Achieving sustainable transportation system for Indian cities – problems and issues

Ashish Verma[1,*], S. Sreenivasulu[1] and N. Dash[2]

[1]Centre for Infrastructure, Sustainable Transportation and Urban Planning, and [2]Department of Civil Engineering, Indian Institute of Science, Bangalore 560 012, India

This article aims at identifying the research issues and challenges that need to be addressed to achieve sustainable transportation system for Indian cities. The same is achieved by understanding the current system and trends of urbanization, motorization and modal shares in India; and their impact on mobility and safety (the two basic goals of transportation) as well as environment. Further, the article explores the efforts by the central and state governments in India to address the sustainability issues, and the problems and issues over and above the present efforts to achieve sustainability. The article concludes by summarizing the research issues with respect to planning/modelling, non-motorized transport, public transport, driver behaviour and road safety and traffic management. It is expected that these research issues will provide potential directions for carrying out further research aimed at achieving sustainable transport system for Indian cities.

Keywords: Driver behaviour, road safety, sustainable transportation, traffic management.

Introduction

IN the recent past, the word 'sustainability' has attained a prominent place in transportation planning, policy and other documents. It can be broadly defined as 'development that meets the needs of the present without compromising the ability of future generations to meet their needs'. In the context of transportation, sustainability would mean developing better transportation systems, options and expectations consistent with the objective of securing future social and economic development within a sustainable environment that ensures community well-being. Sustainable transport can be achieved through measures pertaining to transportation system management, energy management, capacity management and environmental management (Figure 1). Sustainable transport is also important for developing countries from the perspective of climate change, i.e. to improve carbon footprint/ ecological footprint (EF) of transportation. According to some of the studies conducted in the UK and US, it has been found that road transport emits 22–25% of the total output of carbon dioxide. These findings emphasize the need for achieving sustainability in transport not only from the mobility and safety perspective, but also from the perspective of local and global environmental issues. Also, from the responses of a recent survey of 522 stakeholders from the world's 25 major cities[1], it is found that the infrastructure related to transportation is the most serious challenge faced by all cities (matured, transition and emerging cities).

Are current systems and trends in Indian cities sustainable?

It is important to answer this question before discussing the problems and research issues with respect to the Indian scenario. For this, it is essential to first understand the present trends on aspects such as urbanization, motorization, modal share and then their impact on mobility, safety issues and the environment.

Urbanization

An urban area is an area with an increased density of human-created structures in comparison to the areas surrounding it. Urban areas may be cities, towns or conurbations, but the term is not commonly extended to rural

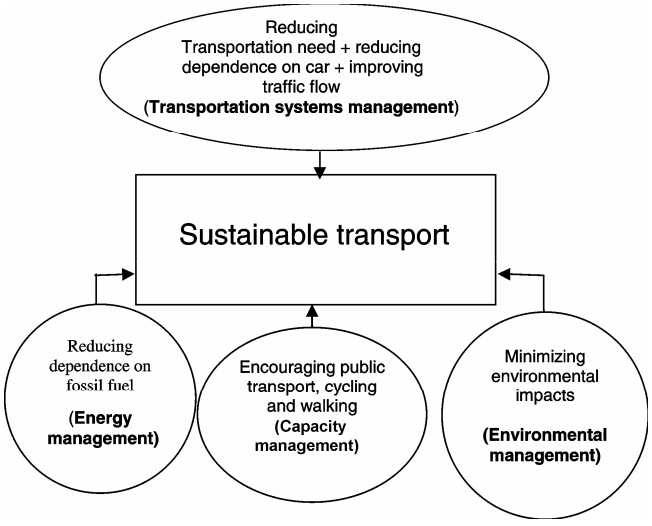

Figure 1. Components of sustainable transport.

*For correspondence. (e-mail: ashishv@civil.iisc.ernet.in)

settlements such as villages and hamlets. The definition of 'urban' varies from nation to nation. The definition of 'urban' in the Indian context is: 'The towns (places with municipal corporation, municipal area committee, town committee, notified area committee or cantonment board), all places having 5000 or more inhabitants, a density of not less than 400 per square kilometre, pronounced urban characteristics and at least three fourths of the adult male population employed in pursuits other than agriculture, are treated as urban areas'.

According to the 2001 census[1] (Table 1), India has 393 towns with a population of more than 0.1 million. Also, during the second half of the last century, the number of cities in India with a population of one million and above has steadily increased from 5 million in 1951 to 35 million in 2001, which is expected to further increase to 70 million by 2025. Observing the historical trends of population growth in India (Table 2), it can be seen that the annual average growth rate in every decade has been positive since 1931. A similar positive trend can be seen for the growth in percentage of urban population to the total population since 1921, which is expected to increase from 28% in 2001 to 58% by 2025. From the trends of the world's urban population, similar trends can be observed for developing countries compared to the developed countries (Figure 2).

Clearly, this growth of the urban population in developing counties has a definite impact on travel demand and subsequently on urban mobility. It is clearly understood that cities are the economical contributors of the nation with their 50–60% contribution to GDP. But, the question is 'how can an urban India survive with the estimated population as indicated above'?

Table 1. Urban conglomerations in India according to 2001 census

Class	Population size	Number
Class I	100,000 and above	393
Class II	50,000–100,000	401
Class III	20,000–49,999	1151
Class IV	10,000–19,999	1344
Class V	5,000–9,999	888
Class VI	Less than 5000	191
Unclassified		10

Source: Census[6].

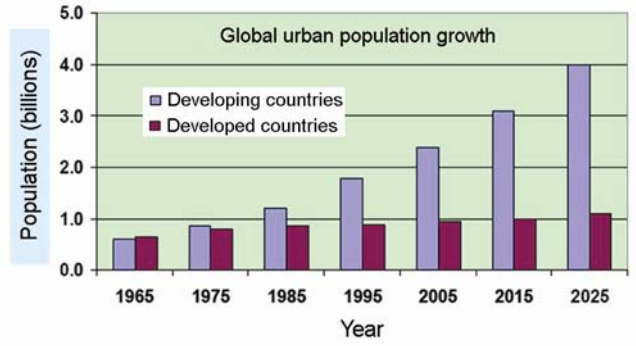

Figure 2. Population growth in developed and developing countries (Source: MOUD[2]).

Motorization

Indian cities have registered an astronomical growth in registered motor vehicles in the last decade (Figure 3). Booming economy, aspirations to own a car, unmatched public transport (with respect to demand, comfort or both), the government's encouraging policies (open car market, easy loan schemes), etc. are a few reasons for increasing motorization at a rapid rate. From 1981 to 2001, population increased by 1.9 times in six major metropolises but the number of motor vehicles increased by 7.75 times[1]. Also, energy demand in transport sector is projected to grow at 5–8% per annum. The estimates of vehicular growth are unimaginable and threatening. For example, Table 3 shows that cars and SUVs will increase 13-fold in 2035 with respect to 2005 statistics under the do-nothing scenario. Unfortunately, a similar growth has not been observed for bus fleets of major transport undertakings in India (Table 4). In fact, the size of the bus fleets has been decreasing in most of the urban transport undertakings except in Bangalore where the annual growth is about 10%.

Modal share

Figure 4 shows mode split in selected cities of India. Also, Table 5 shows the existing modal split for different Indian cities based on population size. As a general trend, with the increase in the size of the city in terms of both area and population, the modal share on public transport has been increasing but there is no evidence either for the reduction of private motorized transport (2-W + car, etc.) share except for the 'five million plus' cities.

One of the important reasons for considerable public transport (PT) mode share is the presence of a substantial percentage of captive riders in most of the Indian cities. But, at the same time, the modal share on non-motorized transport (walk and bicycle) is also considerable; however the policy, infrastructure and facility support are extremely poor for non-motorized transport (NMT) modes in India. Moreover, if we compare the existing modal split with the desired modal split given in Table 6, it is clear that we still have an imbalance in modal split particularly in terms of the desired shares of PT and NMT. From a recent study by MOUD[2], during 1994 to 2007, the average PT share has been reducing for cities with above two million populations (Table 7) and if the PT share is projected further (Table 8) considering the present trend of urbanization and motorization; it is further going to

Table 2. Historical growth of population in India

Year	Population (in lakhs)	Density of population per sq. km	Average annual exponential growth rate	Percentage of urban population to total population
1901	2,384.0	77	–	10.85
1911	2,520.9	82	0.56	10.29
1921	2,513.2	81	–0.03	11.18
1931	2,789.8	90	1.04	11.99
1941	3,186.6	103	1.33	13.86
1951	3,610.9	117	1.25	17.29
1961	4,392.3	142	1.96	17.97
1971	5,481.6	177	2.22	19.91
1981	6,833.3	216	2.20	23.33
1991	8,464.2	267	2.14	25.70
2001	10,286.1	325	1.95	27.82

Source: Census figures of different years.

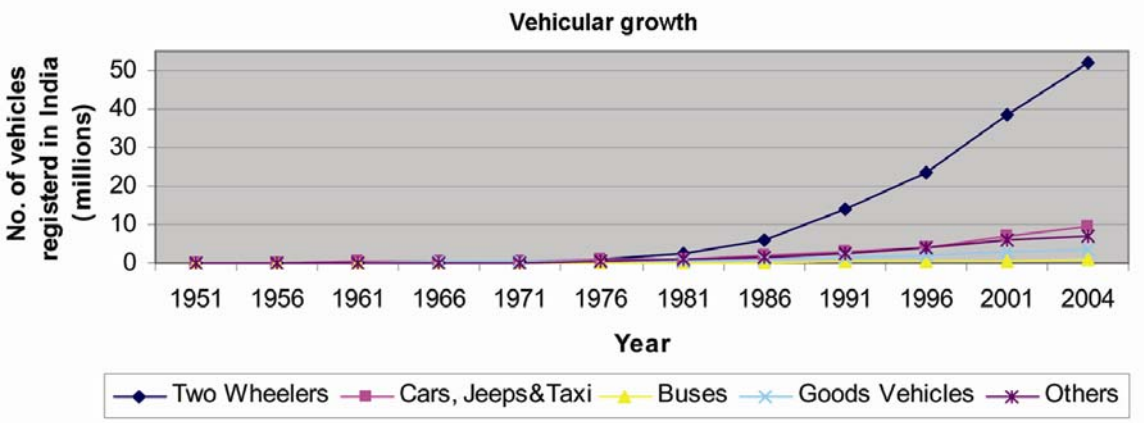

Figure 3. Growth of India's motor vehicle fleet by type of vehicle from 1951 to 2004 (in millions; Source: refs 9–11).

Table 3. Forecast of vehicle populations in India (in million vehicles)

Population	2005	2008	2015	2025	2035
2-W	35.8	46.1	87.7	174.1	236.4
3-W	2.3	3.0	5.3	8.8	13.1
HCV	2.4	2.9	4.6	9.1	16.2
LCV	2.4	3.2	5.7	12.5	26.9
Car, SUV	6.2	8.8	18.0	41.6	80.1
Grand total	49.1	63.9	121.3	246.1	372.7

Source: Lohia[1].
Note: 2-W, two-wheeler; 3-W, three-wheeler; HCV, Heavy commercial vehicles; LCV, Light commercial vehicles; SUV, Sports utility vehicles.

decrease, aggravating the imbalance in the modal split. The MOUD study also highlights that a major portion of vehicular composition during peak hour on important corridors in the metropolitan cities consists of cars, two-wheelers and Intermediate Public Transport (IPT) (even though their mode share is less compared to PT), which clearly indicates the reason for extreme congestion on Indian urban roads during peak hours (Table 9).

After understanding the trends of urbanization, motorization and modal share, it is now important to understand how they affect mobility and safety, which are the two main goals of transportation.

Effects on mobility

Mobility can be assessed in terms of speed, travel times, delays, etc. along the important corridors of the city. According to MOUD[2], the average journey speed in 2007 on important city corridors is in the range of 17–26 kmph, which is considerably low as compared to the

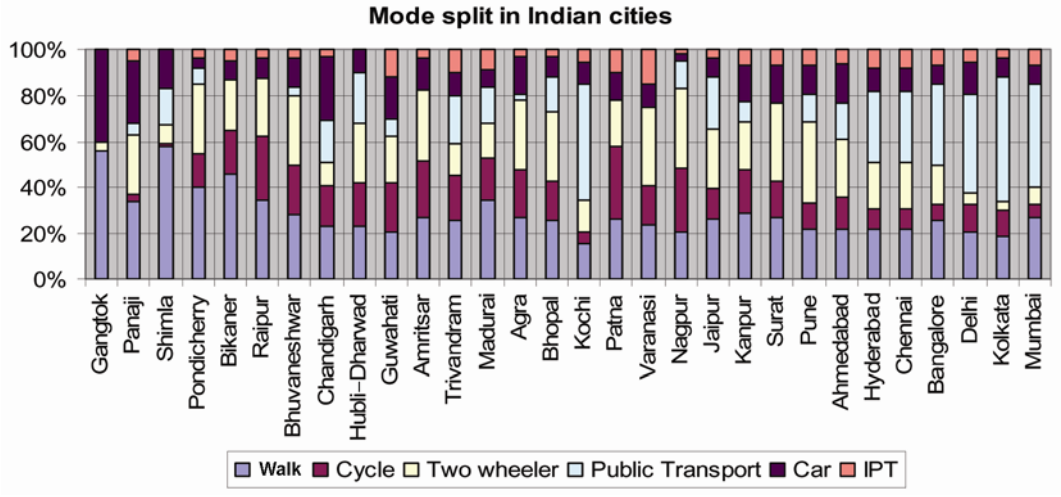

Figure 4. Mode split in Indian cities (Source: MOUD[2]).

Table 4. Growth of state transport undertaking (STU) bus fleet in India

		Year								
City	STU	2000	2001	2002	2003	2004	2005	2006	2007	Annual Avg GR (%) (2000–07)
Mumbai	BEST	3269	3155	3075	3075	3074	3069	3075	3081	–0.8
Delhi	DTC	4916	4330	4466	2496	2905	3010	3143	2814	–7.7
Chennai	CHI-I	2353	2314	2211	2270	2251	2187	2176	2087	–1.7
Kolkata	CSTC	814	821	856	800	769	707	659	635	–3.5
Ahmedabad	AMTS	752	729	630	410	382	371	545	727	–0.5
Pune	PMT	657	664	647	662	697	764	784	752	1.9
Chandigarh	DCHNTU	393	395	404	–	–	–	405	404	0.4
Bangalore	BMTC	2110	2250	2446	2656	3062	3533	3802	3967	9.4

Source: MOUD[2].

Table 5. Existing modal split in Indian cities (as percentage of total trips)

City population (in millions)	Walk	Mass transport	Intermediate public transport		Car	Two-wheeler	Bicycle	Total
			Fast	Slow				
0.10–0.25	37.1	16.4	10.4	20.1	3.3	24.1	25.7	100.0
0.25–0.50	37.8	20.6	8.9	17.2	2.6	29.8	20.9	100.0
0.50–1.0	30.7	25.4	8.2	12.0	9.5	29.1	15.9	100.0
1.0–2.0	29.6	30.6	6.4	8.1	3.3	39.6	12.1	100.0
2.0–5.0	28.7	42.3	4.9	3.0	5.0	28.9	15.9	100.0
5.0+	28.4	62.8	3.3	3.7	6.1	14.8	9.4	100.0

Source: MOUD[7].

Table 6. Desirable modal split for Indian cities (as percentage of total trips)

City population (in millions)	Mass transport	Bicycle	Other modes
0.1–0.5	30–40	30–40	25–35
0.5–1.0	40–50	25–35	20–30
1.0–2.0	50–60	20–30	15–25
2.0–5.0	60–70	15–25	10–20
5.0+	70–85	15–20	10–15

Source: MOUD[2].

Table 7. Change in public transport share

City category	City population range (in lakhs)	WSA study, 2007 (%)	RITES study, 1994 (%)
1	<5.0	0.0–15.6	14.9–22.7
2	5.0–10.0	0.0–22.5	22.7–29.1
3	10.0–20.0	0.0–50.8	28.1–35.6
4	20.0–40.0	0.2–22.2	35.6–45.8
5	40.0–80.0	11.2–32.1	45.8–59.7
6	Above 80.0	35.2–54.0	59.7–78.7

Source: MOUD[2].

Table 8. Projected change in public transport share and estimated mode share for different city categories

Year		2007			2011			2021			2031		
City category	Population	PT	PV + IPT	NMT	PT	PV + IPT	NMT	PT	PV + IPT	NMT	PT	PV + IPT	NMT
Category 1a	< 5 lakh population with plain terrain	5	57	38	4	59	36	3	66	31	2	72	26
Category 1b	<5 lakh population with hilly terrain	8	34	58	7	37	56	5	47	48	3	57	40
Category 2	5–10 lakhs	9	39	53	8	42	50	6	51	43	5	58	36
Category 3	10–20 lakhs	13	43	44	12	46	43	10	52	38	9	57	34
Category 4	20–40 lakhs	10	47	43	9	49	42	8	51	41	8	52	40
Category 5	40–80 lakhs	22	42	36	21	45	35	15	51	34	12	54	34
Category 6	> 80 lakhs	46	24	30	42	28	30	31	40	29	26	46	28

Note: PT, Public transport; PV, Personal vehicle; IPT, Autorickshaw; NMT, Non-motorized transport including walk and cycle.
Source: MOUD[2].

Table 9. Average peak hour vehicle composition at locations within city (%)

City category	Population (in lakhs)	Std bus	Mini bus	Cars/ jeep/van	Two-wheelers	Auto rickshaws	Commercial vehicles	SMVs	Total
Category 1a	< 5 with plain terrain	9	4	17	30	14	9	17	100
Category 1b	< 5 with hilly terrain	6	15	40	33	0	5	0	100
Category 2	5–10	7	2	17	32	20	6	16	100
Category 3	10–20	6	4	19	33	20	5	14	100
Category 4	20–40	6	2	23	36	16	4	13	100
Category 5	40–80	9	2	20	37	21	4	7	100
Category 6	> 80	12	3	31	23	23	3	4	100

Note: Including tourist and educational buses. Source: MOUD[2].

designed speeds for the same roads. Considering the do-nothing scenario, these speeds are expected to fall to single digit by 2031 (Table 10). Also, according to an interesting finding from the MOUD report on calculating congestion index of 30 cities of India (Figure 5), it is concluded that 0.25 is the average congestion index on a scale of 0–0.6, where '0' indicates good and '0.6' indicates poor index value, and most of the major metro cities fare very badly on the congestion index with its value much higher than the average. Here, the congestion index is calculated as $(1 - x/y)$, where x is the observed speed and y is the expected speed. The average volume to capacity (V/C) ratio on major corridors within cities (in 2007) has already reached values closer to or exceeding 1, indicating extreme congestion conditions during peak hour (Table 11). This V/C ratio is expected to reach a value of up to 2 by 2031, under the do-nothing scenario.

Effects on safety

Safety is another important goal of transportation, and as Figure 6 shows, it is a major worrying issue in India because of the ever-increasing trend of road fatalities. Recently, WHO revealed in its global status report on road safety that India topped in road accident fatalities, than any other country in the world, including the most populous China. In India, the number of road deaths is increasing every year whereas in European countries such as Germany, Sweden, England, Denmark, etc., the numbers are either stagnant or reducing which indicates their higher sustainability levels (Table 12). In Sweden, the

Table 10. Anticipated average journey speed (kmph) on major corridors

City category	Population (in lakhs)	2007	2011	2021	2031
Category 1	< 5	26	22	15	8
Category 2	5–10	22	18	13	9
Category 3	10–20	18	13	10	7
Category 4	20–40	22	18	12	9
Category 5	40–80	19	15	10	7
Category 6	> 80	17	12	9	6

Source: MOUD[2].

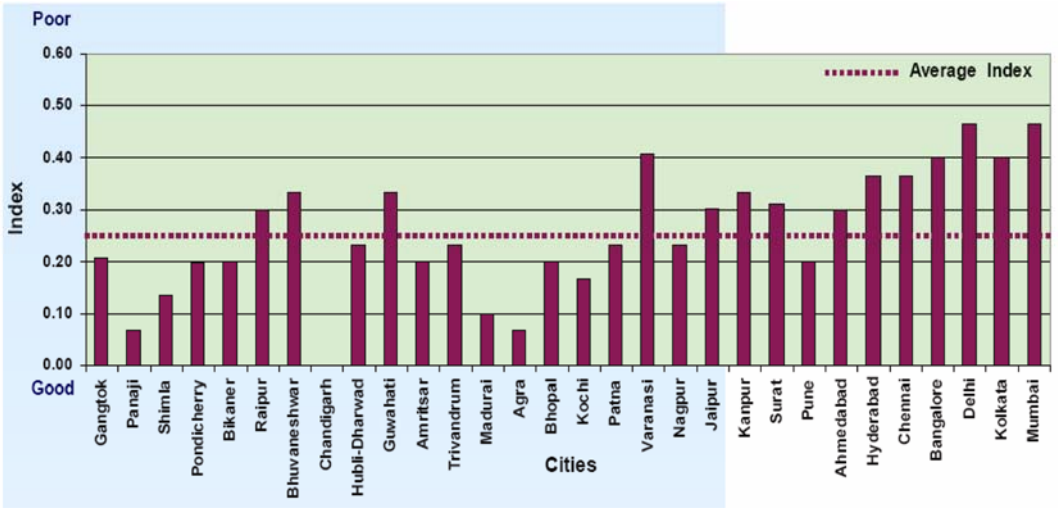

Figure 5. Congestion index of selected Indian cities (Source: MOUD[2]).

Table 11. Average V/C ratio on major corridors under do-nothing scenario

City category	2007	2011	2021	2031
Category 1	0.24	0.33	0.69	1.48
Category 1	0.73	0.78	1.2	1.64
Category 1	0.81	1.24	1.80	1.97
Category 1	0.97	1.05	1.16	1.32
Category 1	1.12	1.51	2.01	2.54
Category 1	1.21	1.79	2.4	2.9

Source: MOUD[2].

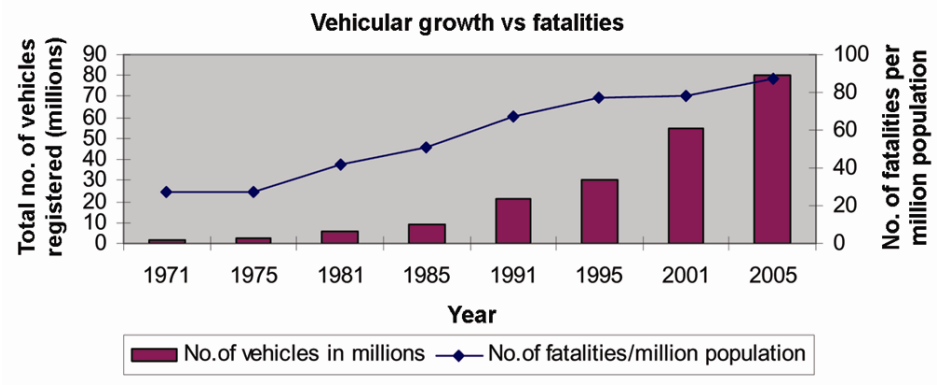

Figure 6. Road fatality trends of India (Source: refs 9–11).

Table 12. Road accidents involving injury, 1980–2004 (in thousands)

Year	Germany	Sweden	Great Britain	Denmark	India
1980	412.7	15.2	257.3	12.3	153.2
1990	389.4	17	265.6	9.2	282.6
2000	382.9	15.8	233.7	7.3	391.449
2001	375.3	15.8	229	6.9	405.637
2002	362	16.9	221.7	7.1	407.497
2003	354.5	18.4	220.1	6.7	406.726
2004	339.3	18	213	6.2	429.91

Source: Data retrieved from ref. 8.

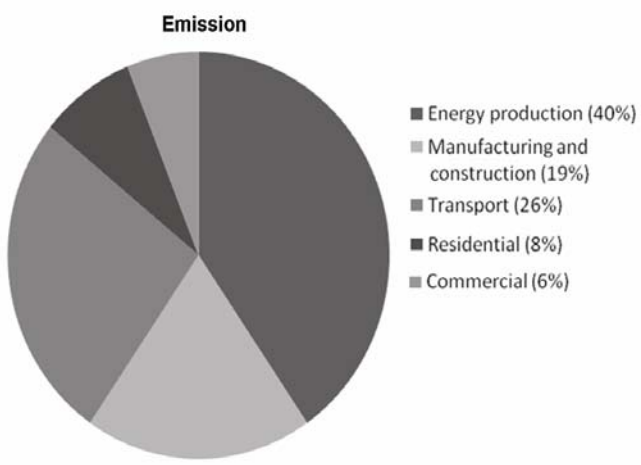

Figure 7. Sector-wise carbon emissions (Source: ref. 12).

government is aiming at zero fatalities in road accidents and advocating policies accordingly.

Table 13. Fuel consumption per day (kilolitres)

City category	Car	TW	AR	Bus	Total
1	36	8	5	6	55
2	603	414	362	280	1659
3	1003	1058	602	376	3039
4	436	393	393	140	1362
5	921	901	553	833	3208
6	4782	1605	2869	7442	16,697

Source: MOUD[2].

Table 14. Emissions per day in tonnes

City category	Car	TW	AR	Bus	Total
1	6	3	0	0	10
2	90	133	24	21	268
3	158	342	125	27	652
4	64	127	37	9	238
5	143	300	143	60	647
6	556	365	451	375	1747

Source: MOUD[2].

Effects on environment

If we consider the current state of sector-wise carbon emissions (Figure 7), it can be observed that the transport sector has a major share of 26% of total carbon emissions as compared to other sectors, such as energy, manufacturing, residential, commercial, etc. Also, within the emissions from the transport sector, road transport has a major share of 65% as compared to rail, air and water transport. Certainly, these facts are closely related to the present trends of urbanization, motorization and modal share. Tables 13 and 14 show fuel consumption per day in kilolitres and emissions per day in tonnes, respectively, by different types of vehicles for different city categories. The major share of fuel consumption as well as emissions is by cars and two-wheelers as compared to buses, except for cities of Category 6, i.e. more than 8 million population, where the fuel consumption is higher for buses but still the emission is less compared to cars. This scenario clearly results from the prevailing imbalance in modal split (as mentioned earlier), which is not only affecting mobility, but also the environment.

According to an Asian Development Bank report[3], transport-related CO_2 emissions from developing countries will contribute in increasing proportion to global CO_2 emissions unless mitigating measures are implemented soon. This phenomenon can be understood from Figure 8 (assuming a datum of 100 for all regions and/or countries in 1980 under reference scenario) which shows that the maximum growth in CO_2 emissions would be in the developing countries of Asia. This projection is closely related to the projected growth in personalized vehicles, namely cars and two-wheelers as observed in the previous section.

To summarize this section, most of the Indian cities today are typically characterized by high-density urban areas, absence of proper control on land-use, lack of proper roads and parking facilities, poor public transport, lack of road-user discipline, etc. This level and type of urbanization in India has caused many problems, especially with regard to its impact on the demand for infrastructure facilities. Urban transport systems have come under heavy strain and this has adversely affected the quality of life of the urban dwellers. Mass transport facilities in the

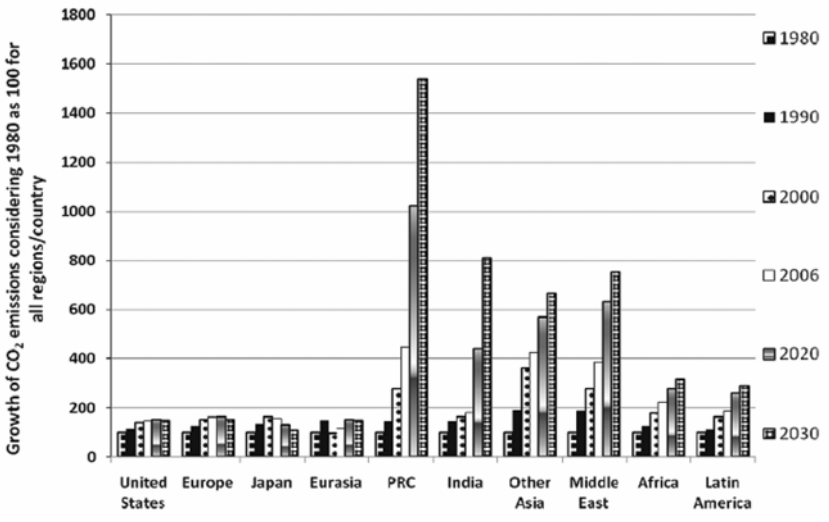

Figure 8. Transport sectors energy-related CO_2 emissions growth considering the 1980 value as 100 for all regions (reference scenario; Source: modified from ref. 13). PRC, People's Republic of China.

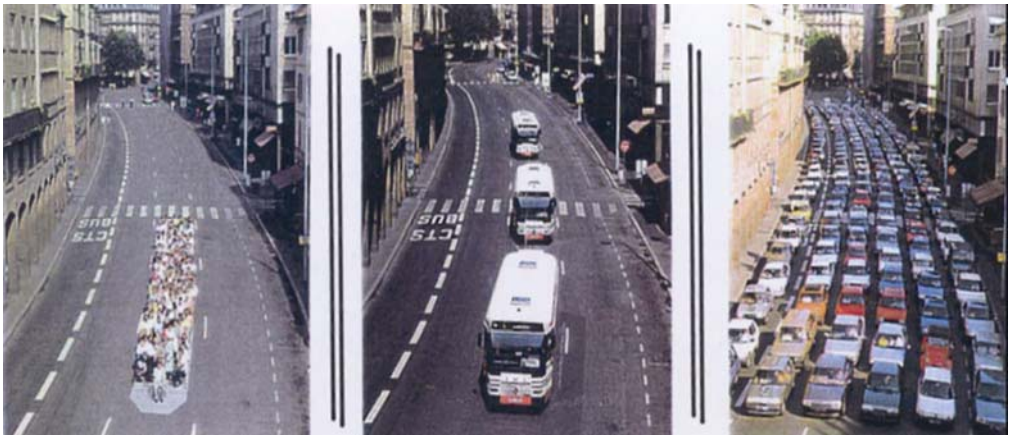

Figure 9. Road space consumed by buses as compared to cars.

cities are grossly inadequate for providing fast, comfortable and convenient travel. This has resulted in heavy shift of commuter patronage from mass transportation to private and intermediate transport and consequently, a huge increase in intermediate and private vehicle ownership. The introduction of small cars such as Tata Nano (people's car), in the Indian market is further adding to the complexity of the transportation situation in the Indian cities. The resultant effects are: increased traffic congestion and transport-borne pollution, heavy fuel consumption, poor level of service to the commuter, etc.

So, it can be clearly said that the current systems and trends in Indian cities are not sustainable.

Efforts made by governments

Realizing the magnitude of the problem, the central and state governments have taken up some major initiatives in the recent past to achieve sustainability in transport.

National Urban Transport Policy 2006

In 2006, the Ministry of Urban Development, Government of India issued the National Urban Transport Policy (NUTP) document, which lays emphasis on moving people rather than vehicles (Figure 9). The following are the objectives of the policy.

- Incorporating urban transport as an important parameter at the planning stage rather than being a consequential requirement
- Reduced travel demand – better integration of land-use and transport planning
- Equitable allocation of road space
- Improved public transport
- Introducing intelligent transportation system (ITS)
- Facilities for use of non-motorized vehicles
- Capacity building – individual and institutional
- Use of cleaner technology
- Innovative financing mechanism

- Greater involvement of private sector
- Better awareness

The NUTP has now become the guiding document for all urban transport improvements in Indian cities.

Jawaharlal Nehru National Urban Renewal Mission (JnNURM)

JnNURM has been recently launched by the central government to provide financial assistance to 63 mission cities for various urban development projects including urban transport. It is a reform-based mission. The statement of the vision is 'Reform-driven fast track planned development of identified cities with focus on efficiency in urban infrastructure/services delivery mechanism, community participation and accountability of urban local bodies (ULBs) towards citizens'. The central government made it mandatory for all urban transport-related proposals to be in consonance with NUTP, for them to be eligible for funding under JnNURM.

Overview of JnNURM

- The selection of cities is primarily based on the population of the cities and the other state capitals and cities with religious or historic importance. Sixty-three cities were selected based on the above criteria and their classification is as follows. The numbers in the brackets indicates, the number of cities falling under that category.
  - Cities/Urban areas (UAs) with 4 m + population 2001 census (7)
  - Cities/UAs with 1 m + but less than 4 m population according to 2001 census (28)
  - Selected cities/UAs (state capitals and other cities/ UA of religious/historic and tourist importance) (28).
- This scheme covers 63 cities/UAs with a population more than 150 million to be benefited.
- The expected order of investment is around Rs 1000 billion in seven years.
- Thrust areas
  - Water supply
  - Sewerage
  - Solid waste management
  - Drainage including preservation of water bodies
  - Urban transport
  - Inner city renewal
  - Development of heritage area
  - Provision of basic services to the urban poor.

Gaps identified in JnNURM: Several gaps were identified including proposals not being part of an overall vision for the city; the projects do not integrate land-use and transportation, pedestrian facilities, non-motorized vehicles (NMV) facilities, parking facilities; alternative analysis not done sincerely in most of the cases; lack of intermodal integration, application of ITS technology, innovative financing mechanisms, parking and advertisement policy, etc.

Identification of problems and issues in achieving sustainable transport

In spite of these and many other initiatives by the central and state governments, the improvements are still not encouraging, as evident from the trends presented in the earlier section. There are many problems and issues that need to be addressed in order to make these efforts successful in achieving sustainability in transportation for Indian cities. The same is discussed under various categories in subsequent sub-sections.

Transport planning and modelling

One of the reasons for unregulated urban growth and sprawl in India is the lack of integration of land-use and transportation planning. For saturated and dense urban areas of Indian cities, questions such as 'what ceiling would be appropriate to restrain the land-use considering the holding capacity of transport infrastructure?' are often important to answer. The current floor space index of 1.6 in urban centres of India compared to indices ranging from 5 to 15 in other Asian city centres[4,5] actually encourages car-centric development. This is one of the reasons for the sprawl and dispersion of development activities.

Also, traditional four-stage demand modelling process is the main modelling technique employed in India for all transportation planning processes. There is no/little use and understanding of other modelling techniques like activity-based modelling, etc. Traditional demand modelling techniques which adopt trip-based approach and uses 'trips' as the basic unit of analysis have limitations of dealing with behavioural issues, for instance, modelling multistop tours, etc. Further, effective use of discrete modal choice models is required to predict the modal shares of NMT, IPT, etc. better, which are often ignored in the Indian context. It is also necessary to represent the realistic behaviour in travel demand modelling particularly because of increasing interests in evaluating the short/ medium-term strategies than long-term capital-intensive strategies. This is essential to understand the behaviour of people against demand management policies such as congestion pricing, staggering of work schedules, etc.

In planning and policy making there is need to clearly understand the effective approaches for framing urban transport strategies for Indian cities. So far, problem-oriented or bottom-up approach is adopted in all transportation studies and strategies in India, whereas top-down approach is seldom adopted or even considered. Actually,

the bottom-up approach is useful for existing policies where minor changes are required but not for a fundamental review of the policy and long-term planning. The following points emphasize the difference in the two approaches.

Bottom-up approach
- In this approach, identification and analysis of comprehensive set of transport problems are made.
- Potential solutions to the problems are assessed in isolation and in combination using a detailed transport model.
- Combination which best solves the problems is taken as preferred strategy.

Top-down approach
- The starting point is a set of goals and objectives.
- The formed goals and objectives represent a broader view of perceived problems.
- The measures are developed and tested to fulfil the objectives and further the goals and not the problems.

Non-motorized transport

One of the basic reasons for the lack of proper infrastructure for pedestrians and bi-cyclists in India is the lack of understanding of the mobility role that each of these modes (as main mode or access/egress mode) can play for Indian cities of different size (physical and population), and shapes. Accordingly, the planning focus and infrastructure provisions will differ. Also, comparing the Central business district (CBD) areas of many European cities with Indian cities, it can be observed that while in European cities, CBDs are mostly pedestrian/bi-cyclists zones and/or public transport only zones; in Indian cities they are the most congested/polluted parts and NMT unfriendly because the private vehicles are allowed to enter a CBD and it is perceived as good for businesses located inside a CBD. One of the important reasons for this situation is the lack of sound approaches to study the impact of NMT and/or PT zones on the overall mobility within and outside a CBD, and on the businesses in general.

Another common issue with respect to pedestrian facilities in India is the encroachment of footpaths by hawkers/vendors. They are desirable to the road users and pedestrians because the services provided by them are cheap and convenient to them. However, the same hawkers/vendors cause inconvenience to them while using walkways for their movement. This contradictory perception of people changes according to their needs and class. Therefore, given the heterogeneous structure of our society and urban areas, street vendors are not only necessary but also inevitable, as they provide services to all commuters with cheap and easily available goods. They have also been a characteristic feature of Indian cities and towns from time immemorial. Unfortunately, there are no recommendations or guidelines in India on how to integrate the street hawkers/vendors into pedestrian policy and facility design. This is the main reason for uncontrolled and haphazard encroachment of hawkers/vendors on footpaths. Therefore, this issue needs to be researched to understand the social elements of street hawkers/vendors and to conduct impact studies on integrating them into pedestrian policy and facility design.

Public transport

The reasons for the present trends of motorization can be listed in two categories: general reasons such as urban sprawl, decentralization, lack of public transportation services, poor level of service offered by public transport, lack of efficiency of bus mode in congested traffic, introduction of small and low-cost automobiles etc.; and socio-economic reasons such as increase in income levels, easily available and attractive credit and financial schemes, increase in number of cars owned per household, rise in middle class aspirations to own a vehicle, etc. An affordable public transport with a desired minimum level of service would always attract ridership in Indian cities; however, the majority of public transport riders in Indian cities are captive riders. This is the major reason behind the increasing trend of motorization because, as soon as the captive rider turns into a choice rider, public transport becomes the less-preferred mode.

In order to make sustainable in Indian cities, one of the important requirements is a good networked public transportation system with time-bound schedules, reliable services, comfort, competitive travel times and affordable prices. These features will improve the generalized cost of travel by PT modes and will make mass transit attractive and will thus bring about a shift from individual mode to public transport. Many Indian cities are now introducing multi-modal mass transit systems which need good integration to be able to effectively serve the overall mobility needs of the city. Inter- and intra-connectivity between modes such as public versus public and public versus private needs to be ensured for an efficient transport system. The other important requirement includes good pre-trip planning system for PT users to plan their trips based on certain needs and criteria.

Driver behaviour and road safety

According to a recent report of WHO on road safety, India tops the lists of road accidents and fatalities in the world. Of the causes of road accidents reported in India, inappropriate driving behaviour plays a major role as compared to pavement and geometric design faults or mechanical defects in the vehicles. With rapid increase in vehicle and human population in developing countries such as India, effective countermeasures are required to reduce the driver's crash risks or to inhibit their exposure to dangerous conditions. Besides road safety problems;

inappropriate or lack of driver education and training also causes mobility issues such as lack of lane discipline; disregard to traffic laws and rules leading to their frequent violation by drivers; disregard to various traffic control measures such as traffic signals, signs and markings; self-centred driving leading to irresponsible vehicle movements; de-motivating for educated drivers to follow good driving practices as other drivers do not follow the same. It is believed that improved driver education, training and licensing along with effective on-road enforcement can act as an effective countermeasure for road safety as well as mobility.

These facts and trends highlight the urgent need for introducing an effective and comprehensive driver licensing and testing programme all over the country for systematically and scientifically evaluating young (learner) as well as professional drivers' for their skills and knowledge to drive safely and avoid collisions in an Indian road environment. These programmes should also be linked with effective and comprehensive driver education courses.

Traffic management

Infrastructure measures are currently under planning and implementation in a big way in India. Numerous flyovers have been constructed and road widening has taken place in urban areas in a quest to meet the exponentially increasing travel demand. However, these measures have proved to be insufficient in tackling the issue of transport sustainability in India and thus clearly indicate the need for a mechanism to improve the existing traffic flow and also control/reduce the travel demand instead of trying to increase infrastructure capacity all the time.

Many Indian cities levy parking charges in CBDs and other busy areas; however, most of these schemes are focused on revenue generation rather than being used as an instrument to control the travel demand. This is because of lack of a clear parking policy which would guide the fixation of tariffs and other restraints on vehicular parking. The impact of parking charges and other parking policy issues have not been studied scientifically to assess the impact and identify the potential measures and strategies to control the travel demand. Congestion pricing is another good instrument to control travel demand. However, there is neither research nor an experience of understanding and quantifying the travel impacts of measures such as congestion charging, in the Indian context.

On the traffic management aspect, issues like heterogeneity and non-lane-based traffic need to be addressed for any modelling or microsimulation tool to be really effective for Indian conditions, and which can then be used to identify and test different traffic management measures that are effective for Indian cities. Also, there have been questions on the suitability of propagating lane-based system for the highly heterogeneous traffic of Indian cities, which need to be scientifically addressed through research.

Research issues to address sustainability in urban transport

The following sections present the summary of research issues that will possibly address and help in achieving sustainability of transport in India.

Planning and modelling issues

The following modelling/planning issues have to be seriously addressed through research:

- Develop goal-oriented (top down) approach for developing urban transport strategies in India.
- Developing models that reflect the impact of changing land-use and/or control policies, slum development, etc. on transportation and vice versa.
- In cases where infrastructure expansion is not possible, assessing the required land-use control considering the holding capacity of transport infrastructure.
- More realistic modelling of mode split, including walk, public transport modes (auto-rickshaws, taxi, bus and rail) and private transport (motorcycle and car).
- Stated response surveys – how to facilitate use of complex choice scenarios for more reliable behavioural models and more accurate response forecasting.
- Exploring possibilities of considering environmental and social cost as part of the planning process (particularly for planning a new urban mass transit or urban road corridor) rather than during post-planning impact assessment.
- Activity-based modelling – still to be developed and attempted in India for possibly better travel demand modelling.
- Better data collection techniques involving technology – for credible and accurate travel and household data (for accurate position, route and distance/time information).
- More realistic assignment of trips to rail and bus networks taking into account the condition in trains, variations in bus speeds and frequency due to changes in overall traffic volume and fares.
- Orienting transport planning to address the climate change issues from developing countries such as India; introducing carbon footprint or ecological footprint as a planning parameter.

NMT issues

- Need to research and define the role of NMT (access only or main mode) in overall mobility of the city (for larger, medium and smaller cities).

- Need for change in planning and policy guidelines, to provide seamless travel using NMT.
- Development of credible ways to assess the impact of pedestrianization, pedestrian zones, etc.
- Ways to integrate hawkers and vendors as part of the pedestrian policy and facility design guidelines.
- Providing pedestrian facilities and developing standards for the same.
- Effective geometric design for NMT to provide seamlessly connected and safe travel across the city.
- Identification of factors that may encourage the use of NMT modes in Indian cities.
- Understanding the effect of urban density, mixed land-uses, neighbourhood features, etc. on NMT use.
- Understanding the potential of traffic calming in pedestrian safety.

Public transport issues

- Need for systems approach in public transportation planning (address O-D travel time effectively, include all modes).
- Inter-modal integration – operational, physical, institutional, still to be effectively developed and achieved in India.
- Need to develop integrated approach for corridor identification (for Metro, BRTS, etc.) in metropolitan cities.
- Better transit ridership estimates – to enhance our understanding of existing and potential transit users, their behaviour, attitudes and opinions.
- To evolve passenger information system design (especially for pre-trip planning) that is suitable for Indian cities (particularly due to weak inter-modal integration, differential importance assigned by users to different legs of the trip, etc.).
- Route and schedule rationalization. Practically no use of optimization for mass transit planning by urban transport undertakings. Needs awareness and better understanding of optimization parameters and constraints to be involved. Which optimization tool is effective and credible to use for better and practical results?
- Better understanding of requirements from optimality in routing and scheduling, i.e. what is required for a transit agency – global optimum, local optimum or set of pareto-optimal solutions?
- How does one provide better comfort and convenience to the public transport passengers?

Driver behaviour and road safety issues

Ways to quantify the impacts of driver attributes, education and behaviour on road safety and mobility. To suggest improvements in the existing system in India. Assessing systems such as graduated driver licensing and effective ITS-based traffic law enforcement, as measures for improving road safety and mobility.

Traffic management issues

- Need to develop effective microsimulation tools for modelling heterogeneous and non-lane-based traffic.
- What is good for Indian traffic? Non-lane-based or lane-based traffic.
- Understanding the impact of traffic demand management measures such as parking fees, road-user charges and congestion pricing, as well as the staggering of working hours, flexible working hours and multiple shift work.
- Impact of car pooling and share auto concepts on traffic flow.
- Right ITS measures and tools for Indian cities.
- Evolving effective traffic management strategies during post-disaster scenario.

These issues provide potential directions for carrying out further research aimed at achieving sustainable transport system for Indian cities.

1. Lohia, S. K., Urban transport in India, Proc. Indo-US conference on Mass Transit Travel Behaviour Research' 08 (MTTBR-08), IIT Guwahati, India, 2008.
2. MOUD, Study on traffic and transportation policies and strategies in urban areas in India, Govt of India, 2008.
3. Schipper, L., Fabian, H. and Leather, J., Transport and carbon dioxide emissions: forecasts, options analysis, and evaluation, Asian Development Bank Sustainable: Working Paper Series, No. 9, 2009.
4. Bertraud, A., The economic impact of land and urban planning regulations in India, 2002, unpublished manuscript available at http://www.Alainbertaud.com/images/AB_%20India_%20Urban_Land_Reform.doc
5. Padam, S. and Singh, S. K., Urbanization and urban transport India: The sketch for a policy, Transport Asia Project Workshop, Pune, India, 2001, http://www.deas.harvard.edu/TransportAsia/workshop_papers/Padam-Singh.pdf
6. Census of India, 2001; http://www.censusindia.gov.in/
7. MOUD, Traffic and transportation policies and strategies in urban areas in India, Final Report. Ministry of Urban Development, Government of India, New Delhi, 1998.
8. European Union Road Federation: European Road Statistics, 2007.
9. Ministry of Road Transport and Highways, Handbook on transport statistics in India, Transport Research Office, Ministry of Road Transport and Highways, Delhi, India, 1999.
10. Ministry of Road Transport and Highways, Handbook on transport statistics in India, Transport Research Office, Ministry of Road Transport and Highways, Delhi, India, 2000.
11. Ministry of Road Transport and Highways, Handbook on transport statistics in India, Transport Research Office, Ministry of Road Transport and Highways, Delhi, India, 2003.
12. IEA, 2000.
13. IEA, World Energy Outlook, 2008.
14. Bhat, C. R. and Koppelman, F. S., Activity-based modelling of travel demand. In *Handbook of Transportation Science* (ed. Hall, R.), Kluwer Academic Publishers, Norwell. A, 1999.
15. International Energy Agency (IEA), 2007; World Energy Outlook; www.iea.org/textbase/nppdf/free/2007/weo_2007.pdf
16. Rastogi, Issues in data collection and non-motorized planning, Proc. Indo-US conference on Mass Transit Travel Behavior Research' 08 (MTTBR-08). IIT Guwahati, India, 2008.