# MOBILITY, ENVIRONMENT AND SAFETY IN MEGACITIES

- Dealing with a Complex Future -

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This paper focuses on issues concerning mobility, pollution and safety in megacities of less motorised countries (LMCs) using Delhi (India) as an example. Issues discussed are: Urban transport and land use patterns, planning, systems management and infrastructure development, fuel quality and alternate fuels, control of car ownership, in-use maintenance and inspection, fuel efficiency and technologies, pedestrian and bicycle environments and road safety. The patterns of traffic and management issues in LMCs are very complex and some of their problems have not been faced by the richer countries in the past. In LMC cities' non-motorised modes of transport and some form of public transport/para-transit already constitute a significant proportion of all trips. It will be difficult to increase this share unless these modes are made much more convenient and safer. Unless people actually perceive that they are not inconvenienced or exposed to greater risks as bicyclists, pedestrians and bus commuters it will be difficult to reduce private vehicle use. Buses and non-motorised modes of transport will remain the backbone of mobility in LMC mega-cities. To control pollution bus use and non-motorised forms of transport have to be given importance without increasing the rate of road accidents. These issues have to be considered in an overall context where safety and environmental research efforts are not conducted in complete isolation.

Key Words: Less motorised countries, Pollution, Safety, Traffic, Sustainability

## 1. INTRODUCTION

Nearly sixty percent of the world's population lives in less motorised countries (LMC) and these countries include 62 of the largest 100 cities in the world. The urban growth rates in Asia, Africa and Latin America are higher than those in Europe and North America (Figure1)<sup>1</sup> and so are the vehicle growth rates. Therefore, we can expect most of the megacities (> 5 million population) of the world to be located in LMCs. Though the per capita vehicle ownership in LMCs at present is much lower than that in highly motorised countries (HMC) the air pollution levels in LMC cities continue to remain unacceptably high. With increases in populations and vehicles this situation can get worse unless concrete steps are taken to control the adverse health effects of road transport in these cities.

In this paper we focus on the issues concerning mobility, pollution and safety in megacities of LMCs using Delhi, India as a an example. According to WHO estimates the situation regarding pollution in LMCs and HMCs can be classified as follows:<sup>1</sup> **HMCs:** 

- SO<sub>2</sub>, SPM, and smoke : decreasing, often below WHO guidelines
- NO<sub>x</sub>, O<sub>3</sub>: constant or increasing, often above WHO

### guidelines

• CO<sub>2</sub> : increasing

#### LMCs:

- SO<sub>2</sub>, SPM: increasing, often above WHO guidelines
- $NO_x, O_3$  : increasing, below WHO guidelines
- CO<sub>2</sub> : increasing





The standard counter measures suggested to control vehicular pollution include the following:

- (a) Promote mixed land use
- (b) Move toward a greater diversity in modal splits with more importance to non-motorised modes
- (c) Lower commuting distances
- (d) Reduce number of trips per family
- (e) Increase use of public transport
- (f) Increase vehicle sharing
- (g) Increase costs of travel and raise fuel prices and introduce road fuel taxation
- (h) Make public transit affordable for the lowest twenty percent income group
- (i) Improve the quality of pedestrian and bicycle environment
- (j) Improve fuel quality
- (k) Improve fuel efficiency and technologies of all vehicles
- (1) Introduce strict in-use inspection maintenance systems
- (i) Phase out old vehicles

Of all the measures listed above, (a) to (g) already exist in some form in Delhi and many LMC cities: these cities have very mixed land use patterns, a very large proportion of all trips are walking or bicycle trips; of the motorised trips more than 50% are by public transport or shared para-transit modes; compared to HMCs trips per capita per day are lower and more than 40% of trips are less than 5 km in length; and costs of motorised travel are high compared to average incomes<sup>2</sup>. In spite of these structural advantages, the air pollution levels in LMC cities remain high. What these cities do not have are very efficient public bus systems, safe and convenient walkways and bicycle lanes, the best in fuel quality and vehicle technology and strict and efficient vehicle maintenance systems. However, improvements in these will take time, large financial investments and may be difficult to implement for a variety of reasons.

In addition to the problems of pollution, deaths and injuries due to road traffic crashes are also a serious problem in LMCs<sup>3</sup>. According to one estimate the losses due to accidents in LMCs may be comparable to those due to pollution<sup>4</sup>. These problems become difficult to deal with because there are situations in which there are conflicts between safety strategies and those which aim to reduce pollution<sup>5</sup>. For example, smaller and lighter vehicles can be more hazardous but they are less energy consuming, congestion reduces probability of serious injury due to crashes but increases pollution, increase in bicycling rates can decrease pollution but may increase crashes if appropriate facilities are not provided.

In the next section we describe the situation in Delhi and other Indian cities to provide and insight into the issues mentioned above.

## 2. CITY AND TRAFFIC CHARACTERISTICS OF DELHI

Transport and land use patterns found in Indian cities are different from those existing in most HMC cities. These patterns reflect a new phenomenon and have not been seen in the West since its earlier days of motorization and urbanization. Most Indian cities can be classified as low cost strategy cities<sup>6</sup>. In comparison to the cities in the West, these cities consume less transport energy and have high density living. Intense mixed land use, short trip distances, and high share of walking and non-motorised transport characterize these urban centres<sup>7</sup>. Their transport and land use patterns are so confounded by the spectre of poverty and high level of complexity that it becomes difficult to analyse their characteristics using the same indices as used for cities in HMCs.

#### 2.1 Urban transport and land use pattern

Most metropolitan cities in India prepared Master Plans in the 1960s. These were patterned along the following themes :

- 1. Demographic projections and decisions on the level at which the population shall be contained.
- 2. Allocation of population to various zones depending on existing density level, infrastructure capacity and future density levels.
- 3. Land-use zoning to achieve the desired allocation of population and activities in various zones as projected.
- 4. Large scale acquisition of land with a view to ensuring planned development.

The planning framework as adopted in the preparation of Master Plans has not been found to be commensurate with ground realities. The net effect of the inadequacies of the planning process has been that the majority of urban growth has long taken place outside the formal planning process. Informal residential and business premises and developments increasingly dominate urban areas. In megacities, where half or more of a city's population and many of its economic activities are located in "illegal" or informal settlements, urban planners still rely on traditional master-planning approaches with their role restricted to servicing the minority, high income residents. However, this process along with rising land prices have led to mixed land use patterns and have successfully curbed the number and lengths of primarily non-work related trips by motorized modes. The number of trips per household for different purposes remain constant regardless of whether the person is living in an "inner area" which has a heavy concentration of employment and commercial activities or the "outer areas" with the planned new developments<sup>8</sup>. The rising cost of transport within the city and long working hours force the workers to live close to their places of work. Unlike the traffic in cities in HICs, bicycles, pedestrians and other non-motorised modes are present in significant numbers on the arterial roads and intercity highways. Their presence persists despite the fact that engineers designed these highway facilities for fast moving uninterrupted flow of motorised vehicles.

However, air pollution, congestion and traffic fatalities have continued to increase in such cities. Increase in the level of congestion has been a major concern for planners and policy makers in the metropolitan cities. In Delhi average speeds during peak hour range from 10 to 15 kmh on central areas and 25 to 40 kmh on arterial streets<sup>9</sup>. Average speeds in some other mega cities are less than those in Delhi. However, Delhi's traffic fatalities in 1993 were more than double that of all other major Indian cities combined<sup>10</sup>. Clearly, criteria for recommending optimal speeds and congestion reduction does not include desired level of safety, pollution and land use patterns.

There is ample evidence to illustrate the mismatch between the careful planning and the growing transportation problems. Unless we understand the basic nature of problems faced by our mega cities, the adverse impact of growing mobility on the environment would continue to multiply in future. The existence of an active informal sector introduces a high degree of heterogeneity in the socio-economic and landuse system. This is assumed to add to our problems of congestion and pollution. However, the informal sector is an integral part of the urban landscape providing a variety of services at low costs, at locations with high demand for these services. Many view hawkers, pavement shops, cycle and motor vehicle repair and part shops as unauthorized developments along the road that reduce the capacity of the planned network. However, since the market demands these services, they continue to exist and grow along the arterial roads as well. It is quite clear that long term land use transport plans must address the needs of the informal sector in order to accomodate it efficiently.

#### 2.2 Traffic patterns and planning issues

A high share of non motorized vehicles (NMVs) and motorized two wheelers (MTW) characterizes the transport system of Indian cities. Nearly 45%-80% of the registered vehicles are MTWs. Cars account for 5%- 20% of the total vehicle fleet in most LMC large cities (Table 1). The road network is used by at least seven catego-

Cities (population in million)	Vehicles ('000)	Vehicle fleet composition, %						
		MTW	Car/Jeep	Taxi	TST	Bus	Truck	Other
Mumbai (12.6)	689	38	42	6	4	1	6	3
Calcutta (11.4)	536	40	40	4	1	3	8	5
Delhi (10.2)	2,543	69	20	1	4	1	6	0
Chennai (6.3)	937	70	22	1	1	0.5	3.5	2
Hyderabad (5.1)	543	81	9	0.4	3.6	1	4	1
Bangalore (4.8)	716	75	16	0.5	2.5	1	3	2
Ahmedabad (3.9)	477	72	11	0.2	9.8	2	2	1
Pune (2.9)	300	75	9	1	6	1	7	2
Kanpur (2.3)	208	85	8	0.03	0.97	0.4	3.6	1
Lucknow (1.9)	266	78	11	0.3	1.7	1	3	5
Jaipur (1.8)	339	66	12	1	2	4	6	9

Table 1 Vehicle composition in selected Indian cities - 1994 (%)

Source: Motor Transport Statistics of India, Ministry of Surface Transport, GOI, 1995.

MTW : Motorised Two Wheelers

TST : Three-wheeled Scooter Taxi

ries of motorised vehicles and NMVs. Public transport and paratransit is the predominant mode of motorized travel in megacities and carry 20%-65% of the total trips excluding walking trips. Despite a significant share of work trips catered for by public transport, presence and interaction of different types of vehicles creates a complex driving environment. The present design of vehicle technology does not take into consideration this environment where frequent braking and acceleration cannot be avoided.

Preference for using buses for journeys to work is high among people whose average income is at least 50% more than the average per capita income of the city as a whole<sup>11</sup>. Whereas increase in fares may or may not reduce the passenger levels, but it will affect the modal preference of a large number of lower income people who spend 10-20% of their monthly income on transport with the present level of fares. A survey result showed that nearly 60% of the respondents in low income areas showed the minimum cost of journey to work trips by public transport (less than US 10 cents per trip) unacceptable<sup>12</sup>. Even the minimum cost of public transport trips accounts for 20 to 30% of the family income of nearly 50% of the city population living in unauthorized settlements. This section of the population is very sensitive to the slightest variation in the cost of public transport trips. In outer areas of Delhi NMVs and pedestrians on some of the important intercity highways with comparatively long trip lengths show that a large number of people use these modes not out of choice but rather lack of other options. Even a subsidized public transport system remains cost prohibitive for a large segment of the population. Market mechanisms may successfully reduce the level of subsidies, however, they also eliminate certain options for city residents.

Because bicyclists and pedestrians continue to share the road space in the absence of infrastructure specifically designed for NMVs, they are exposed to higher risks of being involved in road traffic accidents by sharing the road space with high speed modes. Unlike cities in the West, pedestrians, bicyclists and MTWs constitute 75% of the total fatalities in road traffic crashes. Buses and trucks are involved in more than 60% of fatal crashes<sup>13</sup>. Buses are often very crowded inside and a significant proportion of passengers who die are those who fall from the footboards of buses.

In addition, many indigenously designed vehicles (IDVs) such as three-wheeled scooter taxis, vehicles outfitted with single cylinder diesel engines (designed for agricultural use) are present on the roads of Indian cities because of the absence of efficient and comfortable public transport services and their low capital (typically around USD 2,000) and operating costs. The *tuk tuks* in Thailand, *becaks* in Indonesia and jeepneys in Philippines serve a similar purpose. These IDVs operate as paratransit modes and provide affordable transport, thus serving a very important and useful role in the context of social sustainability. However, they have unique safety and pollution problems which the HMCs have never experienced. They have very high emission levels but cannot be substituted easily by modern vans or buses because of economic and financial circumstance. Yet, safety, efficiency and environment friendly technologies for these vehicles have not assumed priority for research in India or any other country.

There is ample evidence from cities all over the world establishing a close link between urban transport and land use pattern<sup>14</sup>. Higher density patterns, mixed land use developments are conducive to public transport trips, shorter trip lengths and fewer motorised trips. The available tools to achieve these are comprehensive planning, zoning, taxes and impact fees. Indian megacities present an interesting case where these patterns have evolved regardless of the weak implementation of available tools. Economic pressures and necessities of the population have resulted in high density mixed land.

## 2.3 Transportation systems management and infrastructure development

Traffic congestion is a central focus for urban planners and environmentalists. Planners all over the world work on methodologies and policy options to forecast and reduce congestion in urban areas. Most of the western cities with 20-30% of the urban area devoted to transport infrastructure have exhausted their capacity to expand through the building of new infrastructure. The realization of capacity enhancement in several urban areas occurs through proper traffic signalization, ride-sharing programmes, regulations and vehicle restrictions. Relevance of such solutions have to be reexamined in the context of Indian cities. The congestion itself needs to be understood in a broader urban context. Newman and Kenworthy show how congestion can be a force for good, particularly in automobile dependence<sup>15</sup>. Congestion in Indian cities must be understood in the context of the heterogenous traffic pattern itself. The variation in vehicle sizes and their differing speeds and acceleration permits them to advance through the roadway network by accepting lateral gaps (widths) preceding them. This results in more conflicts and adverse effects on the movement of other motorised vehicles. Congestion management under these circumstances requires allocating space for less polluting modes and infrastructure design to minimize the conflicts of various modes. The urban transport system in Indian cities can become sustainable i.e., providing mobility with minimal adverse effect on the environment, only if it provides safe and affordable transport for all sections of the population. For nearly 50% of the population in these cities, living close to the place of employment and travel to work is required for survival. If the planned transport system does not provide for their travel needs, they are forced to operate under sub-optimal conditions. They continue to exist at places which have not been planned for them. Consequently, land-use transport plans are violated and all modes of transport operate under sub-optimal conditions. Therefore, implications of creating sustainable urban transport in Indian cities includes building the necessary knowledge base to deal with the problems of these cities.

## **3. FUTURE DIRECTIONS**

The main administrative actions taken by the government to reduce the amount of pollution generated by motor vehicles include: mandatory pollution testing (CO emission at idling) of vehicles every three months, fitting of catalytic converters on cars, setting of stricter emission norms for vehicles manufactured in the future and availability of lead free petrol in the city. However, in the public perception these measures have not yet had a significant beneficial effect in reducing pollution levels in the city. Various government and non-government organisations have also proposed banning of the threewheeled scooter taxis, taking polluting buses off the road, and strict legal action against vehicles not conforming to emission norms. The regulatory authorities have not been particularly successful in implementing some of these suggestions. Some of the measures not implemented are examined below for their future effectiveness:

### 3.1 Controlling car ownership

Car ownership seems to be mainly influenced by the relative price of cars compared to family incomes. Car use for work trips can be influenced by providing comfortable and reliable public transport options. However, in India, the effect of these measures does not appear to be very strong as a significant number of cars are owned or their use subsidised by the government and private corporations. It is not easy to change this situation as family incomes are likely to rise considerably for the next few decades and car ownership levels are still relatively low by international standards. It may be possible to reduce car use if long term plans are made to introduce car/vehicle sharing systems and technologies and public transportation systems are expanded to such an extent that they are not as crowded and inconvenient as at present.

# **3.2** Improvements in fuel quality and alternate fuels

In most LMCs, decisions have already been taken to phase out leaded petrol. The next phase, reductions in sulphur and benzene content in fuels will take longer and will be more difficult as this requires much higher capital investments. The same will be true for cleaner diesel fuels. Alternate fuels (like CNG) are being introduced in many countries, including India, but widespread use will take time as the infrastructure needed for distribution of fuels like CNG is also time and money consuming. In addition, the real benefit of CNG use comes only if engines and closed loop catalytic converters are specifically designed for such fuels. Such engines are more expensive than the traditional diesel engines and retro-fit technologies are not very effective in reducing overall pollution. Therefore, CNG use though desirable for buses, its widespread use is not likely in the near future.

Electric cars are likely to remain prohibitively expensive for LMC use at least for the next decade or so. However, with careful planning it may be possible for LMC megacities to introduce electric trolley buses in selected areas of cities as they are much less expensive than light rail transportation systems.

#### 3.3 Increase in use of public transport

Construction of metro rail systems is considered an important counter measure for reduction in congestion and pollution. Almost all megacities in Asia have plans to construct such systems. However, the cost effectiveness of such projects in low-income countries is very doubtful. Two major studies done to understand the performance of metro rail systems by the World Bank and the Transport Research Laboratory (U.K.) make the following conclusions:

"It is difficult to establish the impact of metros on traffic congestion, in isolation from other factors. However, there appears to be an impact in 10 of the 12 cities for which information exists. In one of the remaining two, Sao Paulo, the impact was short lived, while time will tell whether this is also the case in Manila. The general conclusion is that contrary to expectations metros do not appear to reduce traffic congestion. The passengers are mostly captured from the buses, but the reduction in bus traffic is not proportional and represents only a small part of the total traffic. The relief to traffic congestion is short lived because private traffic rapidly grows to utilise the released road capacity. There has been very little shift from car use. In most cities in most developing countries it will not be possible to justify metros rationally. In these cities we have sought to direct attention to their priorities and actions to improve the bus and paratransit system which will result in achievable improvements"<sup>16</sup>.

"Several developed countries have industries for metro systems facing lack of demand at home. Part of their foreign policy is to make soft loans to support these industries. At the same time in the developing countries governments are interested because, (1) a large construction project will bring jobs, (2) a metro system seems modern, and (3) because the cost will not be until the project has been built; even then the financing may be about 3%. A reason not to invest, financial discipline is often not regarded as important. There was money to be made, prestige and political power to be won. Short term and long term motivations lay behind the construction of the metro. Firstly, there was the desire to immediately improve political fortunes. In the longer term there was a desire to build a monument to those holding office at that time"<sup>17</sup>.

The experience from Chinese cities supports the conclusions that building metro systems does not necessarily reduce congestion and decrease private transport use. The metro system in Beijing takes only 11% of the public passenger transport volume and a report from Beijing states that "As the advanced track transport system is enormously expensive and requires a long construction period, it cannot be taken as an immediate solution"<sup>18</sup>. Shanghai has built a 22.4 km metro line which carries only 1% of the total number of passengers in the city<sup>19</sup>. The number of public transit vehicle equivalents increased by 91% between 1993 and 1997 but the total number of passengers carried decreased by 53% in the same period<sup>20</sup>. Guangzhou has finished construction of a metro line but details of change in surface traffic are not available. The city has increased availability of public transport standard vehicle equivalents by 97% but the total number of passengers carried has increased by 62% only. In light of this experience Wu and Li conclude:

"Although the central government is actively pro-

moting the Chinese built underground carriages and equipment, the cost of construction and operation of the metro is still too high to bear for most cities. Urban rail transport is vital to megacities like Beijing, Shanghai, Gunagzhou and Tinajin. But for other cities or even the outer areas of the other cities mentioned, alternatives should be considered including bus-only lanes, improved trams, elevated or ground rails and suburban rails... As a matter of fact, the already built metros in some cities have not become a means to commute for the middle or low income class. The practice in developed countries shows that the development of public and rail transport itself does not necessarily block the process of motorisation or reduce the number of motor vehicles. Nor does it alleviate traffic congestion. Thus it cannot fundamentally improve traffic contamination"<sup>20</sup>.

Construction of a metro rail system and an increase in the number of buses would also increase the number of access trips by walking and bicycling. High-density metro corridors increase the presence of pedestrians on the surface. This can result in higher accident rates if special measures for traffic calming, speed reduction, and provision of better facilities for bicycles and pedestrians are not put in place in parallel. Therefore, there is no evidence that the construction of a metro rail system on its own would result in the reduction of congestion, pollution or road accidents. It is important that alternative lower cost methods of transportation be explored much more seriously.

The experience of designing and running a high capacity bus system in the city of Curitiba in Brazil gives us a very good example of what is possible in planning public transportation systems at a fraction of the cost (5%-10%) involved for metro lines<sup>21</sup>. Special bus and bus stop designs have been developed in Curitiba to make access to buses easier, safer and faster. This is combined with provision of segregated bus lanes where necessary, traffic light priority for buses and moving buses in platoons. A specially designed bus system of this sort can carry up to 25,000 - 30,000 passengers in one hour in each direction. Since such systems can be put in place at a fraction of the cost of metro systems without digging or building elevated sections, they can be introduced on all major corridors of a city. Since the total number of lines built would be many more than the high cost of a metro system, the total capacity of this system would also exceed that of a limited metro rail network. An intelligent mix of electric trolley buses and other buses running on diesel and alternate cleaner fuels could take care of pollution issues. The availability of modern computer networks, communication systems and intelligent transport technology holds great promise for making high capacity bus systems even more efficient and user friendly. Even the highly industrialised countries did not have these options available to them in past decades and so very little serious research and development work has been done to optimise designs for megacities in low-income countries. Any investment in this direction should be highly profitable.

# **3.4** Introduction of strict in-use inspection maintenance systems and phasing out old vehicles

Both these measures are likely to have limited success in LMCs for economic, social and political reasons. Vehicle inspection and maintenance costs are relatively high for LMC income levels and need capital intensive equipment and bureaucratic structure. These are not likely to be successful until per-capita incomes rise and costs of such systems are built into the ownership of vehicles. The design and implementation of such systems are likely to take time. Similarly, it will be very difficult to phase out old vehicles as costs of owning vehicles are very high relative to incomes. However, this may not pose that much of a problem as high growth rates in vehicle ownership in LMCs have taken place in the last decade and most of the vehicles on the road in the next decade are likely to be of a more recent origin.

# 3.5 Improve fuel efficiency and technologies of all vehicles

Policies and research in this area are likely to be most beneficial. Research and development work to improve the emission levels from motorcycles and scooters has already been taken up by manufacturers in response to much stricter pollution standards introduced by governments of counties like India, Taiwan and Thailand. These improvements are likely to have a major impact as MTW ownership levels in many LMCs which are very high. Continued work and research in this area is very ncessary.

One set of vehicles completely neglected for improvements are the country specific indigenously developed vehicles discussed in an earlier section. Many policy makers and city governments are considering the ban of such vehicles. However, such moves may not be in the overall benefit for cities and mobility of the lower income people. Replacing such vehicles with high cost vehicles may result in unforseen negative consequences both in social effects and mobility practices. It is possible that an increase in fare prices might result in many commuters reverting to use of personal modes. This would be particularly true for those who own scooters and motorcycles, as the running cost for these vehicles is relatively low. Higher use of these vehicles can offset the environmental advantage of using less polluting vehicles. It would be much more useful and beneficial if government-industry partnerships are formed to develop guidelines and standards for use of alternative less polluting engines without increasing the costs substantially.

# **3.6** Improve quality of pedestrian and bicycle environment

In light of the discussion above, this seems to be the most important policy decision which needs to be taken in all LMC cities. In all LMC cities NMT modes constitute a high proportion of all traffic. Unless these modes are given importance and roads specifically designed for their needs they also make the movement of motorised modes less efficient. In addition to bicycles, non-motorised carts and rickshas are used for delivery of goods like furniture, refrigerators, washing machines etc. Semi-skilled workers, carpenters, masons, plumbers, postmen, and courier services use bicycles or walk. Therefore, the demand for bicycles and other NMT nodes exists in large numbers at present and is likely to exist in the future also. This situation is not explicitly recognised in policy documents and very little attention is given to improving the facilities for non-motorised modes. Technological solutions based on improving fuels, engines and vehicles must be accompanied by improvements in road cross sections and providing segregated facilities for non-motorised transport.

Better facilities for pedestrians and segregated bicycle lanes would also result in enhanced efficiency of public transport buses that can be given the curbside lane or central two lanes for buses as per site demand. Physically segregated lanes also improve safety of vulnerable road users by reducing the conflicts between motorised and non-motorised modes. This would smoothen traffic flow and hence reduce pollution.

Data clearly indicate that if public transport use has to be promoted in mega- cities like Delhi in LMCs much more attention has to be given to the improvement in safety levels of bus commuters and the non-motorised transport segment of the road users. This is particularly important because promotion of public transport use can also result in an increase in the number of pedestrians and bicycle users on city streets. Unless people actually perceive that they are not inconvenienced or exposed to greater risks as bicyclists, pedestrians and bus commuters it will be difficult to reduce private vehicle use. However, in LMC cities non-motorised modes of transport already constitute a significant proportion of all trips. It will be difficult to increase this share of public transport and non motorised modes unless these modes are made much more convenient and safer.

## 4. CONCLUSIONS

Buses and non-motorised modes of transport will remain the backbone of mobility in LMC mega-cities. To control pollution both bus use and non-motorised forms of transport have to be given importance without increasing pollution or the rate of road accidents. This would be possible only if the following conditions are met:

### **Public transport:**

- a. The cost effectiveness of metro rail systems be evaluated very carefully. Current evidence suggests that metro rail systems, especially the construction of two or three lines at great cost, do not help in reduction of private vehicle use, congestion or pollution.
- b. Design and development of modern and sophisticated high capacity bus systems be given priority in megacities of Asia.
- c. Introduction of bus engine and transmission technologies that ensure clean burning and efficient combustion at the passenger loads and driving cycles experienced in Asian megacities.

# Segregated lanes for non-motorised transport and safer pedestrian facilities:

- a. Urban and road design characteristics that ensure the safety of pedestrians and bicyclists.
- b. Provision of segregated bicycle lanes on all arterial roads.
- c. Wider use of traffic calming techniques, keeping peak vehicle speeds below 50 km/h on arterial roads and 30 km/h on residential streets and shopping areas.
- d. Convenient street crossing facilities for pedestrians.

The above recommendations have to be considered in an overall context where safety and environmental research efforts are not conducted in complete isolation. We have to move toward adoption and implementation of schemes that remain at a human scale and improve all aspects of human health. The authors of a report on integration of strategies for safety and environment published by the OECD suggest the following guidelines for policy makers<sup>22</sup>:

- Ask leading questions about safety and environmental goals at the conceptual stage of the project and look beyond the immediate boundaries of the scheme.
- The safety and environmental consequences of changes in transport and land use should be made more explicit in technical and public assessments.
- There should be simultaneous consideration of safety and environmental issues by involving all concerned agencies.

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