Urban Public Transportation System in the Context of Climate Change Mitigation: Emerging Issues and Research Needs in India

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Abstract The transportation sector contributes significantly towards Green House Gas (GHG) emissions which are contributing factors for the global climate change. In developing countries, such as India, the share of urban transportation sector in overall vehicular emissions is significant. The present chapter reports increase in urbanization, growth of vehicle population and characteristics of urban transportation in India. The chapter highlights the need for increasing public transportation ridership as an instrument for reducing traffic congestion and vehicular emissions. The opportunities and challenges associated with urban public transportation systems are identified and the recent initiatives for improvement of urban public transportation system are reported. Finally, the research needs for improvement of public transportation system in urban India in the context of climate change mitigation are highlighted.

Keywords Urban transportation · Public transportation · Vehicular emission · Urbanization · Climate change

1 Introduction

Global warming has started affecting the world climate and taking an adverse shape day by day. Accordingly, global warming and resulting climate change has become a growing concern and threat to civilization (IPCC 2007). There is a dire need to take appropriate measures for mitigation of climate change in order to sustain the

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world as it ought to be. Although there are various reasons for the global warming, the increase in Green House Gas (GHG) emissions is considered as a major reason as GHGs increase the surface temperature of the world resulting global warming (IPCC 2007). The sources of GHG emissions include residential activities, industrial activities, power system, transportation system, etc. (CPCB 2010). The contribution of transportation sector in GHG emission is significant as it produces large emissions of Carbon Dioxide (CO_2), ozone and soot (Berntsen 2004). As per the Kyoto Protocol, the share of transportation sector is about 7 % of the total climate forcing due to its contribution in ozone, soot, and greenhouse gases (GHG) (Kadukula 2008). In 2009, transportation sector was responsible for 23 % of global GHG emissions (ADB 2012). The contribution from transport sector is expected to increase to 46 % by 2035 and 80 % by 2050 (ADB 2012). In Asia, 23 % of global CO_2 emissions are generated from transportation sector, of which the share of road transport sector (both passenger and freight) is 75 % (ADB 2009). Therefore, it is evident that the role of urban transportation, especially in developing countries, is of paramount importance in the context of GHG emissions and resulting global warming which leads to the change of climate. Traffic congestion and resulting GHG emissions are significant in majority of urban areas in developing countries. However, adequate prominence has not been given on improvement of urban transportation system in developing countries to bring down traffic congestion and resulting contribution to GHG emissions.

In India, the traffic congestion and resulting GHG emissions are significant in majority of urban areas. In 2005, the contribution of India in total GHG emissions was about 8 % and it is expected to be about 13 % by the year 2030 (ADB 2009). Therefore, it has become necessary to understand issues related to urban transportation system in India for reducing congestion and bringing down resulting GHG emissions in the context of climate change mitigation.

Traffic congestion and vehicular emissions are influenced by demand, supply and control characteristics of the transportation system. Therefore, improvements of transportation system (say, mitigation of congestion, reduction of vehicular emissions, etc.) may be attempted through various facets of works related to augmentation of supply, management of demand and improvement of control. However, increased public transport usage is considered as an effective instrument for reducing vehicle volumes and thereby bringing down the congestion and resulting GHG emissions in urban areas.

This chapter reviews urban transportation systems in India, justifies the need for improving public transportation system in the context of climate change mitigation and reports recent initiatives taken up by the Governments for improvement of public transportation system in urban India. The chapter also highlights emerging issues and research needs related to improvement of public transportation system as a demand management instrument for reduction in traffic congestion and the resulting GHG emissions. Reduction in GHG emissions through other means such as improved vehicle technology, alternative fuel, etc. are not included within the scope of the present chapter.

The increase in urbanization, vehicle population and road travel in India are reported in Sect. 2, while a review of transportation systems and vehicular emissions in urban India is included in Sect. 3. As the focus of the chapter is on urban public transportation system, Sect. 4 includes the opportunities and obstacles associated with public transportation system in Indian cities. Several initiatives have been introduced by the Government of India and various State Governments for improvement of urban public transportation system. These initiatives are reported in Sect. 5, while Sect. 6 addresses the emerging issues and research needs. Finally, the conclusions of the chapter are highlighted in Sect. 7.

2 Urbanization, Vehicle Population and Road Travel in India

2.1 Urbanization

India is the seventh largest country in the world in terms of its geographical area (CIA 2012). In terms of population, India ranks second in the world (CIA 2012). The present population of India is about 1.21 billion and the share of rural population is 68.83 % (Census of India 2011). In the recent years, the country has achieved GDP growths in the range of 7–8 % indicating a distinct trend of economic development. The country is also experiencing rapid urbanization (Fig. 1). In the last decade (2001–2011), the growth of urban population was 31.16 % as compared to 17.9 % growth of rural population. The number of cities with population of more than one million has increased from 35 to 54 during 2001–2011 and with the present trend of urbanization, the number is expected to increase to 70 by the year 2025 (Census of India 2011). The share of urban population has also intensified from 28 to 31 % during 2001–2011 and likely to be 54 % by the year 2025 (Demographia 2012). The growth of population in Indian megacities is also significant. During the last decade, the capital city, Delhi recorded an average

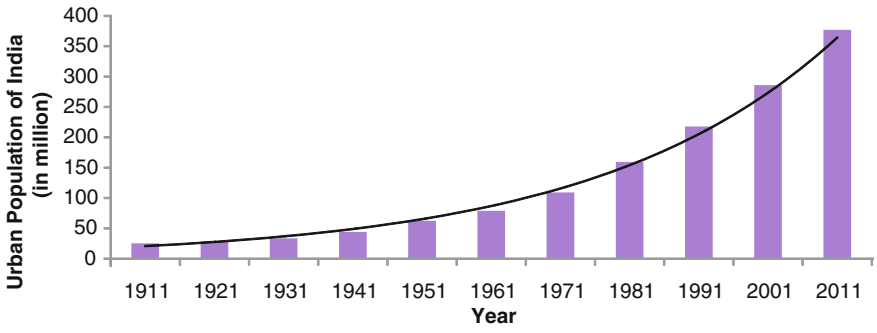

Fig. 1 Urban population of India (*Source* CIA 2012)

annual population growth of 4.52 %, followed by Bangalore, 3.38 % and Mumbai, 2.68 % (Census of India 2011). The population growth rates in other big cities are also momentous. Rapid urbanization caused significant increase of travel in urban areas and made urban transportation a major issue in Indian context.

2.2 Vehicle Population and Road Travel

Over the last few decades, India has experienced substantial growths of vehicle volumes and road travel. During 1980–2004, the share of road sector in the total passenger-km travel increased from 72.2 to 85.8 % and the vehicle population increased by 13.5 folds (Singh 2005). In 2001, the total number of registered vehicles was 55 million while the vehicle population increased to 115 million in 2009 (RTYB 2011). According to statistics provided by the Ministry of Road Transport and Highways (MoRTH), Government of India, the annual rate of growth of vehicle population in India was about 9.7 % during the last decade (2001–2011) (RTYB 2011).

The growths of different categories of vehicle during 1981–2011 are shown in Fig. 2. The category wise vehicle data for the year 2011 are projected from the available yearly vehicle data from 2001 to 2009. During 1981–2009, the number of motorized two-wheelers increased by more than 35 fold, while the number of cars increased by more than 15 fold (RTYB 2011). On the contrary, the population of buses increased only by about 9 fold (RTYB 2011). The percentage share of buses in the overall vehicle population in the recent years is shown in Fig. 3. It may be observed that the share of buses in the overall vehicle population remained only in the range of 1.1–1.4 % during 2001–2009 (RTYB 2011).

Overall, the country is experiencing growth of vehicle population but differential growths are recorded for different types of vehicle. The growths of private vehicles are significantly higher than that of buses. As a result, there is a significant shift in the modal share towards private vehicles.

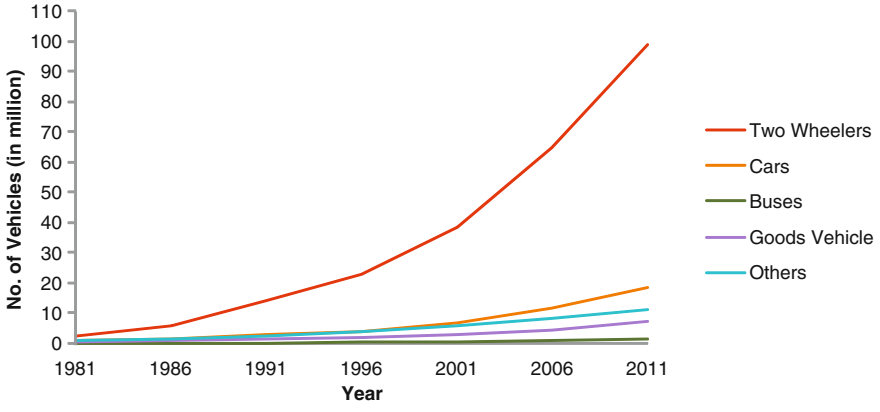

Fig. 2 Growth of different categories of vehicle (*Source* RTYB 2011)

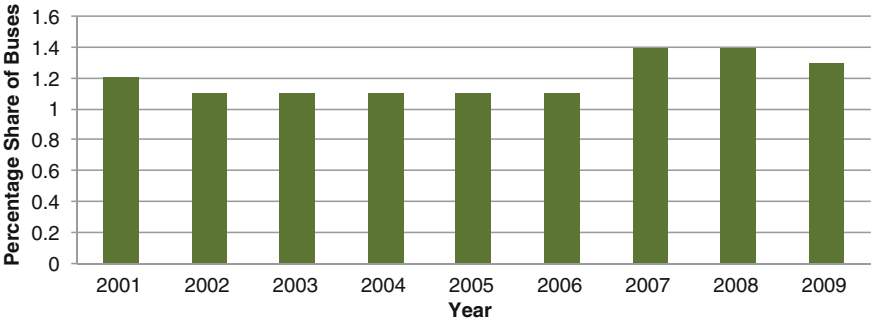

Fig. 3 Yearly statistics (2001–2009) of share of buses as percentage of total number of registered vehicles in India (*Source* RTYB 2011)

3 Transportation Systems and Vehicular Emissions in Urban India

The transportation system in urban India is primarily road based. A few exceptions include some of the metro cities such as Mumbai, Kolkata, Delhi and Chennai where substantial trips are made by the suburban rail or the city rail or even the metro services. However, in these cities the shares of road based trips are also significant.

Traffic streams in Indian cities are heterogeneous in nature, but the degree of heterogeneity varies across different cities. In the megacities, the shares of non-motorized traffic are negligible as compared to the shares of the motorized traffic, while in the medium and small sized cities the shares of non-motorized traffic are considerably higher. Lack of facilities such as pedestrian walkways, bicycle lanes, etc. are prime hurdles towards higher shares of non-motorized traffic in big cities.

The number of registered vehicles in selected metro cities is shown in Table 1. As of March 2009, the 22 metro cities accommodated about 27 % of the total registered vehicles in the country. Delhi, Bangalore, Chennai, Hyderabad and Ahmedabad recorded a registered vehicle population of more than 16.6 million which is about 54 % of the total registered vehicles in all metro cities (RTYB 2011). It may be mentioned that the vehicle population in Kolkata represents only the live vehicles after cancellation of vehicles registered prior to January 1993. Kolkata and other megacities started cancellation of registration of old vehicles every year following judicial interventions aiming to reduce the vehicular emissions. As a result, the growth of total registered vehicles in these cities may not truly reflect the volume of newly added registered vehicles. In reality, significant amount of new vehicles are being registered in all Indian metro cities and the total share of these metro cities in the overall newly registered vehicle population is significant.

The shares of different vehicle types in registered vehicle population for selected metro cities are given in Table 2. It may be observed that among various vehicle types, the share of private vehicles (i.e., motorized two-wheelers and cars)

Table 1 Total number of registered motor vehicles in selected metropolitan cities in India: 2001–2009 (as of March and number of vehicles in thousands) (*Source* RTYB 2011)

Metropolitan cities	Years								
	2001	2002	2003	2004	2005	2006	2007	2008	2009
Ahmedabad	846	899	978	1,075	1,632	1,780	1,451	1,586	1,691
Bengaluru	1,593	1,680	1,771	1,891	2,232	2,617	2,179	2,640	3,016
Chennai	1,257	1,356	1,895	2,015	2,167	2,338	2,518	2,701	2,919
Delhi	3,635	3,699	3,971	4,237	4,186	4,487	5,492	5,899	6,302
Hyderabad	951	1,241	1,319	1,356	1,433	1,522	2,181	2,444	2,682
Jaipur	644	693	753	824	923	1,051	1,177	1,289	1,387
Kolkata	664	801	842	875	911	948	987	573	581
Mumbai	1,030	1,069	1,124	1,199	1,295	1,394	1,503	1,605	1,674
Nagpur	416	459	503	543	770	824	884	946	1,009
Pune	620	658	697	755	827	874	930	1,141	1,153

is significantly higher than that of buses. The economic growth has made vehicle ownership increasingly affordable to middle and upper classes in urban India. The availability of low cost cars is expected to further aggravate the private vehicle volumes in urban India.

Presently, there is no restriction on the usage of private vehicles during different hours in a day or during different days in a week. Therefore, the category wise registered vehicle population is also reflected in the on-road traffic stream. The composition of traffic stream at three major intersections in Kolkata is shown in Fig. 4. It may be observed that the share of private vehicles (i.e. cars and two wheelers together) is in the range of 60–75 %, while the share of buses is only in the range of 4–7 %.

Most of the Indian cities and towns have not been developed following planning principles. The percentage of land allocated for roads in Kolkata, Delhi, Mumbai and Chennai are 5.45, 11.25, 9.5 and 11.13 % respectively (IIR 2009);

Table 2 Private and public transport vehicles in selected metropolitan cities in India in 2009 (as of March) (*Source* RTYB 2011)

Metropolitan cities	Two- wheelers	Cars	Taxi	Buses	Others
Ahmedabad	1,312,601	218,805	6553	17,407	135,680
Bangalore	1,946,767	579,977	111,448	18,176	359,851
Chennai	2,017,816	499,256	58,889	34,491	308,852
Delhi	3,846,721	1,802,251	50,351	41,142	561,702
Hyderabad	1,836,549	417,868	29,436	22,725	375,403
Jaipur	1,035,999	163,479	14,833	18,873	153,528
Kanpur	519,664	73,947	193	691	47,033
Kolkata	173,891	313,900	32,826	6,938	53,693
Mumbai	909,993	484,473	56,958	13,061	209,881
Nagpur	850,276	71,262	2,126	4,160	81,374
Pune	831,029	129,797	10,417	12,800	169,033

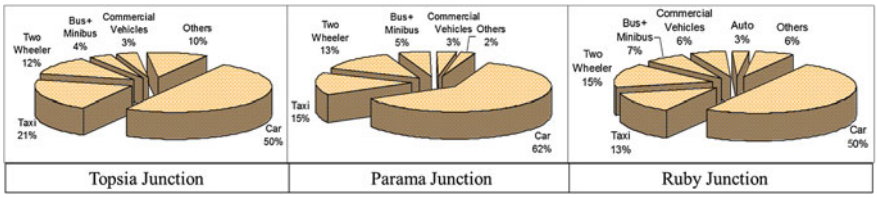

Fig. 4 Composition of traffic stream at selected intersections in Kolkata

while as per Urban Development Plans Formulation and Implementation (UDPFI) guidelines, the land allocation for the transportation should be 15–18 % for metro cities in plain area (ITPI 1996). In other cities also, the land allocated for roads is inadequate. Moreover, roadside activities and encroachment are also common in urban India, which put constraint on augmentation of transport supply. Therefore, with the growth of vehicle volumes, the imbalance between demand and supply of transport and the resulting traffic congestion level are increasing. High levels of traffic congestion have already started affecting the mobility and economic growth of various cities.

The high level of traffic congestion is reflected in the average journey speed of vehicles during the peak period. Average journey speed during peak period in Central Business District (CBD) area of several cities is as low as 10 km per hour or even less. The delay to traffic at signalized intersections has also increased significantly. Highway Capacity Manual 2010 defines six levels of service (LOS) (A to F, where A is the best and F is the worst) for signalized intersections on the basis of the average control delay per vehicle (TRB 2010). Table 3 shows control delay and LOS at different approaches of three major signalized intersections in Kolkata. The amount of control delay per vehicle or the poor level of service clearly reflects the severity of transportation problems in urban areas.

The growth of para-transit modes, especially three-wheelers (called as auto and tempo), is an important feature of urban transport in India. In most cities the bus system is either not fully developed or the quality of service is poor, which has encouraged the large-scale use of three wheelers in urban areas. Most of these three wheelers operate on fixed-routes and serve large number of passengers for

Table 3 Control delay and LOS at different intersections in Kolkata

Intersection	Approach	Control delay (Sec)	Level of service (LOS)
Ruby	Kalikapur	108.4	F
	Gariahat	83.6	F
	Parama	65.4	E
	Anandapur	44.5	D
Parama	Ruby	43.9	D
	Topsia	41.9	D
	Chingrighata	43.6	D
Topsia	Park Circus	35.5	D

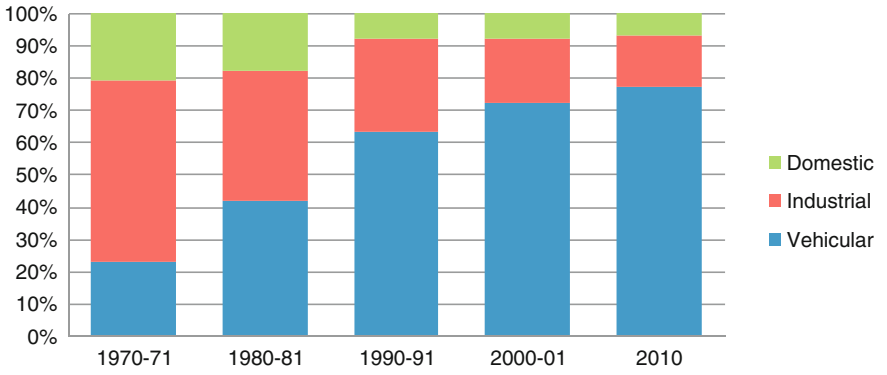

Fig. 5 Sources of air pollution in Delhi (*Source* Govt. of India 2002)

short trips. There is no comprehensive policy to restrict the operation of three wheelers only on selected routes primarily as feeder modes to bus or rail system. Therefore, these vehicles are presently operating indiscriminately in urban areas even as a competing mode to bus and aggravating congestion due to increase in vehicular volumes.

The traffic congestion has also intensified the vehicular emission levels in urban India and as a result the contribution of transport sector in air pollution has increased significantly. The contribution of different sectors in air population in Delhi is shown in Fig. 5. It may be observed that the share of transport sector has increased considerably over the last few decades. In 2002, the contribution of vehicular emission in overall air pollution in Delhi was 72 %. Also, the transportation sector contributed to 76.2 % of CO, 96.9 % of Hydrocarbons, and 48.6 % of NOx emissions in Delhi (Govt. of India 2002).

The pollution loads in different cities are shown in Fig. 6. The quantity of three major air pollutants (CO, HC and NOx) increases drastically with a reduction in vehicle speed (CPCB 2010). Thus, prevailing traffic congestion in Indian cities, particularly during peak periods, not only increases the delay but also increases the pollution levels.

The above discussions indicate that while increase in private vehicle ownership is probably a reflection of economic growth and therefore is desirable, the usage of private vehicles must be reduced, especially during the peak hours, in order to relieve congestion and reduce vehicular emissions in urban areas. In this context, it is necessary to influence the mode choice behavior of urban commuters so as to encourage them to use public transportation services in lieu of private vehicles, which will eventually reduce vehicular volumes and therefore, bring down traffic congestion as well as vehicular emission levels. Among different public transportation modes, city rail or metro rail is capital intensive and the services cannot provide as wide network coverage and door-to-door services as the bus transit. Therefore, bus will remain as an important public transport mode in urban India.

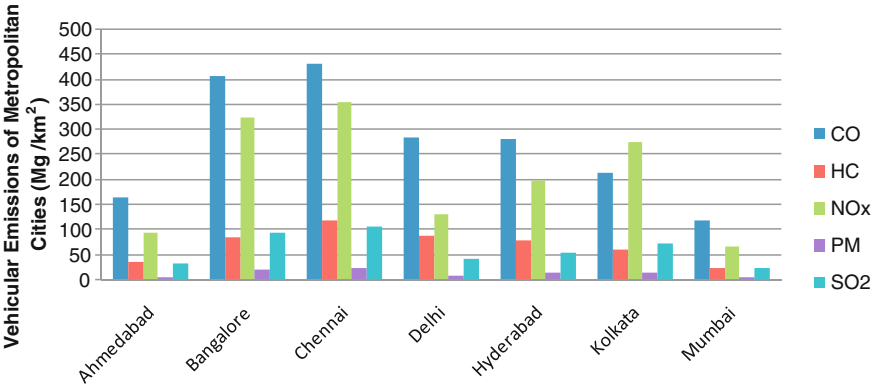

Fig. 6 Air pollution loads in selected major cities (*Source* CPCB 2010)

4 Urban Public Transportation System: Opportunities and Obstacles

It is necessary to improve public transport usage in urban India in order to bring down traffic congestion and resulting vehicular emissions which are affecting the climate change. A key issue is how to increase the public transport patronage in various cities in India. The opportunities and obstacles in this context are mentioned below.

4.1 Public Transport-Opportunities

Public transport users may be classified as captive riders and choice riders. Captive riders are those who do not own private vehicle and accordingly they are completely dependent on public transport for fulfilling their travel needs. Choice riders own private vehicles and therefore, may use public transport only by choice. Presently, public transport in urban India is used largely by captive riders. The growing numbers of private vehicle provide an opportunity to improve public transportation usage by shifting some of these choice riders to public transport. Of course, a higher shift of choice riders to public transport is possible only when the public transportation is improved as per the needs of choice riders.

4.2 Public Transport-Obstacles

There are several obstacles in the process of increasing public transport patronage in urban India.

(a) Overcrowding: In urban India, public transport is highly overcrowded during the peak hours. The discomfort associated with overcrowding of public transport makes it a less attractive alternative to commuters. In Kolkata, both captive and choice riders are found to consider congestion inside buses as a disutility. Interestingly, the Willingness-to-Pay (WTP) of choice riders for getting a seat in lieu of standing at crush load condition is found to be 1.7 times higher than that of captive riders (Maitra et al. 2012). A few other studies in Indian context (MMPG 1997; PhaniKumar and Maitra 2006, 2007) also indicated WTP of commuters for reduction of congestion and/or seat availability inside public transport vehicles.

(b) Poor Quality of Buses: Most of the buses operating in urban India are not attractive in terms of aesthetics and convenience. The noise level is high, the step heights are inconvenient and the appearance is poor. Probably, it is believed that soft factors such as quality of bus are not important in developing countries such as India. The research findings, of course, indicate that trip makers consider 'type of bus' as an important attribute in their choice decision. In Kolkata, the WTP values of captive and choice riders are found to be Indian Rupee (INR) 0.80 per km and INR 2.15 per km respectively for an improvement in the quality of bus (Maitra et al. 2012).

(c) Lack of Reliability and Public Transport Priority: Public transport services are often not reliable and there has been no attempt to improve the reliability of services. Although, no information is available regarding the importance of reliability in the context of bus service in India, but in-vehicle time is found to be an important factor in several studies (MMPG 1997; Phanikumar and Maitra 2006, 2007; Basu and Maitra 2010; Maitra et al. 2012). Practically no attempt has been made to implement bus priority measures in Indian cities for improving in-vehicle time of buses and improving the attractiveness of the bus service.

(d) Lack of Traffic Information: Real time traffic information for buses is not available in Indian cities. On-board travel information is also a missing component in the context of bus service in urban India. A recent study in Kolkata metro city indicates that the WTP of choice riders are INR 2.29 per km for availability of real time bus arrival information at bus stops and INR 1.07 per km for availability of on-board travel information (Maitra et al. 2012). The WTP values indicate that choice trip makers consider availability of traffic information as important factors in the context of bus travel.

(e) Low Fare Structure: Public transport fare is a socio-political issue. As a reasonable share of population even in urban area is from economically weaker section, it is justified to keep the fare as low as possible. But, low fare has been maintained in lieu of the poor levels of hard factors (such as in-vehicle time, waiting time, etc.) and soft factors (such as type of bus, comfort inside vehicle, traffic information availability, etc.) of public transport services. It appears that the low fare alone is unlikely to make the bus an attractive alternative to choice riders.

Adequate investigations have not been carried out to understand what attributes of public transport services need to be improved in order to make public transport an attractive alternative for choice riders. However, the available research works indicate the need for substantial improvement of soft factors and hard factors of public transport service. On the contrary, low fare is the necessity for commuters from economically weaker section. Also, most Governments are not in a position to increase the public transport subsidy which will be required to improve public transport as per the requirements of choice riders but continue the operation with a low fare structure. A clear segmentation of public transportation system appears to be the way out for urban India (Maitra et al. 2012) where two types of bus service (ordinary service and special service) may be operated to serve the needs for captive and choice riders. Ordinary service must have a low fare affordable even by socio-economically weaker section and primarily catering to the need for captive riders, while special service with a high fare but with accounting for both hard and soft factors targeting primarily choice riders.

5 Improving Urban Transportation in India: Recent Initiatives

In the recent years, several initiatives have been taken by the Government of India and various State Governments for improvement of public transportation system in urban India. Some of the major initiatives are mentioned below.

5.1 National Urban Transport Policy

The Government of India proclaimed a National Urban Transport Policy in 2006 (NUTP 2006) inspiring integrated land-use and transport planning in all cities to minimize travel distance and improve the access to livelihoods, education, and other social needs. The policy also emphasized the need for substantial allocation of road space with people, rather than vehicles as its main focus. The policy clearly heartened greater use of public transport and non-motorized modes by offering central financial assistance for such projects.

5.2 Jawaharlal Nehru National Urban Renewal Mission

The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was initiated in December 2005 by the Government of India as a programme to improve the quality of life and infrastructure in Indian cities (JNNURM 2011). The mission aimed to inspire reforms and fast track planned development in identified cities.

The JnNURM set an ambitious target to add close to 15,000 good quality buses in 61 major cities across the country. It intended to provide better public transportation and thereby, reduce traffic congestion and vehicular emissions in urban areas (JNNURM 2011).

5.3 Bus Rapid Transit System

Recognizing the significance of the bus transportation system, some of the Indian cities such as Ahmedabad, Delhi, and Bengaluru have opted for Bus Rapid Transit Systems (BRTS) as a high-quality customer oriented transit. Several other cities are also opting for BRTS in order to boost the share of public transport.

5.4 Other Initiatives for Bus Transport

United Nations Development Programme initiated a five-year demonstration program for operating and testing of fuel-cell buses (FCBs) in Delhi. The major objective was to introduce zero emission and highly efficient bus technology in India for reducing local air pollution and global GHG emissions (FCB Project 2010).

5.5 Metro Rail

Kolkata was the first city in India to have Metro rail in 1984. Subsequently, Delhi and Bengaluru also successfully started operation of metro rail. Various other cities such as Mumbai, Hyderabad, Kochi, and Chennai are also likely to have metro rail system in the near future.

5.6 Sky Bus

Sky Bus is the new rail based mass transit system which was launched in 2003 on an experimental basis for a stretch of 1.6 km in the open area along the railway track near Madgaon station in Goa. Various other cities in India are also considering the possibility of developing Sky Bus system.

5.7 Monorail

The nation's first 20 km long monorail is under construction in Mumbai. Once implemented successfully in Mumbai, it is likely to encourage the use of monorail in other cities in India.

6 Emerging Issues and Research Needs

India has comprehended the need for improving public transportation system in urban areas as an instrument for easing traffic congestion and bringing down vehicular emissions. The country has also initiated steps for improving Public Transportation (PT) Systems. This section presents some of the emerging issues and gaps which need to be addressed through research. The emerging issues and research needs are mentioned below.

6.1 Optimal Public Transportation System

Different types of public transportation system such as BRTS, Metrorail, Monorail, Sky bus, etc. are opted for different cities. There is no rational basis for selecting a particular type of public transportation system for a city. Also, it is unclear if the selected public transportation system is the optimal for the city. Presently, there are no guidelines for selection of optimal type of public transportation system for different cities in India with due considerations to city structure, land use, socio-economic characteristics and user behavior, physical constraints, available public transportation system, fixed cost and variable cost of alternatives public transportation systems, etc. It is necessary to develop guidelines for selection of optimal type of public transportation systems in different cities.

6.2 Travel Behavior and Travel Demand

Travel Demand Forecasting is a key step controlling the economic and financial viability of urban transportation projects. But, in majority of projects, travel demand forecasting is not carried out giving due considerations to the travel behavior of commuters. The quality of public transportation system is a major concern in urban India. It is necessary to identify hard and soft factors of public transportation services which are important to choice riders and include these factors in travel demand model. Also, the benefits likely to be derived from improvement of hard and soft factors should be duly considered in the economic analysis. It is, therefore, necessary to understand the valuation of various attributes

of public transport service. Finally, it is necessary to develop guidelines for uniform and rational estimation of travel demands in various public transportation projects in urban India.

6.3 Public Transport Priority

In terms of journey time, road based public transportation system (say, bus system) is generally less attractive than private vehicles. Several works also revealed the importance of journey time in the context of choice of mode or route in urban India. However, no attempts have been made to incorporate bus priority techniques in urban India to improve the journey time of buses and making bus travel an attractive option to car users. It is important to mention that roadway, traffic and control characteristics prevailing in urban India are much different from those in developed countries. For example, traffic in urban India is highly heterogeneous, lane discipline is absent, pedestrian volumes are often very high, road side activities and encroachments are common. The behavior of drivers and road users are also substantially different in India. Therefore, although bus priority techniques are well known and implemented in several developed countries, it is necessary to carry out research to understand suitability and effectiveness of well known bus priority techniques in urban India. Also, it is necessary to develop warrants or guidelines for application of different priority techniques in India.

6.4 ITS Application

On-broad travel information, real time bus arrival information, etc. are important factors of bus service which are likely to influence the mode choice behavior of choice riders. Application of ITS in several ways can be instrumental in improving the efficiency of bus service in urban areas. Unfortunately, ITS application is yet to take place in urban India for improving the efficiency and attractiveness of the bus system. It is necessary to identify the priority domains for the application of ITS in public transportation and develop a framework for implementation of ITS in public transport system.

6.5 Bus Characteristics and Service Attributes

The type of buses (including dimensions, seat capacity, seat orientation, step height, etc.) vary widely in urban India. Also, it appears that no rational basis is followed for the selection of the type of bus for different routes. The service characteristics, particularly the headways (i.e., time interval between two

successive buses on a particular route) also found to vary widely in different routes. It is necessary to develop a methodology for optimizing the benefits to commuters through appropriate selection of bus characteristics and service attributes giving due considerations to the operational viability. Eventually, guidelines should be developed for selection of the optimal type of bus and service characteristics based on route and demand characteristics.

6.6 Transfer Facilities

There are inherent deficiencies associated with transfer facilities around bus stops, rail stations and metro stations in urban India. Although the impact of these deficiencies on public transport ridership has not been investigated adequately in Indian context, but these deficiencies directly relate to safety and efficiency of transportation system. It may be mentioned that safety of pedestrians is a major issue in urban India and the role of transfer facilities is extremely pertinent in the context of pedestrian safety. It is necessary to identify hard and soft factors of transfer facilities, investigate their role on public transport ridership and prepare guidelines for development of transfer facilities around bus stops, rail stations and metro stations.

6.7 Feeder System

Appropriate feeder system is a basic necessity for the success of metro rail system. Appropriate feeder system is also important for bus system. In India, there are lacunas associated with planning of feeder system in urban areas. Often, feeder modes (particularly, three wheelers) act as a competing alternative to the mainstream public transportation system. The design of feeder system should account for the behavior of commuters. It is necessary to identify the optimal domain of operation of small feeder vehicles in urban areas considering user cost, operating cost, environmental cost, etc. Also, it is necessary to develop guidelines for design of routes, headway of service, etc.

7 Conclusion

The contribution of transportation sector in Green House Gas (GHG) emissions is significant and the increase in GHG emissions is considered as one of the major reasons for the global climate change. Therefore, the role of transportation sector becomes important in the context of climate change mitigation. In India, the contribution of urban transportation sector in overall vehicular emissions has increased significantly due to rapid urbanization, growth of vehicles, physical

constraints associated with road capacity augmentation and growing imbalance between the demand and the supply of transport. It is found that while the growth of private vehicles in urban India has been substantial, the share of buses has not changed significantly. Therefore, increased use of public transportation system is considered as an effective demand management instrument for bringing down vehicular volume, traffic congestion and vehicular emissions in urban India. The opportunities and obstacles associated with urban public transportation systems in India are identified. It is found that the existing public transportation systems generally do not cater to the requirements of choice riders. It is necessary to improve the soft factors associated with public transportation system in order to make public transportation system an attractive alternative for choice riders. The recent initiatives taken up by the Government of India and various State Governments for improvement of urban public transportation system are reported and gaps are identified to highlight the research needs for improvement of public transportation system in urban India in the context of climate change mitigation.

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