogen dioxide** is transformed in the lungs to nitrosamines, some of which are carcinogenic. When exposed to high concentrations of nitrogen dioxide, the tubes that form a part of the respiratory system can contract, thus narrowing the air passage.

**Sulphur dioxide,** a colourless but sharp-smelling gas, affects breathing: air passages, the fine tubes that transport air to the lungs, can become narrower when exposed to it, which means that those

with coughs, colds, or lung diseases, and the very young and the very old, are particularly affected. The characteristic smell in streets congested with lorries, buses, and other diesel-powered vehicles is mainly due to sulphur dioxide.

**Carbon monoxide**, a colourless and odourless gas, combines more readily with blood than oxygen does, thus cutting down the amount of oxygen that reaches our blood. Even in small quantities (100 ppm, or 100 parts of carbon monoxide per million parts of air), carbon monoxide makes us feel drowsy and slows down our reflexes; in large doses, it can make us unconscious and can even be fatal.

**Hydrocarbons** are fine particles of unburnt petrol and oil. Some of the chemicals associated with hydrocarbons are very strong irritants for the eye and the throat, some are carcinogenic, and most are responsible for unpleasant smells.

**Ozone** is a colourless gas with a pungent smell. It is formed when nitrogen dioxide reacts with some of the hydrocarbons in the presence of sunlight. Ozone can make eyes itch, burn, and water; lower our resistance to colds and pneumonia; and make breathing harder, especially for children and the elderly and those engaged in vigorous physical activity. Ozone is worse for those who suffer from asthma because it increases the effect of allergens.

Two or more of the pollutants often act in tandem. Particles of suspended matter act as carriers for gases by trapping them within the fine cavities present inside some porous particles. Air in cities is polluted with these and several other pollutants, though different pollutants are present at times and in differing amounts, depending on the season, time of day, and the sources of pollution. Thermal power stations that burn coal, for example, release large amounts of ash into the atmosphere and cotton mills emit fine particles of cotton. It is necessary to know what the major sources of pollution are in a given city and how much each of them contributes to the pollution—hence the need to measure the extent of pollution and to maintain accurate statistics.

## What do the statistics on air pollution really mean?

'In Delhi, motorized transport (buses, cars, scooters and motorcycles, and so on) is responsible for 64% of the total pollution.' This must be one of the most frequently quoted statistic in any debate or article about air pollution. Revised estimates are even higher (67% in the 1997 White Paper on pollution in Delhi and 70% in the June 1999 issue of *Parivesh*, the newsletter of the Central Pollution Control

Board). No matter what the number is, we should look beyond it: what does the number really mean? Pollution is not a concrete, homogenous entity that can be precisely apportioned. It is not as though there is this large pie called pollution and two-thirds of it is contributed by motorized transport—the facts are a little more complicated than that. First, what the oft-quoted statistic takes as pollution is the total, by weight, of five pollutants, namely (1) suspended particulate matter, (2) oxides of nitrogen, (3) sulphur dioxide, (4) carbon monoxide, and (5) hydrocarbons, emitted to the atmosphere every day. That total is estimated to be 1825 tonnes (data for 1998/99) by the Central Pollution Control Board.

However, the five pollutants are not strictly comparable weight for weight. Carbon monoxide, for example, can be deadly even in very small doses whereas smoke or dust has less serious immediate consequences. Secondly, the actual quantities of each of the pollutant are arrived at by a series of elaborate calculations and not by direct measurement. And estimates of how much pollution is caused by each of the major sources, namely motorized vehicles, thermal power stations, factories, and households, are the result of even more assumptions and calculations.

Thirdly, a city is not a closed box that retains all the pollutants generated within its four walls; the atmosphere is a dynamic system, turbulent and complex, that respects no boundaries. Simply measuring the mass of pollutants is not adequate; we must consider how much room do the pollutants have to disperse. Just as smoking in a small, poorly ventilated room has greater impact on air quality than smoking in large, open spaces, though the amount of smoke is more or less the same, so it is with pollution due to transport. Pollution figures are, therefore, often expressed in terms of the quantity of a pollutant within a given space, grams or micrograms per cubic metre of space, for instance. It is these figures that are quoted for different cities, as a part of the weather report, in the Star News on the television. The concept of air quality standards is explained in Appendix A.

All this is not to say that air pollution in cities is not a serious problem. Something that shortens life, makes hundreds of thousands of citizens more prone to diseases, and lowers the quality of life for all is very serious indeed. But what we have set out to do in this little book is to help you make sense of what you read or hear about the topic through the mass media – and you are going to see a lot of that in the years ahead – and to let you figure out how best you could contribute to making our cities healthy and liveable once again.

## How does transport contribute to air pollution?

All vehicles that are powered by petrol, diesel, natural gas, or any other petroleum product emit, or give out, pollutants as the fuel is burnt inside their engines. However, some vehicles are more polluting than others, depending upon the kind and quality of fuel, how efficiently they burn it, what mechanisms – if any – they have in place to 'neutralize' pollutants, and so on. Thus, petrol-driven vehicles have a different pattern of pollution than diesel-powered vehicles; four-stroke engines (used in cars, some motorcycles, and the newer models of three-wheelers) emit less of unburnt oil than two-stroke engines (used in most scooters, mopeds, some motorcycles, and the older models of three-wheelers) do; and cars that use catalytic converters are less polluting because the pollutants are neutralized to carbon dioxide, water vapour, and nitrogen (an inert gas).

Broadly speaking, petrol-driven vehicles (cars and those motorcycles, scooters, etc. that use the more efficient four-stroke engine) emit more of unburnt petrol and carbon monoxide whereas diesel-powered vehicles (buses and lorries) emit more of soot (the technical term for which is 'suspended particulate matter') and oxides of nitrogen. Autorickshaws, scooters, motorcycles, mopeds, and so on that run on two-stroke engines use petrol mixed with lubricating oil and, as a result, emit large quantities of unburnt petrol besides carbon monoxide and soot. The problem is aggravated if petrol and the lubricating oil are not mixed in the right proportion; there is incentive enough to add excess of oil because it is cheaper. That is why it is now mandatory to use pre-mixed 2T oil. Tyres, brake linings, and clutch pads are also a source of fine particles of aluminium, asbestos, cadmium, chrome, cobalt, copper, nickel, and zinc.

A toxic metal that can be directly traced to transport-related pollution is lead added to petrol. Making the use of lead-free petrol mandatory will eventually reduce the concentration of lead. The Central Pollution Control Board has already reported a decrease in the concentrations of lead after lead-free petrol was introduced in Delhi.

In cities, a large number of vehicles ply within a small area, and the pollutants they release cannot escape easily because open spaces are few; most of the area is taken up by buildings, and high-rise buildings, in particular, often act as barriers to quick dispersal of the pollutants. This makes motorized transport the major cause of air pollution.

It is not just the number of vehicles but the way they are driven on city roads that contributes to pollution. A drive on the city roads is qualitatively different from that on long stretches of straight roads. A

car speeding along a highway at, say, 45 kilometres an hour burns fuel more efficiently than a car in a city that has to slow down and stop frequently.

Typical journeys are represented by a 'driving cycle'. The Indian Institute of Petroleum in Dehra Dun once carried out a detailed study of typical driving cycles in Delhi. The researchers selected four sample routes, each representing a typical journey through (1) a business area, (2) an area with high concentrations of slow-moving vehicles, (3) a highway, and (4) a residential area. As expected, trips on city roads are far from smooth and efficient: within the time it took to cover only 4 kilometres, a car had to repeat the entire cycle of picking up speed, driving at a steady speed, slowing down to a halt, and idling (waiting at traffic lights, for instance) as many as six times. The average speed was only about 25 kilometres an hour and a steady cruising speed was a little under 40 kilometres an hour. It is important to know the patterns of such representative trips in order to estimate the amount of pollutants emitted by different types of vehicles.

So, how much does the transport sector contribute to the air pollution? A rough estimate is that it is responsible for about two-thirds of the pollutants in Delhi, half of those in Mumbai, and a third of those in Calcutta. Such figures are gross approximations, if we see how they are arrived at.

## How is air pollution estimated?

The amount of pollution is taken to be the quantity of pollutants, in tonnes, emitted within a day or over one year. Five pollutants are taken into account for such calculations, namely (1) SPM (suspended particulate matter, which includes airborne dust, pollen grains, fine droplets of oil, soot, and so on), (2) sulphur dioxide, (3) oxides of nitrogen,
(4) carbon monoxide, and (5) hydrocarbons. To arrive at any meaningful estimates, we need to know the following items of information.

- How many vehicles of each type (cars, buses, two- and three-wheeled vehicles, and so on) ply regularly within a city?
- How many kilometres does each type of vehicle travel in a typical day?
- How much fuel is consumed to cover that distance?
- How much of each of the pollutants – carbon monoxide, oxides of nitrogen, particulate matter, and so on – is emitted by each type of vehicle (expressed in milligrams per litre of fuel, for example)?
- What is the total quantity of pollutants from all other sources – thermal power stations, factories, natural sources, and so on – released into the air every day?

Appendix B shows how the amount of pollutants emitted by different categories of motorized vehicles is calculated step by step, taking the example of diesel-operated buses in Delhi. As you can see, each number can only be an approximation. Secondly, each number is subject to change, depending on many factors: season, quality of fuel, quality of maintenance, quality of roads, accuracy in recording data, and so on. Thirdly, at least some of the numbers keep changing all the time: new vehicles come on the road, old ones are discarded, more efficient machines are developed (which changes the amount of pollutants given out for each kilometre), and so on.

The extent of pollution is expressed in different ways: as a total quantity, as a concentration, and as exposure. It is essential to understand the difference because different agencies often choose the numbers most convenient to them. Earlier in this section, and in the above list, we talked of pollution as a total quantity, expressed in grams, tonnes, or other units of mass. This is a broad measure, most convenient but least meaningful because it does not relate easily to air quality. To take a simple example, half a kilo of salt gives us no indication of how salty it can be: it can be extremely salty if dissolved in a litre of water and not salty at all if dissolved in 1000 litres.

Concentration is a better measure because it relates pollution to air quality: it tells us how much pollutant there is in a given quantity of air (usually expressed in micrograms per cubic metre). Air quality standards use concentrations and not total quantity. In the above example, the water is salty in the first case because there is 500 grams of salt per litre of water (50% concentration) and not salty at all in the second case because there is only 0.5 gram per litre of water (0.05%).

To assess the effects of pollution on health, however, it is important to know not only the concentration but also the time over which one is exposed to it. Within certain limits, higher concentrations by themselves may be less harmful if one is exposed to the pollutants for a short time compared to a longer exposure to lower concentrations. The exposure is thus a function of not only how bad the air is but also of how long one is exposed to such bad air. Exposure is accordingly expressed in, say, micrograms per cubic metre per hour. It is this that makes indoor air pollution a serious matter especially for the poor, who cannot afford such clean fuels as gas or electricity: women and very young children spend long hours in ill-ventilated kitchens full of smoke from firewood or coal.

## Traffic, congestion, and pollution

Polluted air is a symptom, not a cause—the cause is the absence of a coherent, integrated policy for transport. Attempts to control air pollution without improving the way transport is managed in cities is like dipping the thermometer in a bucket of ice to escape summer heat. To find out why more and more people now prefer using their own transport – scooters and motorcycles, cars, vans, and so on – to public transport such as buses, we must find out why they travel in the first place and the basis on which they choose one 'mode' of transport over the others; in the jargon of management, we need to consider 'travel demand' and then see how that demand can be met effectively. In fact, OECD (Organisation for Economic Co-operation and Development) sponsored two major workshops on individual travel behaviour that brought together social scientists including psychologists and cultural anthropologists to discuss how insights from these fields could be used to influence transport choices of people and transport policies of governments. The report of the workshop that investigated culture, choice, and technology offers a rich fare to transport planners and describes how learning and perception influence travel behaviour and how childhood experience of mobility shapes the choices made on reaching adulthood. Since travelling to school or a college ranks next only to travelling to the place of work as the most common purpose of travel, the modal choice – whether schoolchildren use public transport (including school buses) or are ferried by their parents in cars or on motorcycles and so on – can have a substantial impact on the transport scenario in any city. 'Because of ··· parents' fear of traffic accidents, children are increasingly ferried around in cars. This leads to the vicious circle in which the streets and public transport become even more dangerous leading to still greater dependence on the car. As this cycle progresses from generation to generation, people develop new car-based cognitive maps of their surroundings and lose accumulated knowledge of non-car travel, further reinforcing the inevitability of car use. Participants [in the workshop on travel behaviour] felt that one important policy objective would be to help children and young adults develop new cognitive maps of their world based on a number of different transport modes. This necessarily involves allowing children to experience non-car-based mobility.'

Finding out why people travel and providing them acceptable alternative means can effectively reduce the number of vehicles on the

road. And the reasons for undertaking the journey may not be the same for men and women. A survey in Delhi showed that travelling for work accounted for 66% of the trips in the case of men but only 32% in the case of women: education, on the other hand, was the purpose behind 55% of the trips undertaken by women but only 26% by men. (Education in this case included taking children to school.) One survey in Britain found that many parents use cars to take their children to school, and a safe and efficient bus service can serve the purpose equally well: soon after such a bus service was introduced, the number of car trips fell markedly. A bus operator in Nottingham provided 'seven days of free travel to 200 motorists who had not used the bus for five years. ··· Of the 200 motorists, 60% were still using the bus on at lease three days per week two years later.'

In terms of efficiency, public transport wins hand down against personal or private motorized transport on nearly all the counts. In one hour, buses can transport 1400 people along a distance of 10 km whereas cars can transport only 320. Similarly, a bus emits only about 110 grams of pollutants to move 1000 passengers over a distance of 10 kilometres whereas cars would emit roughly 150 grams in the process. In terms of fuel, the cost would be roughly 80 litres of diesel for the bus and 270 litres of petrol for the car. And these differences multiply when we consider the extent of travel: in Delhi, more than 4 million people travel every day over distances that range from 2 to 20 kilometres. For large cities, the average travel demand runs to billions of passenger-kilometre a day. (A passenger-kilometre is a useful unit in transport; 5 passengers who travel 10 km each amount to 50 passenger-kilometres and so do 25 passengers travelling 2 km each.)

Transport planners talk in terms of 'trips' and 'modal split'. A trip refers to a single journey performed by one individual. If you commute to work every day, it amounts to two trips but if you return home for lunch, it would mean two more trips. 'Modal split' means the share of each 'mode' of transport – walking, cycling, a ride on a public bus or railway, hiring a taxi, or using your own transport (a car or a motorcycle and so on) – in the total number of trips made in a day in one city. For example, one survey, carried out in 1994, showed that public buses accounted for roughly 62% of the nearly 4 million trips in Delhi; cars and two-wheeled vehicles accounted for nearly 25%; cycles, another 6.6%; and taxis and autorickshaws, 2.9% (Figure 3). In Mumbai, on the other hand, buses and railway accounted for 80% of the trips. A study conducted by the Central Road Research

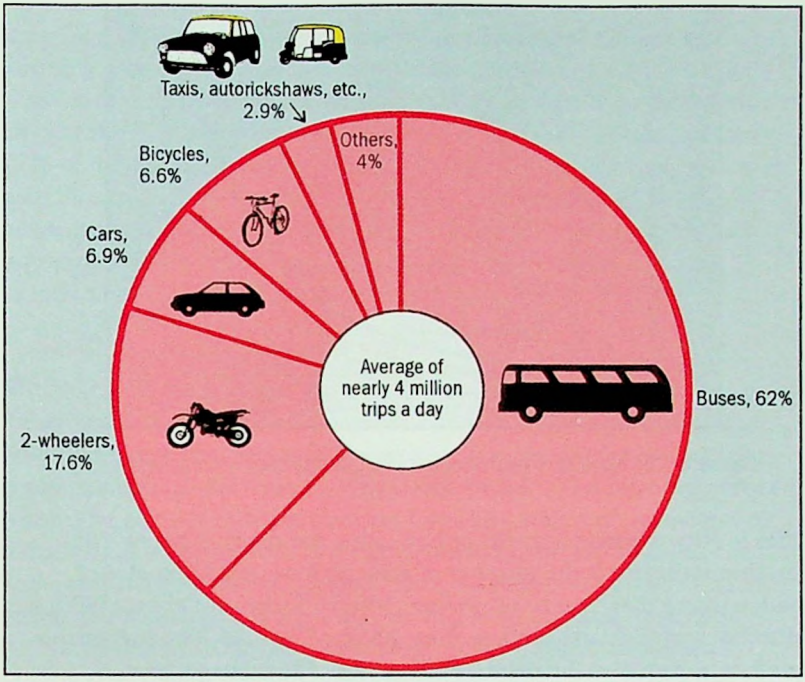


Figure 3 Different modes of travel by people in Delhi

Institute showed that on many arterial roads of Delhi, during peak hours, bicycles make up more than 30% of the traffic.

However, such information too is based on many assumptions and subject to all the limitations that apply to it. To collect reliable information, in quantities that are adequate for the purpose of planning, is expensive. The Central Institute of Road Transport in Pune, the Central Road Research Institute in New Delhi, and RITES (Rail India Techno-Economic Services), also in New Delhi, are some of the major institutions that undertake surveys of transport demand, modal split, and so on, and so do the corporations that run public transport. The latest years for which such data are available are 1995 for Delhi and Chennai and 1986 for Mumbai.

As cities continue to grow and expand, the number of vehicles on the road also goes up, and so does the amount of pollutants (Figure 4). As cities expand, more and more people need to travel over increasingly longer distances. But the network of roads grows very slowly, if at all. A useful measure is the space occupied by roads as a percentage of the total area of a city. The standard for metropolitan

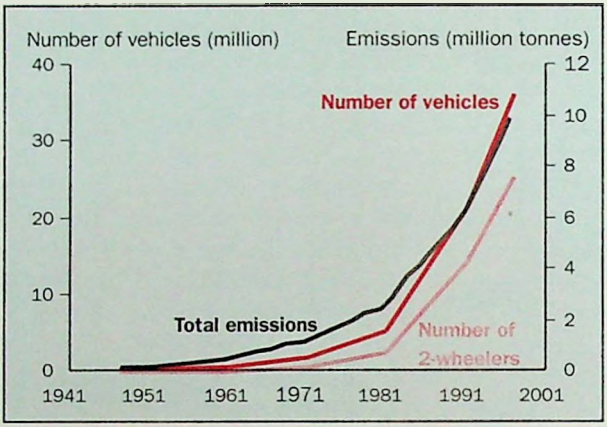


Figure 4 The number of two-wheelers in cities has been increasing steeply

cities is 30% whereas in most Indian cities, the figure is below 10%. Another indicator is the number of vehicles for every kilometre of road, a figure that runs to more than 500 for Delhi and about 350 for Mumbai and Calcutta but less than 100 for Chennai. The higher this number, the greater the need for efficient traffic management.

Given such congested roads, traffic jams are inevitable. Buses and cars move much more slowly on the city roads than before. In Delhi, average speeds dropped by as much as 65% between 1985 and 1995. In central Delhi, the average speed ranges from 15 to 28 kilometres per hour. On Lady Jamshedji Road in northern Mumbai, the average speed was 32 km in 1962; by 1979, it was only 16 km. The average waiting time at traffic signals also continues to increase—and slow-moving or idling cars emit more pollutants than those moving at cruising speeds.

Hundreds of vehicles – scooters and motorcycles, cars, buses, and lorries – idling at traffic intersections is a common sight in many cities. What do such hold-ups cost? The more obvious cost is that of the wasted fuel, which could well be the tip of the iceberg. The true costs, in terms of pollution, wasted time, and effects on mental and physical health can be staggering. In terms of fuel alone, the figure was over 100 000 litres of diesel and over 320 000 litres of petrol *a day*, as estimated in a recent study of major traffic intersections in Delhi by the Central Road Research Institute. The Tata Energy Research Institute made a detailed study of one of the busiest intersections in Delhi, namely the ITO (which takes its name because of the income

tax office). The results of the study are particularly illuminating: during a typical day, cars and two-wheelers account for 65% of the vehicles that arrive or pass through the ITO junction but carry only 18% of the commuters: buses form only 9% of the vehicles but carry 77% of the commuters. Imagine, then, the chaos at this busy junction with hundreds of vehicles of all sorts vying for the limited space, moving at a snail's pace or waiting for traffic lights to go green, and pumping pollutants into air all the time—small wonder that the junction has been rated the most polluted in Delhi.

## Seven basic strategies to reduce air pollution

Whether it is fine particles of soot, tiny droplets of unburnt petrol or diesel, or such gases as carbon monoxide and sulphur dioxide, all air pollution caused by motorized vehicles – cars, motorcycles and scooters, buses, and so on – can be ultimately traced to the burning of fuel within the engines of these vehicles. Logically, therefore, strategies to reduce such pollution aim at reducing fuel consumption, using cleaner fuels, and trapping the pollutants. Seven strategies are presented here, grouped into management strategies and technological strategies.

Management strategies redefine the problem of controlling air pollution as that of meeting the travel needs of a large population efficiently and effectively. And a successful approach to that problem is unlikely to be 'predict and provide', as the recent white paper on transport in the UK puts it. No city can expand its road network to keep pace with the number of automobiles on its roads; there is neither room nor money for that. Perhaps transport planners should look at those who work in the power sector; after all, meeting public demand for a regular supply of electricity and meeting the public's travel needs have a great deal in common. 'Demand-side management' is a well-recognized concept in the power sector: it aims at influencing the ways in which consumers use electricity to ensure that it is used efficiently. Advising consumers to avoid wasting electricity, encouraging them to use energy-efficient appliances, and promoting the use of such alternatives as solar water heaters and solar cookers are all examples of good 'demand-side management'. These measures seek to check demand instead of increasing supply.

Technological strategies typically treat the problem of containing air pollution not as a management issue but a technical problem: that of reducing the amount of pollutants emitted from different engines and of trapping the pollutants once they are produced. The source of all pollutants is the fuel itself. The way it is burnt within an engine also

determines the amount of pollutant emitted from the engine. Accordingly, strategies to reduce pollution include such options as using alternative fuels, using cleaner grades of conventional fuels (petrol and diesel), burning them more efficiently, neutralizing or trapping the pollutants before they are released, and preventing them from spreading by putting barriers. Each of these approaches has its own pros and cons. Lead-free petrol is free of lead all right but contains benzene, which increases the amount of another pollutant, known to be carcinogenic, namely polyaromatic hydrocarbons. More practically, lead-free petrol is not as commonly available outside the major metropolitan cities, at least at present (early 2000).

Here are the seven strategies, each of which is elaborated later.

1 *Reduce the demand for travel.* By reducing the need to travel in the first place – by relocating offices and factories, by ensuring that newer cities are better planned, by encouraging 'telecommuting', and so on – or by providing such alternative means of transport as car pools and public buses, we can reduce the total number of kilometres covered by a given fleet of vehicles.
2 *Manage travel demand more efficiently.* No matter how successful we are in cutting down the total travel in motorized vehicles, they are here to stay. Therefore, we need to see how we can make that travel least polluting. Good traffic management (e.g. disciplined parking, synchronized traffic lights, priority for buses) is the key to managing travel demand. We must remember that using road space equitably means focusing more on moving people, not vehicles, more efficiently.
3 *Use fuels that do not contain the polluting component at all.* These alternative fuels include not only such futuristic fuels as hydrogen, electricity, and solar power but also the more traditional ones as animal power (horse-drawn carriages, bullock carts, etc.) or even human power (cycle rickshaws and bicycles, for example).
4 *Use fuels that contain only traces of pollutants.* Using low-sulphur diesel, which contains only 0.05% sulphur (whereas the diesel commonly used in India contains five times as much), is an example of a strategy that seeks to check pollution at source by using superior-quality fuels.
5 *Burn fuels more efficiently.* The amount of pollutants emitted by an engine depends not only on the quality of fuel but also on how efficiently that fuel is burnt. Lean burn engines, for example, achieve better combustion by ensuring that air and fuel are mixed in the right proportion in the combustion chamber of an engine.

6 *Trap the pollutants before they escape into the atmosphere.* Catalytic converters illustrate this approach. These devices, fitted near the exhaust pipes of cars, neutralize three major pollutants, namely carbon monoxide, hydrocarbons, and oxides of nitrogen, by converting them to harmless gases, namely carbon dioxide, nitrogen, and water vapour. Devices that trap the pollutants have also been developed for diesel-powered buses.
7 *Prevent pollutants from spreading by putting barriers in their path.* The last strategy aims at reducing the extent to which we are exposed to pollution by putting barriers in the path of the pollutants. Leafy trees, for instance, can remove dust from the atmosphere. Face masks are perhaps the last bastion in the battle against pollution.

In the following pages, each of these seven strategies is discussed briefly. The management strategies are discussed in greater detail because they are about actions that we can take right now – without waiting for the more refined technologies – and about actions that are more cost-effective.

## Reduce the demand for travel

*Eliminate or reduce the need to travel*

As cities expand, more and more people are forced to cover increasingly longer distances. Mumbai provides an extreme example: several hundred, living as far away as Pune and Surat, travel to Mumbai daily for work-train journeys that take at least 3.5 hours each way, claiming nearly a third of every commuter's total working life. Planning may eliminate such long commutes but, as a solution, it offers little hope to cities that are already bursting at their seams. Staggering working hours, relocating large offices, and streamlining civic administration to reduce the number of visits citizens are required to make for routine tasks (paying electricity bills, for instance) are some of the measures that can reduce travel demand.

Perhaps the most promising way to cut down the need to travel is offered by information technology, particularly the World Wide Web. Just as e-mail has caused a perceptible drop in the volume of mail handled by the post office, transacting routine tasks over the Internet or telephone can eliminate thousands of trips. Recent newspaper reports put the total cost of constructing the 20 flyovers planned for Delhi at over four *billion* rupees: it will be interesting to estimate the potential benefits of investing that amount in promoting public transport and information technology.

### *Make public transport good enough to compete with private transport*

Public transport may be seen as 'a good thing'; a high-profile figure travelling on a public bus – as Delhi's chief minister did on the day he ceased to be one – generates about as much impact on pollution as a VIP planting a sapling does on afforestation. However, public transport must compete with the automobile and win (with a helping hand from policy-makers, technocrats, and those who influence public opinion). At present, a typical commuter in any of the large Indian cities chooses public transport only because it is cheap (and for many, it is not particularly cheap either—the poor can end up spending as much as 30% of their monthly income on transport) whereas public transport must be made attractive to those who do not use it at present—the owners of cars, motorcycles, and scooters. And they can be persuaded to leave their cars and motorcycles home only if they can be assured of a service that is not only cheap but reliable, comfortable, fast, frequent, and easily accessible as well. The passengers' charter published by London Transport, for example, promises to provide at least one bus route within 400 metres of most homes; cut 'extra waiting time' to 1 minute and 30 seconds; repair minor damage to bus-shelters within one working day and major damage within a month; and ensure that the number of buses running early does not exceed 4%. The charter even mentions refunds: 'If you are delayed more than 15 minutes because of our failure, we will give you a refund voucher to the value of the delayed journey.' Table 1 highlights what constitutes a quality service standard for buses.

**Table 1** Quality service standards for buses

| Parameter | *Average recommended value* | *Maximum permissible value* |
|---|---|---|
| Waiting time | 5 to 10 minutes | Not more than 20 minutes |
| Distance to the nearest bus stop | 300 to 500 metres | Not farther than half a kilometre |
| Journey times | 30 to 45 minutes | Not more than 1.5 hours |
| Expenditure on travel (as a percentage of household income) | 10% | – |

**Source** Armstrong-Wright A and Thiriez S. 1987. **Bus services: reducing costs, raising standards.** Washington, DC: The World Bank. 97 pp. [World Bank Technical Paper No. 68, Urban Transport Series]

In a survey to find out what exactly makes the 'chartered' buses in Delhi more attractive to their users, the participants were asked to choose any one reason for their choice from among such factors as speed, regularity, comfort, assured seating, and so on. Comfort turned out to be the most common reason: 58% of the respondents said they preferred a chartered bus because it is more comfortable. Regularity was next (18%), followed by assured seating (12%). Such charter services are privately operated and provide a daily service for regular commuters between residential areas and the central business district. Usually, only two trips are run every day, one in each direction. Regular commuters can buy a monthly pass whereas others may choose to pay for each trip. A survey of commuters in Hyderabad showed similar results: commuters said that when they preferred ordinary services to special services (Metroliners and Metro expresses), it was not because the ordinary services were cheaper but because they were more frequent. The survey requested commuters from different income-groups, namely very low, low, intermediate, and high, to rank such factors as cost, punctuality, travel time, comfort, and ease of boarding—comfort was at the top in all the income-groups.

Let us follow a user of public transport – a city bus in this case – along a trip and make stops along the way to explore what makes the trip a pleasant or an unpleasant experience. In particular, we shall see the difference information can make to making such travel smoother. In the words of Darien Goodwin, who chaired a recent conference titled *Promoting travel by bus: how to make publicity pay*, 'If you have not used buses, how do you start? What number bus do you get? Where do you get it? What ticket do you ask for: a single, a return or something else? How much cash do you need? Will the driver refuse to change your £20 note? How do you know when you have reached your alighting stop? ...'

*Information for passengers.* One of the most neglected areas in public transport in India is passenger information. As mentioned earlier, if public transport is to succeed in persuading those who use scooters and motorcycles to travel by public buses, it must offer incentives other than money. And detailed and up-to-date information about services, timetables, and fares is one of the crucial factors. The conclusions of a survey by John Hibbs, a British expert on transport management, state the argument clearly enough: '... the availability of information to the public has been suicidally neglected, and of innovation there has been little or none. Your local paper is filled with advertisements offering every imaginable service—except bus services. There is

turn-over to be gained from potential customers waiting to find out where buses run and at what price, and it's no good expecting someone else to tell them.'

Granada Television's *World in Action* programme (in the UK) once investigated the extent to which people are dependent on the car. As an experiment, one family in Lancashire gave up using cars for a week. The resulting documentary, in one of the scenes, showed the family grouped around the dinner table studying bus timetables for the first time in years, trying to extract some useful information from them. It was clear that the timetables had been difficult to obtain, and were thoroughly confusing.

Birmingham Friends of the Earth, a voluntary group that campaigns on environmental issues, recently identified some practical measures that would make the city's bus services more attractive and easier to use. One Saturday in April, a few volunteers stuck timetables to six bus stops on a busy street. They also put up posters that displayed the destinations of all the buses calling at those bus stops. As the group reports, 'passengers queuing at the bus stops loved it'. The report concludes that even such a simple measure as displaying the destinations and routes at all bus stops goes a long way in serving the commuters. The BEST (Brihanmumbai Electricity Supply and Transport undertaking) bus service in Mumbai has been providing such displays at major junctions for several years now. It also publishes a city map (and another for its suburban services) for the convenience of passengers. On its web site <www.bestundertaking.com>, it even offers a small map with the requested route picked out in another colour (Figure 5). Another pilot project in the suburbs of Mumbai makes use of GIS (geographical information systems) to display information on bus routes and bus stops: for any location selected by a user, it is possible to display the route numbers of bus services serving that location, their respective routes, the names of bus stops, and the locations of those stops.

London Transport is an outstanding example of the commitment to providing better information to passengers (Figure 6). Each bus stop displays not only a map of that area but a detailed timetable of all the buses that call at the bus stop. Such displays are continually revised and their designs tested with actual users to check whether the format meets their needs. Individual leaflets are published for each route giving detailed information about the timetable, fares, and so on. Compare this with the route guide published by the Delhi Transport Corporation, which has not been updated since 1989. Besides, all it


Figure 5 Maps of individual bus routes in Mumbai are available on the Web


Figure 6 London Transport is committed to providing quality information to its users

does is to offer a route-by-route listing of services, which is of little use to prospective passengers who want to know what direct bus, if any, links their starting point and destination and if it does not, the points at which they must change buses. They would also want to know the timetable and how long it might take to complete the journey.

*Waiting time.* Let us assume that our hypothetical user now turns up at the appropriate bus stop. The first thing that confronts the user is the crowd; it may not deter the regular user but remember that we are talking about persuading those who use their own vehicles, particularly two-wheelers and cars, to use public transport. The BEST, which operates buses in Mumbai, has introduced the concept of 'zero waiting time' on some routes during peak hours at points that serve a large number of people, such as close to railway stations, central business districts, and large housing colonies. 'The BEST ensures that a bus is always waiting for a passenger rather than having it the other way around', as the BEST's web site puts it. Overcrowding particularly deters women. A survey of commuters in Pune asked men and women whether they found public transport safe, acceptable, and comfortable. The difference between sexes was marked: only 45% women said that public transport was safe and only 40% said it was comfortable

whereas as much as 65% of men thought it was safe and 55% found it comfortable. However, only 2% of women favoured 'women only' buses; 32% wanted more buses to ply and 39% wanted the buses to run more regularly. The BEST in Mumbai not only runs some women-only trips but allows women to board first on some routes at peak hours, a feature it calls 'Ladies first at Starting Points'.

*Signs on buses and bus stops.* The bus stops themselves need to be signposted clearly. Not only is the new colour combination (red on blue) seen on bus stops in Delhi harder to read but the name of the stop itself is completely masked by advertisements (Figure 7). Then there is the matter of finding out whether the bus approaching your bus stop is the bus you want. Signage specifications for transit vehicles (developed by the American Foundation for the Blind) recommend that destination boards displayed at the front should be in letters that are at least 15 centimetres tall, with the route number displayed even more prominently, in numbers at least 20 centimetres tall. Displays at the side must be in letters at least 5 centimetres tall and route numbers should be at least 10 centimetres tall. Mr Vincent B McKenna, of McKenna Brothers, a British firm that supplies destination boards and related material, has this to say on the topic: 'In the '80s we saw the introduction of electronic dot displays on buses. Whilst these type of displays are convenient for the operator to use, they have proved difficult to read for the passenger, especially the partially sighted. ··· we presented printed displays for appraisal by partially sighted groups. These displays were placed side by side with other systems such as Dot-matrix, Red LED [light-emitting diodes] and Seven Segment. The unanimous decision by the groups was our printed displays were far easier to read. Research shows that yellow on black ··· destination blinds [boards] ··· are the best and most effective medium.'


**Figure 7** Advertisements completely mask the name of a bus stop, already poor owing to the weak contrast between the background (blue) and the foreground (red)

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Take the citing of bus stops, for instance. There are stops in Delhi that serve as many as 50 to 60 routes. The 'bus boxes' that mark off a strip of the road as the point at which a bus is expected to stop can at best be only of cosmetic value because it can accommodate only one bus at a time whereas it is far more likely that several buses would arrive at such busy points at the same time.

*Buying a ticket.* Now that our commuter has managed to board a bus, the next step is to buy a ticket. In Mumbai, as in most other cities, it is the bus conductor who walks up and down the aisle to collect fares and to issue tickets. The buses operated by the Delhi Transport Corporation offer a complete contrast: it is the passengers who have to make their way to the conductor to buy a ticket, with the resultant overcrowding around the conductor's seat, which is aggravated by the delay in issuing the tickets as the conductor laboriously tears each ticket at two points in a crude attempt to mark the starting point and the destination point for each ticket. The BEST in Mumbai has already introduced smart cards for AFC (automatic fare collection) on some of its services, beginning with No. A-1, an air-conditioned service plying between Oshiwara Depot and the World Trade Centre. Regular commuters buy the card for Rs 200/- in advance. On boarding a bus, the commuter flashes the card in front of a machine that can read the card. The minimum fare is deducted automatically. While getting off, the commuter presents the card again, and the machine deducts the correct additional fare depending on the journey. Information on correct fare is not always easy to come by. In Delhi, this information is displayed *inside* a bus (Figure 8) whereas, ideally, a user would like to know the fare beforehand.

Buses run by private operators in Delhi, on the other hand, 'market' their services aggressively indeed. Overcharging is rampant but so is overcrowding. In one incident, a commuter who protested against overcharging was beaten up by the staff. This prompted a public interest litigation 'seeking to end the ill treatment of passengers by the staff of local buses plying in the city', as reported in a newspaper recently. The High Court in Delhi has admitted the petition and issued a notice to the transport authorities.

*Completing the trip.* Once inside, passengers must know in advance that they are approaching their destination. Whereas timetables and maps provide information for planning a journey, commuters need 'on board' information as well. For instance, bus conductors should be encouraged to announce each stop clearly as the bus approaches that stop. Similarly, 'live help' can be stationed at major bus stops to announce the next bus due, its destination, and the bus stops along its

Figure 8 A fare chart displayed inside a bus

route. Those who offer such a service may even carry pagers so that they can offer 'real time' information.

Getting off a bus, by itself, can prove to be an ordeal, especially for the elderly and the infirm. Low-floorboard buses score over other models in this regard. Curitiba, in Brazil, offers another solution, namely raised platforms for boarding and alighting.

*The return journey.* Our hypothetical commuter is now at work but would like to return home in the evening, preferably without having to wait for a long time for the bus. Many innovative information systems are already in place in major European cities and include 'countdown' displays at bus stops that show the next bus due and approximate time of arrival, real-time information about late running buses, easy-to-use maps and folders about individual bus routes, and so on. It is even possible to track the progress of Superoute 66 (between Ipswich railway station and Martelsham Heath in the county of Suffolk in the UK) on the Internet. Commuters can even request automatic notification: every evening, for example, you will receive a message on your pager or cellphone that your regular 5.30 p.m. bus is now expected to arrive at the usual stop in ten minutes. The same information is also available on telephone in the form of IVR (interactive voice response), as shown using a made-up example in Figure 9.

In Marshall, Minnesota, and Bangor, Maine, in the United States, for about $10 a month, residents can subscribe to a telephone information service that automatically calls them to let them know that the

A typical dialogue between a user and the IVR (interactive voice response) system

1 The user dials the IVR telephone number.
2 IVR: Welcome to the real-time information service. At which bus stop will you board the bus?
3 User: Gandhi Market.
4 IVR: Which direction, A B C Hospital or X Y Z Terminus?
5 User: A B C Hospital.
6 The next bus to A B C Hospital is expected to reach your bus stop at 4.50 in the evening. The next bus after that will be at 5.30 in the evening.

Figure 9 Interactive voice response system supplies current information

daily school bus is only a few minutes away. A global positioning device tracks the movement of the bus and a telephone data channel relays that information to a central control point. The central station then automatically calls the subscribers with a pre-recorded message.

The recent government white paper on the future of transport in Britain, titled *A new deal for transport: better for everyone*, repeatedly emphasizes the need for 'wider availability and provision of information on timetables, route planning and fares'. Britain's Transport Research Laboratory has recently published a report, titled *Information for bus passengers: a study of needs and priorities*, which reviews the provision and use of information; assesses how useful it is to the general public and the extent to which it influences travel demand; identifies deficiencies; and suggests how the supply of information could be improved.

Nearer home, a pilot project is already under way in Hyderabad. The AVLDS project (for automatic vehicle location display system) will supply current information to those waiting at bus stops. Special display boards at bus stops will show expected arrival times 10 minutes in advance for city services and 30 minutes in advance for district services. The system consists of a VHF (very high frequency) monitor mounted atop each bus, which lets a central computer track the movement of the bus. The central system then relays that information to appropriate bus stops. The AVLDS project also seeks to transmit information on how many seats are vacant, a particularly useful piece of information on long-distance routes, so that those many seats can be sold in advance.

Matters such as siting of bus stops, the possibility of buying tickets in advance, and orderly queues can all do their bit to attract passen-

gers. If the idea is to attract those who use two-wheelers to public transport, the inducements need to be such that public transport is seen as a comfortable and dependable means of travel.

### *Market public transport effectively*

Public transport offers good value for money but do potential buyers of that service know about it? More important, do those potential buyers who are likely to be willing to pay more know about it? Subsidized public transport does fulfil a social need and, for many, it is the only option. But if public transport is to attract those who currently ride motorcycles or drive cars, it has to offer much more than merely the means of getting cheaply from A to B. The 'Greenline' and 'Whiteline' buses in Delhi, the 'Metroliners' of Hyderabad, and the luxury and air-conditioned buses in Mumbai are examples of special services but they have not been successful enough to reduce congestion. Public transport needs far more sophisticated marketing, selling different services to different segments. Stagecoach Manchester, for instance, 'have segmented the market by socio-economic group, and by time of day: different people travel at different times of day, and people's needs are different at different times of day.' Mumbai, for instance, is a narrow rectangle with clear traffic patterns: in the morning, southbound services run at peak capacities whereas northbound services have spare capacity; in the evenings, it is just the opposite. Effective marketing can certainly help in tapping that spare capacity, if only such information is made available to people. Most transport operators run special services to clear the rush due to such specific events as fairs and festivals but they are not marketed aggressively enough. However, marketing will not sell badly designed products. Take reliability and punctuality: for users to be confident enough to leave their own cars home and take a bus, they must be convinced that the promised bus will turn up and turn up on time. People with higher incomes tend to place a higher value on their time and expect a higher standard of service—public transport must offer that if it is to capture that segment of the market. Nottingham CityTransport engaged the services of a market research company to find out what people wanted, what they disliked, and what they saw as barriers. Most respondents cited lack of knowledge about the bus system as a major obstacle.

Concern for personal safety is yet another factor that may deter potential users of public transport. A study in Britain estimates that patronage of public transport could be boosted by at least 10%,

mainly during off-peak hours, if commuters, especially women, felt safer when travelling.

### *Improve the image of public transport*

Public transport has a poor image in many cities, which costs it dear in terms of customers. The costs to society are even higher if we take into account the loss of productive hours spent on driving, the ill effects of pollution on health, the cost of fuel, and so on. Increased awareness of how our day-to-day activities affect the environment has served to promote recycling, vermi-composting, energy conservation and so on and corporate houses are turning increasingly 'green'. Public transport must cash on this trend to promote itself as a green service.

As mentioned earlier, those who use public transport when young are less likely to avoid it later. This idea can be extended to positively encouraging schoolchildren to use public transport by promoting it as an interesting activity; holding a quiz competition to test how well they know the transport system in their own town or city, organizing a 'treasure hunt' in which the participants are allowed to use only public transport, and even getting celebrities to travel on public buses are some possibilities to give public transport a more upmarket image. Involving NGOs, citizens' groups, and schoolchildren in supplying information – the 'live' help at bus stops mentioned earlier – is another possibility.

### *Discourage private modes of transport*

If cheap, reliable, and comfortable travel is the carrot, stiff parking fees, expensive fuel, and heavier toll charges make up the stick. Other deterrents include denying the use of some lanes on major roads to those vehicles that have only one occupant and keeping some roads (or one or more lanes within a road) exclusively for buses. All such measures have cumulative benefits: they make roads less congested, which means traffic moves faster, and attract more commuters to public buses because they move even faster in their own reserved lanes; the smoother and faster the traffic, the lower the amount of pollutants it emits.

*Parking charges.* Stiff parking charges and setting a limit to the number of parking slots available within a locality can have a marked impact on driving habits. A study carried out by the US Department of Transportation found that the number of employees who drive to work alone can come down by 20% if they have to pay for parking.

Haphazard parking disrupts traffic: if roads are the blood vessels of a city, undisciplined parking is the clot that can block circulation. A recent TERI study of a busy market in New Delhi estimated that organized parking can speed up traffic by nearly 150%.

*Charges for road use.* Yet another strategy is to impose toll charges at peak hours. Just as you can make telephone calls at discounted rates so long as the calls are made outside the peak hours, drivers are charged extra for the use of roads during those times of the day when the demand is higher.

*Administrative measures to check emissions.* The recent directive from the Supreme Court banning commercial vehicles that are more than 15 years old from plying on the streets of Delhi is just one example of administrative intervention to check pollution. The periodic checks on emissions of pollutants from all motorized vehicles is another. However, the extent of benefits from such measures is far from clear. Let us imagine for a moment that, overnight, all the motorized vehicles plying on the streets of Delhi bring the amount of carbon monoxide and suspended particulate matter they emit within the prescribed limits. Will it also make Delhi's air healthy overnight? What will be the likely levels of carbon monoxide and suspended particulate matter then? Even rough estimates of such figures are seldom provided. In a survey conducted by the Indian Institute of Petroleum in Dehra Dun in 1984, only 30% of the cars tested met the standards; the figure dropped to only 20% in the case of relatively new cars (5 years or less), for which the norms are more stringent. Some ten years later, when the Automobile Association of Upper India conducted a series of random checks in Delhi in May 1995, the results were better: approximately 44% of the older cars and 56% of the newer cars passed the test. But these figures are much lower than those given by the state-owned vehicle inspection unit in Burari in Delhi, where the success rate is 80% to 85%. So how reliable are the data?

The automobile association also offers another interesting statistic: it says that only about 50 vehicles can be properly checked in an 8-hour day (assuming that it takes about 10 minutes to check each vehicle). If you relate this figure to the total number of registered vehicles in Delhi – 3.8 million in January 1999 – and keep in mind that the 'pollution under control' certificate is valid only for 3 months, the total number of checks works out to more than 10 million a year—a massive undertaking indeed, the futility of which can be apparent to anyone. A recent newspaper report (from *The Hindu*, of 14 April 2000)

seems to confirm this: quoting the official figures available with the Delhi Pollution Control Committee, it says that 2.9 million vehicles underwent the PUC (pollution under control) check in 1997 but the figure was down to 2.2 million in 1998 and to 1.7 million in 1999.

## Manage travel demand more efficiently

As the executive summary of the report *Blueprints for sustainable development* puts it, 'Solutions to road-transport derived pollution such as catalytic converters and road pricing and even improved public transport do not properly tackle the problem: the demand for transport itself needs to be managed rather than try to satisfy a thirst that can never be quenched'.

In a market-driven economy, public transport faces stiff competition from private, individually-owned transport. This competition is not as straightforward as that between, say, rival brands of soap—if you prefer one brand, that by itself has no influence on the choice made by others. But as more and more privately-owned personal modes of transport – cars, scooters and motorcycles, and so on – begin to appear on city roads, all modes are affected because of the resulting congestion. If buses have to compete with cars and motorcycles for road space, buses are going to be heavily outnumbered. This makes them slower and thus less attractive as a mode of transport and in turns drives even more people to choose their own means of transport, bringing even more vehicles on the roads. And those who cannot afford to do so get a progressively worse deal. This also raises the question of equity: is the road space being shared fairly by all? Do all citizens have access to affordable means of transport?

So where does this vicious circle end? We need to turn to market forces and state intervention for answers because, as mentioned before, public transport can compete only if it is cheap, reliable, comfortable, fast, frequent, and easily accessible—attributes that cost money and require both political will and enlightened management. Market forces alone cannot provide a solution because even the minimum fare charged by buses is beyond the means of many: a recent survey in Delhi showed that just the minimum fare amounts to 20% to 30% of the monthly income of nearly half of the city's population living in unauthorized colonies.

*Managing travel demand.* The argument so far has been that air pollution in Indian cities is serious and continues to get worse; that motorized transport contributes to it substantially; and that encouraging people to choose public transport – to take a bus or a train –

instead of individually-owned transport (using a car or a two-wheeled vehicle) is one of the most effective means to reduce air pollution. This is easier said than done, and at once raises many questions: How to make public transport more attractive? Who should do that? How much will it cost? How long will it take? How do we know whether the methods are working?

It is neither possible nor within the scope of this book to offer definitive answers to these and similar questions. Many experts, over many years and in many different forums, have offered many solutions. Some of these have been implemented and many more are likely to be implemented.

*Demand-side management.* 'Demand-side management' in the context of transport in cities includes such measures as staggered working hours and staggered weekly offs, providing alternative means of transport (bicycle tracks, efficient parking facilities near railway stations and major bus depots), promoting safer and high-quality services to transport schoolchildren, and so on. In broader terms, demand-side management is all about analysing what makes people travel in the first place instead of simply estimating travel requirements and then providing for them.

Curitiba, in Brazil, is an outstanding example of what integrated transport planning can achieve: though Curitiba ranks second in the country in terms of car ownership (one car for every three people), the city's petrol consumption is only 70% of that in any of the eight comparable cities. Public buses in Curitiba carry 50 times more people than what they did 20 years ago. Instead of investing money on such conventional solutions as underground or above-ground rail, Curitiba managed to channel its growth along existing and established traffic corridors that ensured that public transport continues to remain an attractive option for its citizens.

More than anything else, Curitiba's success is rooted in planned use of land. Most Indian cities have grown haphazardly. Their pattern of growth is based not so much on long-distance commuting by individually-owned transport as on non-motorized, short-distance trips: on an average, most people in Indian cities travel short distances, and they either walk or use a bicycle. Again, to cite a survey conducted in 1994 in Delhi, 40% of the trips were 2.5 kilometres or shorter and another 17% were between 2.5 and 5 kilometres. And bicycles accounted for 70% of those trips. The proportions could be different for Mumbai because it offers suburban railway as a reasonably cheap alternative but the conclusion remains much the same, namely that

making streets safe for cyclists and pedestrians can effect substantial savings in the use of petrol and diesel, thereby reducing both pollution and traffic congestion.

*Bus-only streets and priority for buses.* Considering that buses carry many more people, giving buses priority over other modes of transport sounds logical enough. A study by TERI of one of the busiest traffic intersections in Delhi, which is also one of the most polluted, showed that keeping a few critical corridors open only to buses during peak hours could cut delays by as much as 80% (with such attendant benefits as reducing fuel consumption and pollution). Bus-only streets, in effect, bring the benefits of rail transport at a fraction of the cost incurred on building a rail network. Urban planners, unfortunately, perceive a motorist's time to be more valuable than that of a pedestrian, a cyclist, or a user of public transport.

## Use fuels that do not contain the polluting component at all

Walking, cycling, and using animal power (horses, mules, camels, and so on) for transport are some of the cleanest option available to us: in the simplest terms, this mode of transport burns sugar and gives off carbon dioxide. Transport experts use the term NMV (non-motorized vehicles) or NMT (non-motorized transport) to refer to such means of travel.

Bicycles are becoming an increasingly attractive option in many European cities, which have introduced several innovative schemes to encourage cycling. A pilot project in Amsterdam allows any citizen to pick up a bicycle from any of the bicycle depots using a prepaid smart card and either return it to the same spot or leave it any other depot. The citizens gain points for using the bicycle and may use those points to obtain other services. Copenhagen has made not only made the operation simpler but free of charge: commuters use coins to release the bicycles from racks and the coins are automatically returned when the bicycles are 'parked' again in their slots.

Cycling and walking may be merely recreational or 'green' in Europe; in much of the developed world, these are the only means that many can afford and are estimated to account for as much as 50% of all the trips in Indian cities and 60% to 90% in China. A survey in Delhi showed that walking and cycling made up 65% of all the trips undertaken by the poor (and buses accounted for 31%). Gender is an issue as well, as revealed in another survey: only 8% of men walked, compared to as much as 17% of women; 38% of men used buses whereas for women the figure was nearly 58%.

Most of us automatically assume that such slow-moving vehicles as bicycles and cycle rickshaws are more likely to congest the roads; however, this is a fallacy: a car needs roughly 4 times as much space as a bicycle when on the move and as much as 16 times the space for parking.

## Use fuels that contain only traces of pollutants

As mentioned earlier, diesel-powered vehicles emit more of particulate matter – the thick, black smoke that comes out of the exhaust pipe of a bus or a lorry – compared to petrol-powered vehicles. Though this is mainly because of the way the two fuels are ignited in their respective engines, diesel that contains more sulphur produces more smoke. At present, sulphur content of the diesel sold in the metropolitan cities in India is about 0.25% by weight (roughly 2 grams for every litre of diesel). Low-sulphur diesel, sometimes referred to as 'city diesel', is a highly refined fuel especially effective in eliminating the smell and smoke normally associated with diesel engines. In initial trials by London Transport's Buses Emissions Research Programme, which involved over 700 buses and was conducted over 3 months, city diesel decreased smell and visible smoke, cut down emissions of particulate matter by as much as 40%, and also reduced carbon monoxide and oxides of nitrogen. More important, it was the emission of finer particles (smaller than a micrometre), which are far more dangerous because they penetrate the body's respiratory system the deepest, that was cut down the most by the high-quality diesel.

Cars that run either on electricity or on CNG (compressed natural gas) are certainly environment-friendly. Battery-operated vehicles are zero-emission vehicles and practically noise-free. However, they have a limited range: the batteries need to be charged every 90 kilometres or so, a far from feasible option in India. (In Agra, they are used to ferry tourists between the car park and the Taj Mahal in an effort to reduce pollution around the monument.) Compressed natural gas appears a more promising candidate. About 2000 taxis in Mumbai reportedly use CNG. Compared to petrol, CNG is not only cheaper but gives better mileage. It is practically soot-free and prolongs engine life. On the other hand, it requires a higher initial investment; reduces storage space in the trunk of a car; makes a car slightly slower in picking up speed; and is available only at few petrol pumps. In Delhi, at the end of 1999, it cost about 33 500 rupees to convert a car so that it could run on CNG. The means to store and distribute the gas are not in place so far.

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## Burn fuels more efficiently

The amount of pollutants emitted by an engine depends not only on the quality of fuel but also on how efficiently that fuel is burnt. Lean burn engines, for example, achieve better combustion by ensuring that air and fuel are mixed in the right proportion in the combustion chamber of an engine.

Insistence on more stringent norms (the Euro II norms, for instance, which lay down maximum permissible limits for emissions) is a typical techno-fix. However, in India, motorized vehicles are used for many more years than they are in the West. It takes more than 40 months' earnings for a person to buy a basic car in India; in USA, only 9 months' income is enough to do that. No matter how stringent the norms for new vehicles, most vehicles in any city will be old vehicles. Even in five years' time (in 2005), roughly only 10% of the two-wheelers plying in Delhi is likely to be compliant with the norms laid down for 2000: roughly 40% will be pre-1991 vehicles (no limits on emissions were in force then), about 15% will be compliant with the 1991 norms, and another 18% will be compliant with the 1996 norms. Mandating that emissions of carbon monoxide be cut from up to 30 grams per kilometre to 2 grams per kilometre (which is the norm for two-wheelers from April 2000) is no doubt impressive but to what extent such norms will succeed in cutting down total pollution has not been estimated.

However, some data are now available on the quality of air in Delhi after about 4000 old buses (8 years or older) and 17 000 autorickshaws were withdrawn from the city's fleet from 1 April 2000. Sixteen traffic intersections were monitored across the city to determine the concentration of key pollutants. 'Though it will take time to calculate the figures, there has been a drop of about 15% in the air pollution levels', said the secretary of the Delhi Pollution Control Committee, as reported in the press. The concentration of suspended particulate matter, for example, was found to have dropped from 1417 micrograms per cubic metre to 1204 micrograms per cubic metre at the ITO junction.

## Trap the pollutants before they escape into the atmosphere

Catalytic converters offer yet another approach to cutting down pollution. These devices, fitted near the exhaust pipes of cars, neutralize three major pollutants, namely carbon monoxide, hydrocarbons, and oxides of nitrogen, by converting them to harmless gases, namely carbon dioxide, nitrogen, and water vapour. It is mandatory for all cars manufactured after 31 March 1995 to be fitted with catalytic

converters. However, the converters begin to work only when the exhaust is warm, which happens only after the engine has been running for a while—at the point of start, when emissions are maximum, the converters are ineffective. Secondly, cars fitted with converters cannot run on petrol that contains lead because it 'poisons' the catalyst.

Devices that trap the pollutants emanating from diesel-powered vehicles, especially buses and lorries, are known as 'after-treatment' devices. However, most of them can work only with ultra-low-sulphur diesel (0.005% sulphur), which is currently not available in India. A diesel particulate filter with additives (a mixture of iron and strontium) is reported to work with low-sulphur diesel (0.05% sulphur) and reduce the emissions of fine particles, which are a particular health hazard.

## Prevent pollutants from spreading by putting barriers in their path

The last strategy aims at reducing the extent to which we are exposed to pollution by putting barriers in the path of the pollutants. Leafy trees, for instance, can remove dust from the atmosphere. Detailed studies show that most of the particles recovered from leaves are of the so-called PM10 category (10 micrometres or smaller), which are a greater health hazard because such fine particles can reach our lungs. Some trees are more efficient than others in trapping the particles, probably because their leaves are covered with fine hair.

Face masks are perhaps the last bastion in the battle against pollution. The rising number of two-wheelers is often blamed for contributing most to the pollution but the alleged villains of the piece are perhaps the worst sufferers at the same time, as a TERI study showed. The study involved sampling the air that a traveller would actually breathe in during the journey by using different modes of transport, and it turned out that those who ride scooters and motorcycles breathe in more than seven times as much of pollutants as those taken in by those who drive a car. Those who travel in autorickshaws and buses are exposed to roughly the same amount of pollutants, which is twice the amount car drivers are exposed to.

## Information technology for better transport

Whereas the technological solutions mentioned above relate directly to emissions of pollutants, a totally different set of technologies attacks the problem from another angle, aimed more at managing traffic than at controlling emissions. The Japanese government estimates that more than 10% of the fuel used in automobiles is wasted only because

of traffic jams. To help traffic move faster and more smoothly, information technology is being put to greater use. Imagine how much it would help the drivers if they are provided with up-to-the-minute information as they drive: how dense is the traffic at particular locations; whether any of the roads is closed for traffic; what processions, if any, involving large crowds on foot, are in progress at any given time; how easy it is going to be to find a parking space; and so on. Broadcasting such information on the FM band has been common enough, particularly in the West, but information technology has moved far faster: Panasonic in Japan has developed an advanced car navigation system that collects traffic information sent from several sources, including radio broadcasts and optical devices, which can help drivers in planning alternative routes to their destinations that avoid the more congested roads. Driver-assistance systems can even sense when a car is too close to the one ahead and alert drivers accordingly. Large databanks that monitor traffic can store traffic patterns in their huge memories act as early-warning systems that enable those who guide the traffic and operate traffic signals to take timely action and thus avoid worse traffic jams.

Electronic toll collection systems linked to central databanks make it possible to pay toll charges without the car having to stop. Users buy a small hand-held device, which serves as an identity tag, and hold it behind the wind shield as their vehicles approach a toll gate. A sensor at the toll gate 'reads' the tags, automatically deducts the appropriate amount, and lets the vehicles pass. Users are also automatically alerted when it is time to recharge the device. The signals can even be linked to a bank account, which is debited automatically.

Telecommuting, which allows people to work from home instead of in an office, is another of the 'futuristic' technologies that have a bearing on city traffic, at least in theory. In practice, it is a question of traffic patterns: cities in which the 'white collar' workforce is significant and trade, services, and the 'knowledge-industry' are major activities stand to gain more from telecommuting than those with predominantly 'blue collar' workforce in which manufacturing is the major industry.

Technical solutions can be innovatively combined with known social patterns. Most car journeys in cities are short and typically undertaken with only one occupant. 'Marrying the environmental benefits of EVs (electric vehicles) with the personal flexibility offered by cars, the Crayon EV commuter system is designed for efficient, short-distance transportation. It is a practical system based on the

latest technology, and is now being road-tested by Toyota for local transport between company facilities in Toyota City, Japan.' Crayon is an electric car; once charged, it can cover about 100 kilometres. It can be recharged at home from the mains supply or at charging points available at each of the Crayon depots located at strategic points throughout the city. Each depot maintains a fleet of cars ready for use. The cars are available to members, who use smart cards not only to unlock the cars but also to maintain a log. Each car is fitted with a mobile telephone and a navigation device linked to a central computer and an online information system. Users can book a car over the Internet (or even a corporate intranet) or simply visit any convenient depot and collect a car.

## Integrated strategy for better transport in cities

Each of the seven strategies can be considered separately only for convenience; to be effective, they need to be combined into an integrated strategy aimed at better transport: transport that is reliable, comfortable, quick, and environment-friendly and offers value for money.

However, current initiatives related to transport have focused more on air pollution and less on meeting the transport needs of people. In the absence of a coherent policy, different players have attacked the problem piecemeal. As TERI's report titled *Transportation in megacities: a comprehensive analysis of sustainability in developed and developing economies* puts it, '··· fragmentation and overlapping of responsibility and authority have made planning and management of urban transportation a complex task. ··· as many as 16 agencies directly or indirectly influence the provision of transportation infrastructure, its operation and regulation in Delhi.'

Whether it is oil companies, who need to supply cleaner fuel; automobile manufacturers, who need to produce cleaner engines; traffic police, who need to enforce discipline on the roads; or transport corporations, who need to run a more efficient service, every agency has a role to play—including every individual. If you would rather light a candle than curse the darkness, here are some ways to begin.

- Cut down your use of cars and two-wheelers; cover short distances on foot where possible and explore such alternatives as cycling.
- Ensure that traffic flow is not obstructed when you park.
- Keep your vehicles well-tuned; service them regularly.
- Use public transport and encourage others to do so.
- Organize car pools.

## Conclusion

It is customary to conclude with a list of recommendations – who should do what or, more often, what 'should be done' (the passive voice ensures that no agent is identified) – aimed at reducing pollution. However, the purpose of this book is not so much promote direct action as provide insights, not so much provide answers as prompt the right questions, and not so much provide information as influence attitudes. A few key suggestions offered in the document are listed below as a brief recap; this is what the concerned citizens should demand collectively.

- Focus more on better transport than on air quality: aim at curing the disease instead of merely attacking the symptoms.
- Accord priority to buses or keep some roads open only for buses at peak hours.
- Make information about public transport easily accessible to all users and potential users.
- Collect and maintain up to date and reliable statistics on all aspects of transport and use such statistics for better management.
- Set performance objectives for services instead of insisting on 'static compliance' (e.g. specify that every commuter should get a bus within 10 minutes on a busy corridor between 8 a.m. and 8 p.m. instead of stipulating that a service provider should increase the fleet by adding 200 buses).
- Promote equitable use of road space.

Air pollution is a problem that cannot be wished away. If present trends continue, it can only worsen in the future—and motorized transport will contribute the most to it. If we wish that bumper-to-bumper traffic, air full of acrid smoke that literally moves you to tears, and hopelessly overcrowded buses are not to be our lot in the 21st century, the time to act is now. Mere insistence on the right to clean air, increasingly stringent regulations with little prospect of implementing them, or proclamations of dire consequences for future generations will not make the air in our cities any cleaner: informed judgement, action backed with adequate reflection, and a healthy mistrust of simplistic solutions and quick fixes will.

## Appendix A

### Air quality standards and what do they tell us

What are these guidelines, and what do they tell us? Take suspended particulate matter for example, which consists of dust, soot, fine droplets of oily substances, and so on. The national ambient air quality standards, stipulated by the Central Pollution Control Board, offer no fewer than 6 figures – ranging from 70 to 500 – all expressed in micrograms per cubic metre. This is because the standards are different for different areas; for residential areas, for example, the requirements are more stringent than those for industrial areas. The CPCB recognizes three categories, namely (1) sensitive areas, (2) residential areas, and (3) industrial areas. Also, there are separate standards for long-term averages and short-term averages. Carbon monoxide, for example, is so dangerous that even a brief exposure, say for 15 minutes, can be hazardous if the gas is present at high concentrations. Therefore, standards for carbon monoxide are stipulated for periods ranging from 15 minutes to 8 hours—the so-called 'time-weighted averages'. The effects of exposure to suspended particulate matter are less acute, and standards are prescribed for two periods, namely 24 hours and 1 year: for residential areas, the 24-hour standard is set at 240 micrograms per cubic metre and the annual standard at 140 micrograms per cubic metre. Though the term 'standard' is used, it does not imply a desirable value that the city administration should aim at: it is not quite the same as saying that the standard body weight for an adult male who is 1.75 metres tall is 65 kg. Rather, think of the air quality standard as an upper limit or a threshold that should not be exceeded.

## Appendix B

### How the statistics related to air pollution in Delhi are calculated

The Central Pollution Control Board estimates that motor vehicles release as much as 1046 tonnes of pollutants a day in Delhi (as published in the June 1995 issue of its newsletter, *Parivesh*). However, this figure was presumably obtained simply by assuming a 120% across-the-board (in all the twelve Indian cities and for all the five pollutants) increase in its estimates as on 31 March 1987. The abridged report on assessment of vehicular pollution in metropolitan cities, published by CPCB in 1988/89, puts the figure at 872 tonnes.

TERI researchers estimate that, in Delhi, motorized vehicles of all types taken together add 1730 tonnes of pollutants to the atmosphere every day. This is how the amount emitted by just one category, namely buses, was calculated.

1 The average distance covered by each category of vehicle – cars, bus, motorcycles, and so on – was estimated. Each bus, for example, was found to cover approximately 186 kilometres every day on an average.
2 By the end of 1997, about 2.85 million vehicles were registered in Delhi out of which 29 572 were buses (statistics published by the Ministry of Surface Transport). However, not all of them would be on the road on any given day. On the other hand, a large number of vehicles plying in Delhi at any given moment are not registered in Delhi. In this example, the number of buses was taken to be 16 572.
3 By multiplying the two estimates (average distance travelled by each category of vehicles and the number of vehicles in that category), the total number of kilometres covered by each category of vehicle was calculated. Thus, all the buses in Delhi, taken together, cover 3 082 392 kilometres a day, on an average.
4 Indicative figures are available on how much of each pollutant is given out by each category of vehicle for each litre of fuel: for instance, for every litre of diesel that it consumes, a bus emits roughly 6.5 grams of particulate matter, 4 grams of sulphur dioxide, 70 grams of oxides of nitrogen, 7 grams of hydrocarbons, and 42 grams of carbon monoxide.
5 Assuming that a bus covers 3.3 km per litre of diesel and taking the total distance covered by all the buses in Delhi in a day as 3 082 392 km, the total diesel consumption works out to be 934 058 litres.

6 Multiplying the 'emission factors' (in grams per litre) mentioned earlier in Item 4 by the amount of diesel consumed gives us how much of each of the pollutant is emitted by each category of vehicles (buses, in this example, add 121 tonnes of pollutants to the atmosphere a day, as shown in Table B1).

Table B1 Calculating the total amount of pollutants emitted by buses

| Pollutant | *Emission factor* (grams of pollutant emitted per litre of fuel consumed) | *Amount emitted per day* (tonnes) *from 934 058 litres of diesel* |
|---|---|---|
| Particulate matter | 6.5 | 6.07 |
| Oxides of nitrogen | 70.0 | 65.38 |
| Sulphur dioxide | 4.0 | 3.74 |
| Carbon monoxide | 42.0 | 39.23 |
| Unburnt hydrocarbons | 7.0 | 6.54 |
| Total | – | 120.96 |

Similarly, we can calculate the amount of pollutants added by each category of vehicle so as to build an 'emissions inventory'.

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Air in India's metropolitan cities is so severely polluted that it can make a white sheet of paper look like carbon paper within 8 hours. If this strikes you only as a cosmetic effect, consider another statistic: more than 2% people in the prime of their life (from 15-year olds to 44-year olds) die prematurely of breathing- or heart-related disorders in Delhi because of the increased pollution. The single largest contributor to pollution is urban transport.

*Cleaner Air and Better Transport in Cities: making informed choices* emphasizes the need to make public transport attractive enough for those who currently use cars, motorcycles, and scooters and highlights the role of Information Technology to achieve that objective by providing quality information to users of public transport. This little book presents facts objectively to help you make sense of what you read or hear about the topic through the mass media and to make informed choices and judgements.

If you have ever sought answers to any of the following or similar questions, this book is for you.

- Which pollutant contributes most to air pollution?
- How is air pollution actually measured?
- Why is carbon monoxide injurious to health?
- How can public transport be made more efficient?
- Where can I find more information?

Air pollution is a problem that cannot be wished away. If present trends continue, it can only worsen in the future—and motorized transport will contribute the most to it. If we wish that bumper-to-bumper traffic, air full of acrid smoke that literally moves us to tears, and hopelessly overcrowded buses are not to be our lot in the 21st century, the time to act is now. Mere insistence on the right to clean air, increasingly stringent regulations with little prospect of implementing them, or proclamations of dire consequences for future generations will not make the air in our cities any cleaner: informed judgement, action backed with adequate reflection, and a healthy mistrust of simplistic solutions and quick fixes will.

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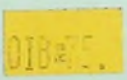

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