CO_2 EMISSIONS FROM PASSENGER TRANSPORT IN INDIA: 1950-51 TO 2020-21

Sanjay Kumar Singh
Associate Professor of Economics, Indian Institute of Management Lucknow, India (sanjay@iiml.ac.in)

Abstract
The main aim of this study is to forecast the level of traffic mobility and CO_2 (carbon dioxide) emissions from the land-based passenger transportation in India up to the year 2020-21. There are typically two ways to estimate future traffic mobility. The first approach is generally based on independent projections of traffic volume per mode of transport over time. Typically, each modal projection is built on a different method, and the total traffic volume becomes simply an aggregate of the independent estimates for the various modes. The second approach is based on projection of motorized mobility in a first step, and the related modal split is computed afterwards. The second approach is a better one for developing long-term scenarios since it takes into account the competition between modes. This paper follows the second approach to allow formulation of aggregate and long-term scenarios. This aggregate approach will be useful when we analyze the transport systems' impact on the environment. The forecasting model used in this paper is mainly built on two explanatory variables: Gross Domestic Product (GDP) and population. Annual data from 1950-51 to 2000-01 are used to estimate the future traffic volume in India. It is found that the motorized traffic volume in India will very nearly touch the mark of 13000 billion passenger-km in 2020-21, out of which 91.7% will be provided by the roads and the rest by railways. Based on the projected values of aggregate traffic volume and modal split, the paper estimates the level and growth of CO_2 emission from passenger transport sector in India. If there is no reduction in modal CO_2 intensities, CO_2 emission is projected to increase from 19.80 million metric tons of carbon equivalent in 2000-01 to 93.25 million metric tons of carbon equivalent in 2020-21. Even when we assume a reduction of 1% per year in CO_2 intensity of all modes of transport, CO_2 emission is projected to increase at the rate of 7% per year between 2000-01 and 2020-21.

Keywords: passenger transport, India, CO_2 emission

1. Introduction
Passenger mobility in India relies heavily on rail and road. Passenger travel by air and water is negligible in comparison to rail and road. On an average, an Indian traveled 285 Kms in a year during 1950-51, out of which 185 Kms was by rail and 100 Kms by road. In a span of five decades their annual travel figure jumped to 3470 Kms – 449 Kms by rail and 3021 Kms by road. From 1950-51 to 2000-01, passenger travel per capita (measured in terms of passenger-kilometers per capita; PKm/cap) by road and rail taken together increased at the rate of 5.13% per annum against the per capita Gross Domestic Product (GDP) growth of around 2.23% per annum. The growth of road-based passenger mobility (PKm) during the last 50 years has been around 9.17% per year against the corresponding compound annual growth rate of 3.93% by rail. Consequently, the road share in passenger mobility increased from 35% in 1950-51 to 87% in 2000-01.

Rapid increase in travel demand and increasing reliance on road transport has serious implications for environment. Already, transport sector is the major cause of air pollution in urban areas. It contributes significantly to major environmental challenges both at local as well as global levels. Designing and implementation of effective strategies to reduce transport sector's impact on environment require a reliable projection of motorized mobility for the forthcoming years. This paper lays the foundation for the same.

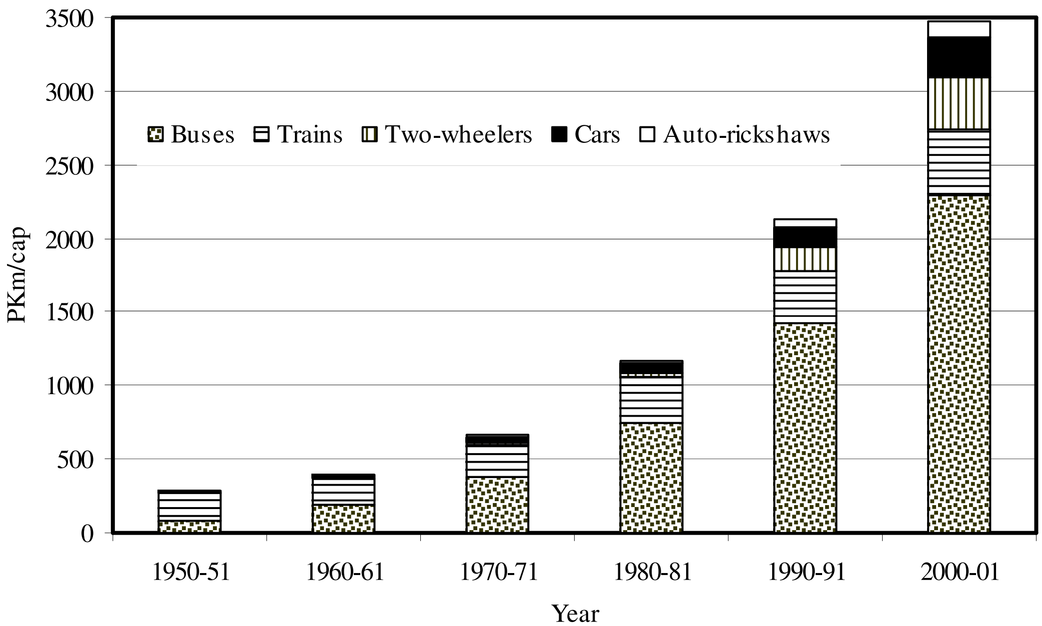
The paper is organized as follow. Section 2 presents the aggregate as well as mode-wise traffic volume data from 1950-51 to 2000-01. Section 3 deals with the model, model estimation, projection of per capita as well as absolute mobility, and estimation of modal split changes from 2000-01 to 2020-21. Section 4 describes the CO_2 emission scenarios. The paper's findings are summarized in Section 5.

2. Passenger mobility in India during the past five decades

Time series data of land-based traffic volume in terms of passenger-kilometer from 1950-51 to 2000-01 are estimated. The data sources and estimation methods are summarized in the Appendix. These data account for the five major modes of transport, namely cars (including jeeps and taxis), two-wheelers, auto-rickshaws, buses and railways.

Passenger traffic volume in India increased from 102 billion passenger-kilometers (BPKm) in 1950-51 to 3536 BPKm in 2000-01 due to a 12.18-fold increase in annual distance traveled by the people (from 285 Kms in 1950-51 to 3470 Kms in 2000-01), and a 2.84-fold rise in population (from 359 million in 1950-51 to 1019 million in 2000-01). Analysis of per capita mobility data shows that the average annual distance traveled by the people triples in every two decades (Figure 1). Although a large proportion of the mobility need is still catered to by the buses, there is increasing reliance on automobiles in recent years. For example, during 1990s per capita mobility by two-wheelers, auto-rickshaws and cars increased by 124%, 130% and 90% respectively, against the corresponding increase of 60% for buses and a meager 27% for railways. Thus, mobility share of private- and para-transit modes increased from 16.2% in 1990-91 to 21.2% in 2000-01, whereas share of both buses and railways declined during the same period (Figure 2).

Figure 1. Mode-wise motorized mobility per capita in India

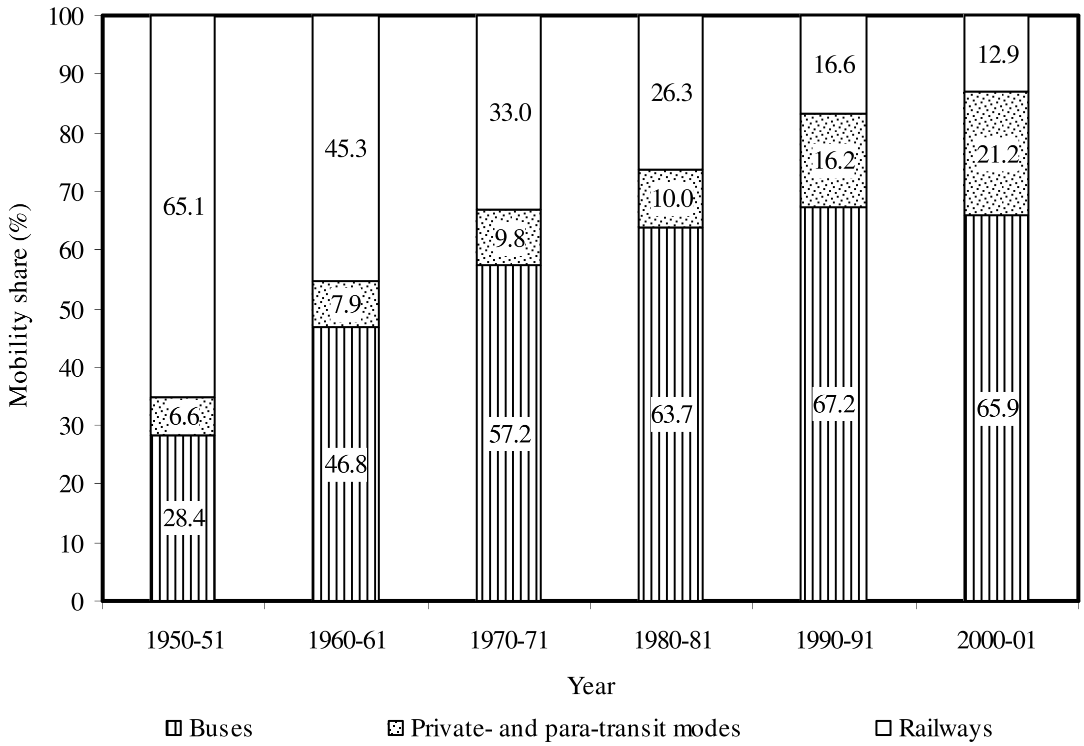


Although railways had played a dominant role in providing passenger mobility from the second half of the nineteenth century to the early 1950s, the rail-system has been continuously loosing its ground from the late 1950s. Between 1950-51 and 2000-01, rail-based passenger mobility increased at the rate of 3.93% per annum against the corresponding annual growth rate of 9.17% for roads. This was largely due to tremendous increase in the motor vehicle population in the last three decades or so. Currently, motor vehicle population in India is growing at a rate of around 10% per annum. In 1990-91 there were about 21 million vehicles in the country. After 10 years in 2000-01, this number increased by more than 2.5 fold to 55 million.

The vehicle population in India is growing faster in the category of two-wheelers and three-wheelers (auto-rickshaws). During 1950-51 to 2000-01, the two-wheeler and three-wheeler population grew at an average annual rate of 15.6% and 14.9% respectively. The growth in population of car was relatively modest. In the last five decades, car population increased at the rate of 7.9% per year. The corresponding figure for buses was 5.7%. If we compare the growth rate in recent years, say from 1995-96 to 2000-01, we find that both cars as well as two-wheelers were growing at the rate of around 10.5%

per year, and three-wheelers (auto-rickshaws) increased at the rate of 11.3% per annum. During the same period bus population increased only at the rate of 4.5% per annum, whereas total motor vehicle population increased at the rate of 10.2% per annum. As income of the people increases demand for personalized modes of transport is expected to increase more rapidly. The modal split indicates that in 1970-71, about 31% of the total vehicles were two-wheelers, which increased to 70% in a span of just three decades. As a result, the percentage share of buses in total motor vehicle population declined from 4.9% in 1970-71 to 1.0% in 2000-01.

Figure 2. Share of different modes in providing passenger mobility in India



3. Passenger mobility in India during the next two decades

3.1. The model

The demand for mobility depends on various socio-economic factors such as age distribution and household composition, employment, educational level, supply of public transport services, infrastructure availability, government policy towards automobiles and transport, prices of different transport services, fuel and vehicle prices, income of the people, etc. At the national level, the relationship between per capita mobility and factors influencing the same can be written as:

$$\frac{PKm}{cap} = f(X) \qquad \textbf{(1)}$$

where $\frac{PKm}{cap}$ is passenger-kilometers per capita (representing per capita mobility) and X is a vector of variables determining the level of per capita mobility.

Using equation **(1)**, it is possible to estimate the future level of mobility if data for each of the variables on the right hand side are available. However, time series data for many of these variables are not readily available for India. In this situation, it is important to find out the key determinants of mobility for which time series data are available. Schafer (1998), Dargay and Gately (1999), Schafer and Victor (2000), Preston (2001) and many others have shown that there is a close relationship between income and demand for mobility. The strong relationship between income and mobility is found for both cross-

country as well as time-series data. Figure 3, which presents the relationship between per capita mobility and per capita GDP for India, reiterates the same. Therefore, in this paper, per capita GDP is used as the main explanatory variable to project future passenger mobility in India. Assuming that time captures the effects of the omitted variables, equation **(1)** can now be approximated by

$$\frac{PKm}{cap} = f\left(\frac{GDP}{cap}, time\right) \tag{2}$$

In a practical forecasting problem, the statistical nature of the data-generating process is unknown and the forecaster's task is to select a model that best approximates the 'real life' data generating process. For a time series like the per capita passenger mobility, it is conceivable that the series converges to a maximum as income reaches a certain level. If we plot level of passenger mobility per capita against GDP per capita, the graph is expected to look like some sort of a *S*-shaped curve. Passenger mobility is expected to increase slowly at the lowest income levels, and then more rapidly as income rises, finally slow down as saturation is approached. There are a number of different functional forms that can describe such a process; for example, the logistic, Gompertz, logarithmic logistic, log reciprocal and cumulative normal functions (Dargay and Gately, 1999). An overview of such functional forms is given in Meade and Islam (1998); see also Meade and Islam (1995), Bewley and Fiebig (1988), Franses (2002), and Mohamed and Bodger (2005). Application of such functional forms to project the traffic mobility in India can be seen from Ramanathan (1998), Ramanathan and Parikh (1999), and Singh (2000). These studies in the Indian context have used time as the only explanatory variable to project the future mobility in India. Among various functional forms, the logistic and Gompertz functions are the two most widely used ones to describe a process represented by a *S*-shaped curve. This paper also uses these two functions to model and forecast passenger mobility in India.

The logistic model can be written as

$$\left(\frac{PKm}{cap}\right)_t = \frac{\alpha}{1+\gamma\exp(-\beta(\frac{GDP}{cap})_t - \lambda(time)_t)} + \varepsilon_t \tag{3}$$

where α is the saturation level and ε_t is an error term at period t. All the parameters α, β, γ and λ are positive.

Similarly, the Gompertz model can be written as

$$\left(\frac{PKm}{cap}\right)_t = \alpha\exp(-\gamma\exp(-\beta(\frac{GDP}{cap})_t - \lambda(time)_t)) + \varepsilon_t \tag{4}$$

where α is the saturation level and ε_t is an error term at period t. All the parameters α, β, γ and λ are positive. Parameters γ, β and λ define the shape or curvature of the function.

Models **(3)** and **(4)** need to be transformed into a linear form in order to estimate them using Ordinary Least Squares (OLS) method. The logistic model **(3)** can be transformed in a linear form as follows

$$\ln\left(\frac{\alpha}{(\frac{PKm}{cap})_t} - 1\right) = \beta_0 + \beta_1(\frac{GDP}{cap})_t + \beta_2(time)_t + \varepsilon_t \tag{5}$$

where α is the saturation level and ε_t is an error term at period t. Parameter β_0 is positive and both β_1 and β_2 are negative.

Similarly, the Gompertz model **(4)** can be transformed as

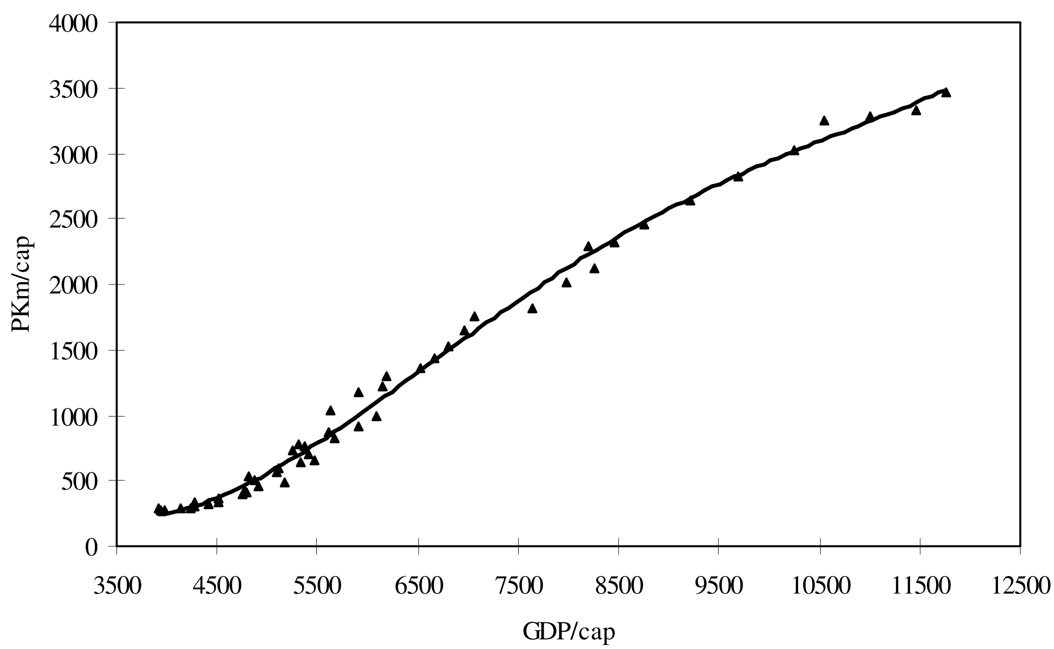
$$\ln\left[\ln\left(\frac{\alpha}{(\frac{PKm}{cap})_t}\right)\right] = \beta_0 + \beta_1(\frac{GDP}{cap})_t + \beta_2(time)_t + \varepsilon_t \tag{6}$$

where α is the saturation level and ε_t is an error term at period t. Parameter β_0 is positive and both β_1 and β_2 are negative.

Models **(5)** and **(6)** can be estimated by OLS provided we know the saturation level α. Although it is possible to estimate the saturation level, there is no guarantee that the final estimate of the saturation level, α, is close to the global optimum (Heij C. et al., 2004). Therefore, to estimate the models, it is

essential to get a reliable estimate of the saturation level of per capita mobility. It's possible to get a reliable estimate of the saturation level by making a reasonable assumption about the time spent on travel per person per day (i.e., travel time budget) and average speed of vehicles. For example, if all demands are met at an average speed of 30 km/hour and the travel time budget is fixed at 1.1 hour/capita/day, the total annual distance travel would be around 12000 km/capita. Schafer (1998) shows that the time spent on travel per person per day are virtually unchanged with respect to per capita income across the countries. Although the reason for travel time budget stability is not very clear, Marchetti (1994) argued that a travel time budget of around one hour per capita per day reflects a basic human instinct. He argued that perhaps security of the home and family, the most durable unit of human organization, limits exposure to the risk of travel. Also, traveling is naturally limited by other activities such as sleep, leisure, and work. Even when time spent on any of these activities changes, there is evidence that the travel time budget remains constant (Marchetti, 1994). Time-use and travel surveys from numerous cities and countries throughout the world suggest that travel time budget is approximately 1.1 hour per person per day (Schafer and Victor, 2000). So, if we assume that all demands are met at a maximum possible (average) speed of 30 km/hour, mobility per capita of 12000 will be the saturation level. Considering the socio-economic characteristics of India (such as population density, rapid increase in telephone density, expected boom in information technology, greater reliance on public transport, high fuel prices, etc.) and the level as well as growth in per capita mobility in the developed world, 12000 PKm per capita appears to be the appropriate saturation level for India.

Figure 3. Motorized mobility (car, two-wheeler, auto-rickshaw, bus, and rail) per capita vs GDP per capita in India between 1950-51 and 2000-01



3.2. Model estimation

The logistic model **(5)** and the Gompertz model **(6)** are estimated using the econometric software LIMDEP Version 8.0. Both the models have been estimated for three different saturation levels: 12000, 16000 and 20000 PKm/capita. Annual data of passenger mobility per capita (PKm/capita) and GDP/capita (Rs. in thousand at 1993-94 prices) from 1950-51 to 2000-01 are used for the estimation of the models. The variable *time* takes the following values: 1 for 1950-51, 2 for 1951-52, 3 for 1952-53,……, and so on.

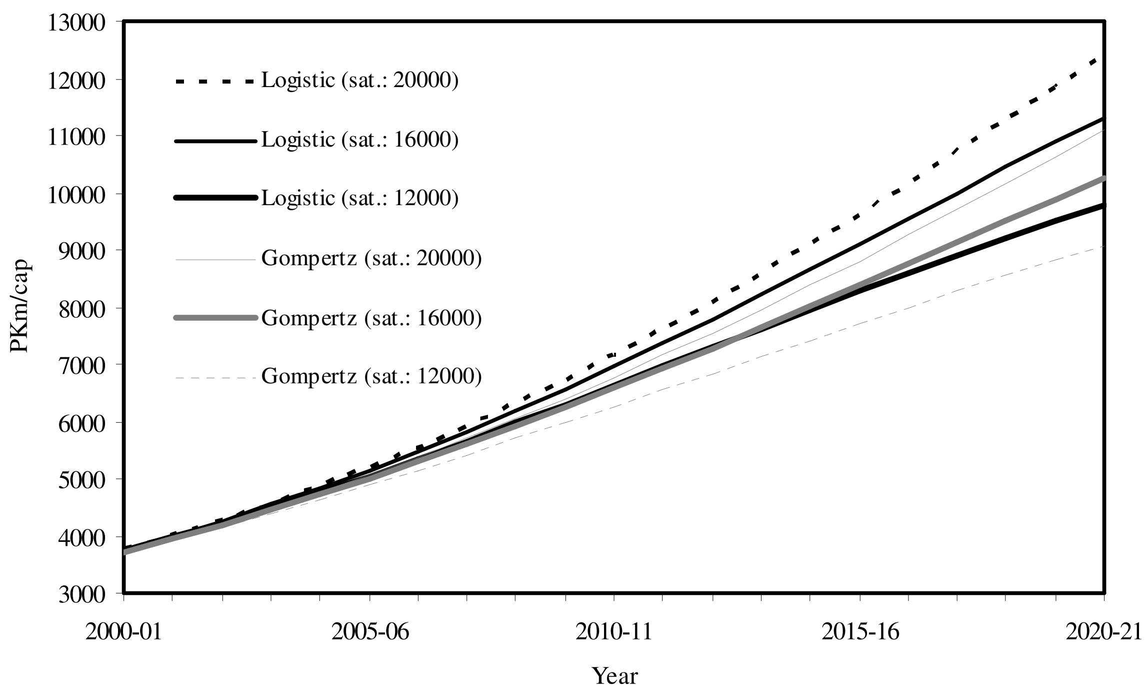
Table 1 reports the estimation results. According to the R^2 values, the models fit the data very well. We also compare the predicted values with the actual values of PKm/capita over the sample period and found the same. The Mean Absolute Percentage Error (MAPE) presented in Table 1, is in the range

of 3.86 to 3.93 for the logistic models and 5.77 to 6.08 for the Gompertz models. All the estimated parameters have the expected signs and most are highly significant. To project the future per capita mobility up to the year 2020-21, we have to make reasonable assumptions about the per capita GDP growth rate. Between 1993-94 and 2003-04, per capita GDP in India increased at the rate of around 4.3% per annum. Assuming that GDP/capita will increase at the same rate up to 2020-21, passenger mobility per capita has been projected for the future (Figure 4). Since according to MAPE the logistic model is a better model than the Gompertz, and as discussed in the Section 3.1, saturation level is expected to be around 12000 PKm per capita, the next stage of the discussion will be based on the estimated logistic model with saturation level at 12000 PKm per capita.

Table 1. Parameter estimates of the logistic and Gompertz models (with t-statistic in parentheses)

Model	Estimate
Saturation level, α = 12000	
Logistic **(5)**	β_0 = 4.29110 (127.9), β_1 = -0.08260 (8.2), β_2 = -0.04948 (34.3); R^2 = 0.996; MAPE = 3.93
Gompertz **(6)**	β_0 = 1.71227 (101.1), β_1 = -0.07661 (15.0), β_2 = -0.01263 (17.3); R^2 = 0.993; MAPE = 6.08
Saturation level, α = 16000	
Logistic **(5)**	β_0 = 4.52723 (140.0), β_1 = -0.06914 (7.1), β_2 = -0.04962 (35.7); R^2 = 0.996; MAPE = 3.89
Gompertz **(6)**	β_0 = 1.71740 (115.9), β_1 = -0.06131 (13.7), β_2 = -0.01207 (18.9); R^2 = 0.993; MAPE = 5.90
Saturation level, α = 20000	
Logistic **(5)**	β_0 = 4.72272 (149.4), β_1 = -0.06189 (6.5), β_2 = -0.04966 (36.5); R^2 = 0.996; MAPE = 3.86
Gompertz **(6)**	β_0 = 1.73150 (128.4), β_1 = -0.05268 (13.0), β_2 = -0.01160 (20.0); R^2 = 0.993; MAPE = 5.77

Figure 4. Assumptions and projections of land-based per capita mobility in India



3.3. Projection of per capita as well as absolute mobility up to 2020-21

On the basis of the estimated logistic model for 12000 PKm per capita saturation level and assumptions concerning population and GDP, projections of per capita as well as absolute mobility up to 2020-21 are obtained. As stated in the previous section, per capita GDP is assumed to grow at the rate of 4.3% per annum up to 2020-21. Based on *World Population Prospects: The 2004 Revision Population Database* published by the United Nations Population Division, population of India is assumed to grow at the rate of 1.56% per annum from 2000-01 to 2005-06, 1.41% per annum from 2005-06 to 2010-11, 1.27% per annum from 2010-11 to 2015-16, and 1.11% per annum from 2015-16 to 2020-21.

Figure 5 presents the future mobility trends up to 2020-21. It shows that in 2020-21, average Indians will travel about thrice as many kilometers as they traveled in 2000-01. Absolute passenger mobility in India at the end of 2020-21 will virtually touch the mark of 13000 billion PKm. On an average, per capita mobility and absolute traffic volume in India are expected to increase at the rate of 5.31% and 6.72% per annum respectively in the next two decades. However, growth in both mobility per capita and absolute traffic volume are expected to be higher during 2000-11 than 2010-21 (Table 2).

Figure 5. Future mobility trends in India

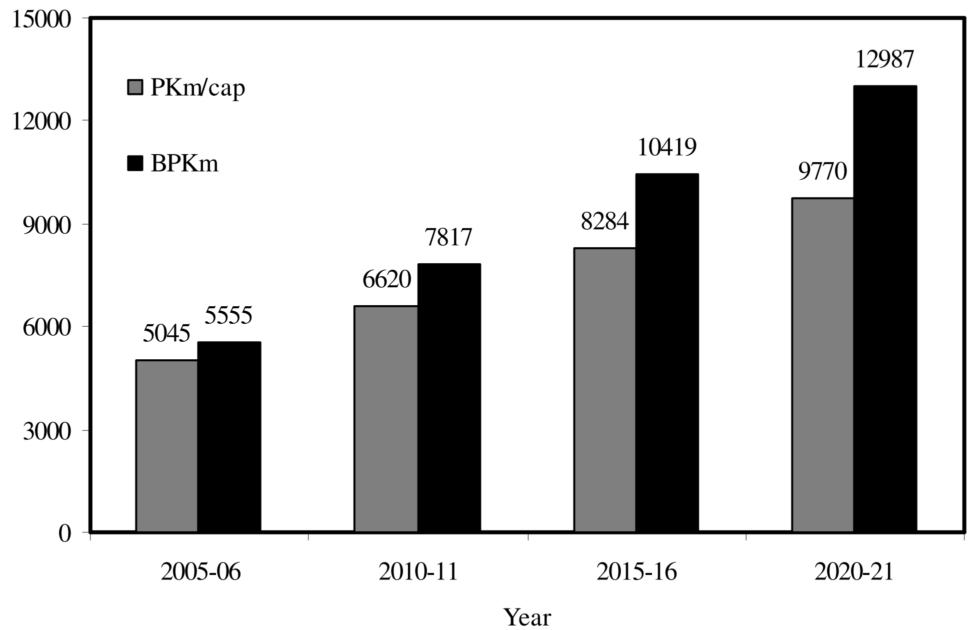


Table 2. Level as well as growth of land-based passenger mobility in India from 1950-51 to 2020-21

	Per capita mobility (PKm/cap)	CAGR in per capita mobility (since the previous period)	Absolute mobility (BPKm)	CAGR in absolute mobility (since the previous period)
1950-51	285	-	102	-
1960-61	395	3.3%	171	5.3%
1970-71	661	5.3%	358	7.6%
1980-81	1169	5.9%	794	8.3%
1990-91	2125	6.2%	1783	8.4%
2000-01	3470	5.0%	3536	7.1%
2010-11	6620	6.7%	7817	8.3%
2020-21	9770	4.0%	12987	5.2%

3.4. Modal split changes

As shown in Figure 3, increase in per capita GDP results in rise in per capita motorized mobility. Assuming that an average person spends some fixed time (approximately 1.1 hour per day) on travel, mean travel speed has to increase with the increase in per capita mobility. Because different transport modes operate with different ranges of speed, increase in mobility changes the modal split towards flexible and faster transport modes. Thus, as per capita mobility and per capita GDP increase, traffic share of public transport modes such as buses and trains decrease and share of private- and para-transit modes increase. Figure 6 shows the relationship between mobility and share of low speed public transport. The share of public transport modes went down from 93.4% in 1950-51 to 78.8% in 2000-01 in a linear fashion as per capita mobility increased from 285 Km in 1950-51 to 3470 Km in 2000-01. Similar relationship is found between share of public transport modes and per capita GDP (Figure 7). Both provide somewhat identical future values for the share of public transport modes up to 2020-21.

It is estimated that the share of low speed public transport (buses and trains) in India will be around 52% during 2020-21 (Figure 8). Since the share of buses and trains in the public transport modes are virtually unchanged from 1993-94 onwards at around 84% and 16% respectively, we assume that the same pattern will be followed up to the year 2020-21. Based on this assumption, the share of buses and trains in meeting the passenger travel demand in future has been projected. It is estimated that 43.6% of traffic mobility in India in 2020-21 will be provided by the buses and 8.3% by the trains (Figure 8).

Similarly, we projected the share of high speed private- and para-transit modes (cars, two-wheelers, and auto-rickshaws) up to 2020-21. Figure 9 presents the same along with the share of individual modes. It is estimated that the combined share of these modes in India would be around 48% during the year 2020-21. Since, in this case also, the share of cars, two-wheelers, and auto-rickshaws within the private- and para-transit modes are virtually unchanged from 1993-94 onwards at 37%, 49%, and 14% respectively, we assume that the same pattern will be followed till 2020-21. Based on this assumption, the share of individual high speed modes in meeting the passenger travel demand in future has been projected (Figure 9). It is estimated that, during the year 2020-21, 17.8% of the land-based traffic mobility in India will be provided by the cars, 23.6% by the two-wheelers, and 6.7% by the auto-rickshaws.

Figure 6. Traffic share of public transport modes (buses and trains) at different level of per capita mobility between 1950-51 and 2000-01

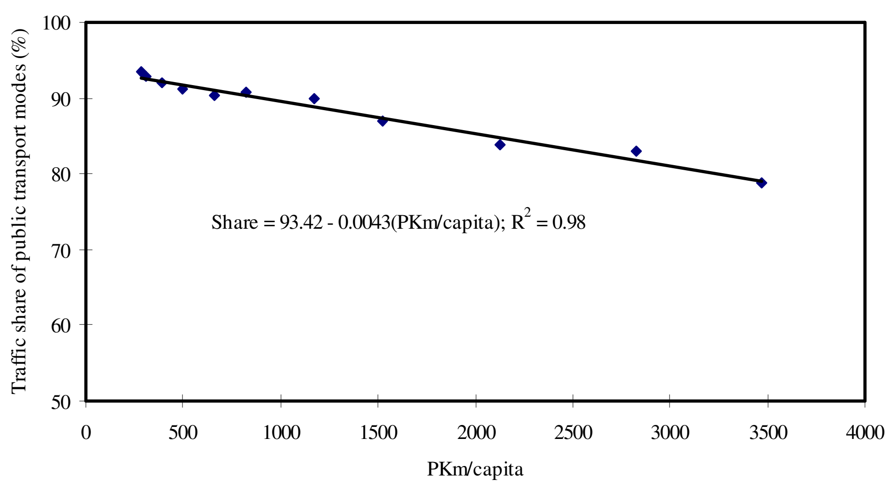


Figure 7. Traffic share of public transport modes (buses and trains) at different level of income between 1950-51 and 2000-01

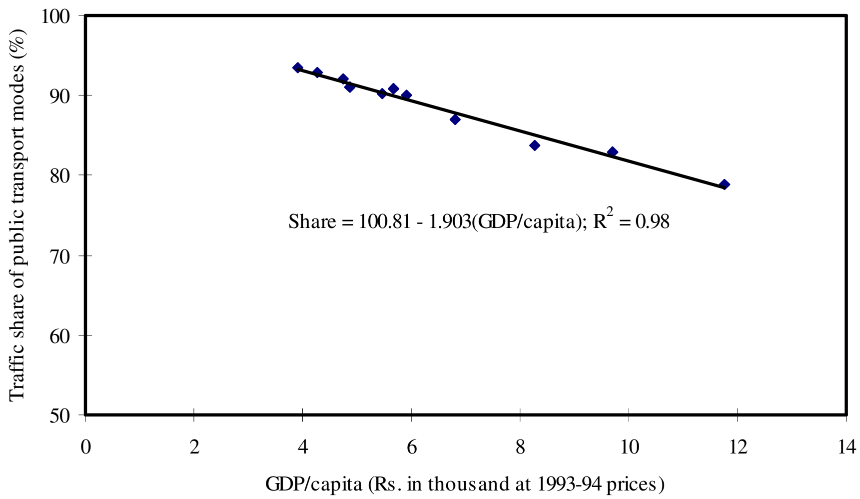


Figure 8. Share of public transport modes (buses and trains) during the next two decades

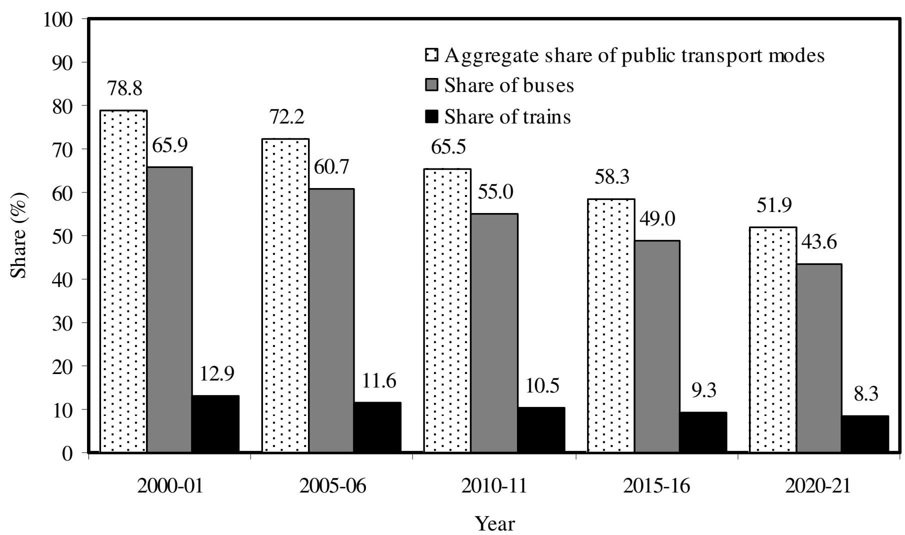
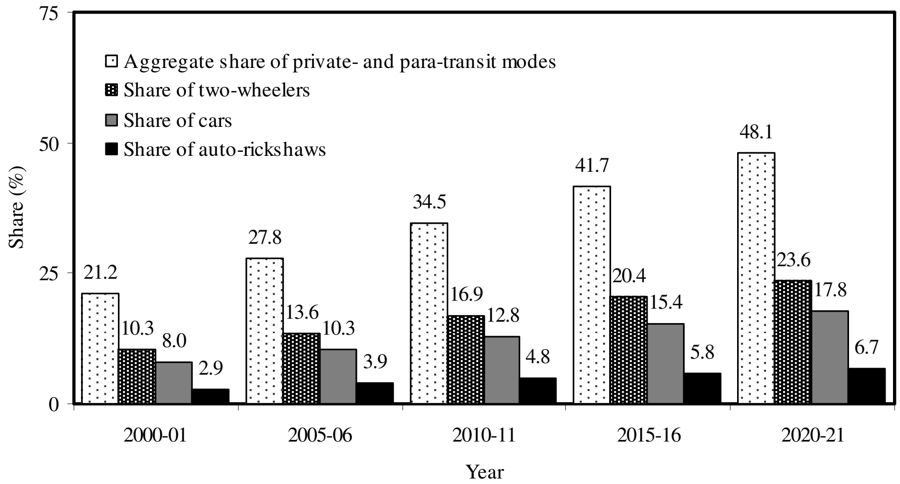


Figure 9. Share of private- and para-transit modes (cars, two-wheelers, and auto-rickshaws) during the next two decades



4. CO_2 emission from passenger transport sector

The problem of climatic change is one of the most serious consequences of the emission of large quantities of CO_2 and other greenhouse gases into the atmosphere. Transport in general and road transport in particular constitutes a major share in the CO_2 emissions. Vehicles using fossil fuels (diesel and gasoline) produce CO_2 emissions in quantities that depend on the carbon present in the fuel molecule. Globally, the transport sector now contributes 25% of all the CO_2 emissions released into the atmosphere. Approximately 80% of those emissions are from road transport. Although, currently, India is one of the lowest per capita emitters of CO_2, at 0.27 metric tons of carbon equivalent, energy sector's carbon intensity is high, and the country's total CO_2 emissions rank among the world's highest. In 2002, CO_2 emission in India was around 280 million metric tons of carbon equivalent which was around 4% of the world total (International Energy Annual 2002). Between 1980 and 2002, India's carbon emission increased at an astonishing rate of 5.7% per annum against the world average of 1.26%.

The aim of this section is to estimate the present as well as future CO_2 emission from the passenger transport sector in India. For this, we have to estimate the CO_2 emission intensities for all the major modes. Table 6 and 7 summarizes the estimated 2000-01 CO_2 intensities and their projected values for 2020-21 along with the level of CO_2 emission from the sector (2000-01 CO_2 intensities by mode have been estimated on the basis of the data provided by Ramanathan and Parikh (1999)). Here, two scenarios, business as usual and efficiency gain, are discussed.

4.1. Business as usual (BAU) scenario

In the BAU scenario, the 2020-21 CO_2 intensities of all ground transport modes except rail are assumed to remain at 2000-01 levels. The rail CO_2 intensity is different because we assume that the electrified routes will cater to the need of 80% of the rail passenger traffic in 2020-21 rather than the current level of 40%. In the BAU scenario, CO_2 emission is projected to increase from 19.80 to 93.25 million metric tons of carbon equivalent in a span of 20 years between 2000-01 and 2020-21 (Table 6). Figure 10 presents the per capita CO_2 emission from passenger transportation during the year 2000-01 and 2020-21. In the BAU scenario, CO_2 emission per person is projected to increase at the rate of 6.63% per year from 19.43 kilograms of carbon equivalent in 2000-01 to 70.17 kilograms of carbon equivalent in 2020-21.

4.2. Efficiency gain scenario

In the efficiency gain scenario, the CO_2 intensities of all modes decline at the rate of 1% per year up to 2020-21 by assuming that this may happen due to the technological change (fuel efficiency improvements and transportation fuels with lower carbon content), improvement in transportation system management and/or some combination of these two. Emphasis on efficiency improvements is expected to reduce the

CO_2 emission significantly. In this scenario, the CO_2 emission in 2020-21 is estimated to be 76.36 million metric tons of carbon equivalent, around 18% less than the emission in the BAU scenario (Table 7). Similarly, per capita CO_2 emission in 2020-21 in this scenario is projected to be 57.41 kilograms of carbon equivalent rather than 70.17 (Figure 10). One should note that even if there is a reduction in CO_2 intensity of all modes by 1% per year, the level of CO_2 emission from passenger transportation in India will increase at the rate of around 7% per year from 2000-01 to 2020-21.

Figure 10. Per capita CO_2 emission from different modes of transport (kilograms of carbon equivalent)

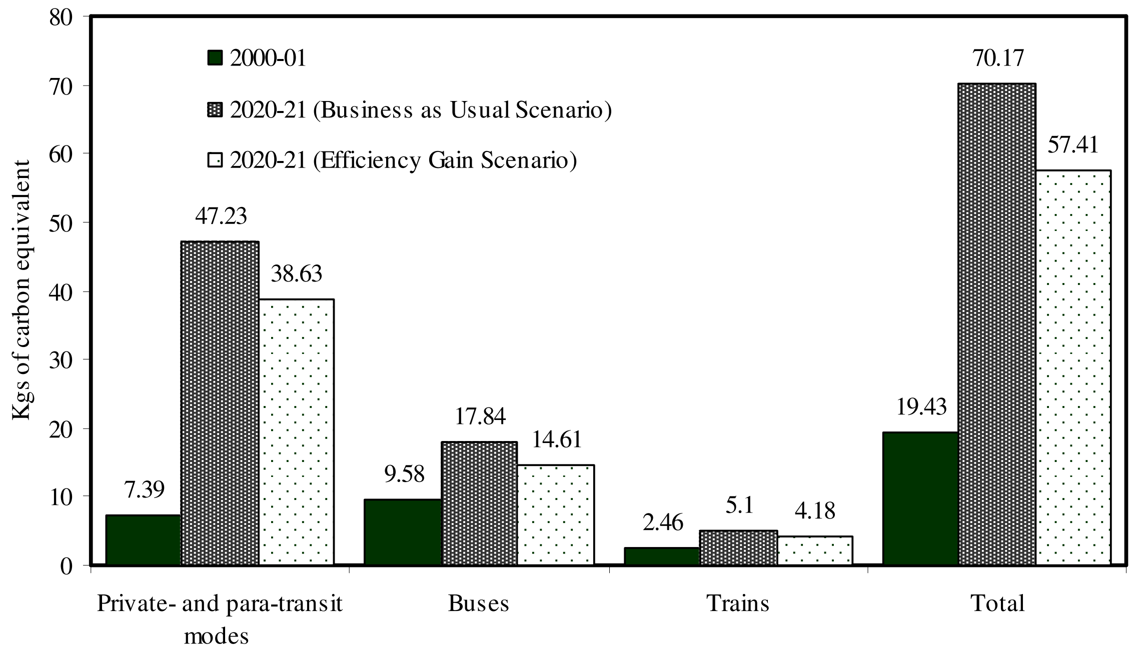


Table 6. Intensities and the level of CO_2 emission from different modes of transport; business as usual scenario

Mode of transport	2000-01			2020-21 (Business as Usual Scenario)		
	BPKm	CO_2 intensity (grams of carbon equivalent per PKm)	CO_2 emission (million metric tons of carbon equivalent)	BPKm	CO_2 intensity (grams of carbon equivalent per PKm)	CO_2 emission (million metric tons of carbon equivalent)
Private and para-transit modes (car, two-wheeler, and auto-rickshaw)	749	10.05	7.53	6247	10.05	62.78
Bus	2330	4.19	9.76	5662	4.19	23.72
Rail	457	5.50	2.51	1078	6.29	6.78
Total	3536	5.60	19.80	12987	7.18	93.25

Table 7. Intensities and the level of CO_2 emission from different modes of transport; efficiency gain scenario

Mode of transport	2000-01			2020-21 (Efficiency Gain Scenario)		
	BPKm	CO_2 intensity (grams of carbon equivalent per PKm)	CO_2 emission (million metric tons of carbon equivalent)	BPKm	CO_2 intensity (grams of carbon equivalent per PKm)	CO_2 emission (million metric tons of carbon equivalent)
Private and para-transit modes (car, two-wheeler, and auto-rickshaw)	749	10.05	7.53	6247	8.22	51.35
Bus	2330	4.19	9.76	5662	3.43	19.42
Rail	457	5.50	2.51	1078	5.15	5.55
Total	3536	5.60	19.80	12987	5.88	76.36

5. Concluding remarks

In this study, we projected the level of traffic mobility and CO_2 emission from land-based passenger transportation in India up to 2020-21. The level of land-based passenger traffic in India increased at the rate of 7.75% per year during last two decades from 794 BPKm in 1980-81 to 3536 BPKm in 2000-01 and is expected to increase at the rate of 6.72% per year during the next two decades. Land-based traffic volume in 2020-21 is projected to be nearly 13000 BPKm, out of which, 91.7% will be provided by road and the rest by rail. Analysis of modal split reveals that the share of public transport modes (buses and trains) in providing passenger mobility in India will decline from 78.8% in 2000-01 to 51.9% in 2020-21, whereas share of private- and para-transit modes will increase from 21.2% to 48.1% during the same period. The expected rapid increase in mobility and greater reliance on private- and para-transit modes will have huge implications for CO_2 emissions from passenger transportation in India.

In the business as usual scenario (i.e., assuming that the CO_2 intensity of all modes remains unchanged), CO_2 emission is projected to increase from 19.80 to 93.25 million metric tons of carbon equivalent in a span of two decades between 2000-01 and 2020-21. In the efficiency gain scenario (i.e., assuming that the CO_2 intensity of all modes declines at the rate of 1% per year), the CO_2 emission in 2020-21 is projected to be 76.36 million metric tons of carbon equivalent. One should note that even in efficiency gain scenario, the level of CO_2 emission from passenger transportation in India is expected to increase at the rate of around 7% per year during the next two decades.

Apart from CO_2, substantial amount of local pollutants like carbon monoxide (CO), unburnt hydrocarbons (HC), nitrogen oxides (NO_x), sulphur dioxide (SO_2), lead (Pb), and suspended particulate matters (SPM) are also emitted by the passenger transport sector. The air pollution problem due to vehicular emission in most of the metropolitan cities in India is taking serious dimension and worsening people's quality of life (Singh, 2005). Pollutants from vehicular emission have various adverse health effects. One of the main pollutants SPM, particularly fine PM, has serious health effects, especially in the form of respiratory diseases. The ambient air pollution in terms of SPM in all metropolitan cities in India exceeds the limit set by World Health Organization (WHO).

India faces significant challenges in balancing its increased demand for mobility with the need to protect its environment from further damage. Population growth and urbanization make the task all the more difficult. Rapid increase in vehicle ownership will aggravate the already existing air pollution problem and urbanization will increase the health risks from that pollution. In the absence of coordinated government efforts, including stricter enforcement, air pollution is likely to continue to worsen in the coming years. India's ability to safeguard its environment will depend on its success in promoting policies that keep the economy growing while fulfilling the energy demand in a sustainable manner.

Note:- Another version of this paper titled as "Future mobility in India: Implications for energy demand and CO_2 emission" has been published in the Transport Policy (2006; Vol. 13, Issue 5; pp. 398-412).

References

(1) Bewley, R., and Fiebig, D. (1988), ‘Flexible logistic growth model with applications in telecommunications’, International Journal of Forecasting, 4(2), 177-192.

(2) CMIE database on Energy and Infrastructure (various issues), Centre for Monitoring Indian Economy (CMIE) Pvt. Ltd., Mumbai, India.

(3) Dargay, J., and Gately, D. (1999), ‘Income’s effect on car and vehicle ownership, worldwide: 1960-2015’, Transportation Research Part A, 33(2), 101-138.

(4) Franses, P.H. (2002), ‘Testing for residual autocorrelation in growth curve models’, Technological Forecasting and Social Change, 69(2), 195-204.

(5) Heij C. et al. (2004), “Econometric Methods with Applications in Business and Economics”, Oxford University Press, New York; pp 209.

(6) International Energy Annual 2002, Energy Information Administration, Washington DC, USA. Available on http://www.eia.doe.gov/emeu/iea/carbon.html.

(7) Marchetti, C. (1994), ‘Anthropological invariants in travel behavior’, Technological Forecasting and Social Change, 47(1), 75-88.

(8) Meade, N., and Islam, T. (1998), ‘Technological Forecasting – Model Selection, Model Stability, and Combining Models’, Management Science, 44(8), 1115-1130.

(9) Meade, N., and Islam, T. (1995), ‘Forecasting with growth curves: An empirical comparison’, International Journal of Forecasting, 11(2), 199-215.

(10) Mohamed, Z., and Bodger, P. (2005), ‘A comparison of Logistic and Harvey models for electricity consumption in New Zealand’, Technological Forecasting and Social Change, Forthcoming issue.

(11) National Accounts Statistics of India: 1950-51 to 2002-03, EPW Research Foundation, Mumbai, India.

(12) Preston, J. (2001), ‘Integrating Transport with Socio-economic Activity – A Research Agenda for the New Millennium’, Journal of Transport Geography, 9(1), 13-24.

(13) Ramanathan, R., and Parikh, J.K. (1999), ‘Transport Sector in India: An analysis in the context of sustainable development’, Transport Policy, 6(1), 35-45.

(14) Ramanathan, R. (1998), ‘Development of Indian Passenger Transport’, Energy – The International Journal, 23(5), 429-430.

(15) Schafer, A. (1998), ‘The Global Demand for Motorized Mobility’, Transport Research: Part A, 32(6), 455-477.

(16) Schafer, A., and Victor, D.G. (2000), ‘The Future Mobility of the World Population’, Transport Research: Part A, 34(3), 171-205.

(17) Singh, S.K. (2005), ‘Review of Urban Transportation in India’, Journal of Public Transportation, 8(1), 79-97.

(18) Singh, S.K. (2000), ‘Estimating the Level of Rail- and Road-based Passenger Mobility in India’, Indian Journal of Transport Management, 24(12), 771-781.

(19) TERI Energy Data Directory & Yearbook (various issues), TERI, New Delhi, India.

(20) World Population Prospects: The 2004 Revision Population Database, United Nations Population Division, United Nations. Available on http://esa.un.org/unpp/index.asp?panel=3.

APPENDIX: Data descriptions

Although, annual time series data of the level of rail-based passenger mobility in India from 1950-51 to 2000-01 is readily available (e.g., in Statistical Abstract of India published by the Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India, New Delhi), similar series for road-based passenger traffic volume is not offered by any source. Therefore, it is decided to estimate the level of road-based passenger traffic from 1950-51 to 2000-01 on the basis of services provided by the different modes. The estimates are based on the following passenger vehicles: (i) Cars (ii) Two-wheelers (iii) Auto-rickshaws and (iv) Buses. Cars include jeeps and taxis as well.

Table A1 reports category-wise motor vehicle population in India for selected years between 1950-51 and 2000-01. This is based on data given in the Motor Transport Statistics published by the Ministry of Road Transport and Highways, Government of India, New Delhi and Statistical Abstract of India published by the Central Statistical Organization, Ministry of Statistics and Programme Implementation, Government of India, New Delhi. The traffic mobility provided by the different categories of vehicles has been computed after making reasonable assumptions regarding their average annual utilization and average occupancy. These assumptions are based on studies like National Transport Policy Committee Report (1980), Planning Commission, New Delhi; Road Development Plan 1981-2000 (1984), Indian Road Congress, New Delhi; Estimation of Road Transport Passenger and Freight Demand (1986), Study Report of Ministry of Surface Transport, New Delhi; Report of Steering Group on Transport Planning (1987), Planning Commission, New Delhi; and Singh M. and Kadiyali L. R. (1990) written book on Crisis in Road Transport published by the Konark Publishers Pvt. Ltd., New Delhi. Annual utilization of cars, two-wheelers, and auto-rickshaws are assumed to be 12600, 6300, and 33500 Kms respectively. Average occupancy of a car, two-wheeler, and auto-rickshaw are assumed to be 3.18, 1.5, and 1.76 respectively. Accordingly, the level of passenger mobility provided by these modes has been computed and presented in Table A2.

Estimation of traffic mobility provided by the buses requires data on bus population, average annual utilization, occupancy ratio (ratio of number of passengers to the seats offered), and average seating capacity. These data are taken from various sources such as State Transport Undertakings: Profile and Performance (various issues) published by the Central Institute of Road Transport, Pune; TERI Energy Data Directory & Yearbook (various issues) published by the TERI, New Delhi; and Singh M. and Kadiyali L. R. (1990) written book on Crisis in Road Transport published by the Konark Publishers Pvt. Ltd., New Delhi. Table A3 presents these data. Assuming that the average seating capacity is 52, the level of passenger mobility provided by the buses has been computed and presented in both Table A2 and A3. Rail-based passenger mobility data is readily available from 1950-51 onwards. Passenger mobility data for rail, road, and land (aggregate of rail and road) for selected years between 1950-51 and 2000-01 have been reported in Table A4.

Table A1. Motor vehicle population in thousand and its compound annual growth rate in percentage since previous period (in parentheses)

Year	Cars	Two-wheelers	Auto-rickshaws	Buses	Total passenger vehicles	Total motor vehicles
1950-51	159.3 (-)	26.9 (-)	1.7 (-)	34.4 (-)	222.2 (-)	306.3 (-)
1955-56	203.2 (5.0)	41.0 (8.8)	2.5 (8.8)	46.5 (6.2)	293.1 (5.7)	425.6 (6.8)
1960-61	309.6 (8.8)	88.4 (16.6)	6.2 (19.9)	56.8 (4.1)	461.0 (9.5)	664.5 (9.3)
1965-66	455.9 (8.0)	225.6 (20.6)	16.1 (20.8)	73.2 (5.2)	770.8 (10.8)	1099.1 (10.6)
1970-71	682.0 (8.4)	576.0 (20.6)	36.7 (17.9)	91.4 (4.5)	1386.1 (12.5)	1865.0 (11.2)
1975-76	779.0 (2.7)	1057.0 (12.9)	59.4 (10.1)	114.2 (4.6)	2009.6 (7.7)	2720.0 (7.8)
1980-81	1160.0 (8.3)	2618.0 (19.9)	142.1 (19.0)	153.9 (6.2)	4074.0 (15.2)	5391.0 (14.7)
1985-86	1780.0 (8.9)	6245.0 (19.0)	336.9 (18.9)	227.6 (8.1)	8589.5 (16.1)	10577.0 (14.4)
1990-91	2954.0 (10.7)	14200.0 (17.9)	617.4 (12.9)	331.1 (7.8)	18102.5 (16.1)	21374.0 (15.1)
1995-96	4204.0 (7.3)	23252.0 (10.4)	1009.0 (10.3)	449.0 (6.3)	28913.9 (9.8)	33786.0 (9.6)
2000-01	7058.0 (10.9)	38556.0 (10.6)	1725.4 (11.3)	560.0 (4.5)	47899.4 (10.6)	54991.0 (10.2)

Table A2. The level of passenger mobility provided by different modes of road transport during selected years (in BPKm)

Year	Cars	Two-wheelers	Auto-rickshaws	Buses	Road transport
1950-51	6.38	0.25	0.10	28.99	35.72
1955-56	8.14	0.39	0.15	50.52	59.19
1960-61	12.40	0.84	0.37	80.15	93.76
1965-66	18.27	2.13	0.95	123.29	144.63
1970-71	27.33	5.44	2.16	204.72	239.65
1975-76	31.21	9.99	4.68	306.88	352.76
1980-81	46.48	24.74	8.38	505.81	585.40
1985-86	71.32	59.02	19.86	757.48	907.68
1990-91	118.36	134.19	36.40	1198.32	1487.27
1995-96	168.45	219.73	59.49	1830.36	2278.03
2000-01	282.80	364.35	101.73	2329.60	3078.49

Table A3. Growth of Indian bus industry; 1950-51 to 2000-01

Year	Bus population	Average annual utilization (Kms)	Occupancy ratio (percent)	BPKm
1950-51	34411	36000	45	28.988
1955-56	46461	41000	51	50.518
1960-61	56792	46000	59	80.149
1965-66	73175	54000	60	123.285
1970-71	91406	59000	73	204.717
1975-76	114193	68000	76	306.878
1980-81	153909	79000	80	505.807
1985-86	227608	80000	80	757.479
1990-91	331100	87000	80	1198.317
1995-96	448970	98000	80	1830.361
2000-01	560000	100000	80	2329.600

Table A4. Trends in rail, road, and land-based passenger mobility in India

Year	Rail pass.-km (in billion)	CAGR in percentage wrt previous period (Rail)	Road pass.-km (in billion)	CAGR in percentage wrt previous period (Road)	Land pass.-km (in billion)	CAGR in percentage wrt previous period (Land)
1950-51	66.52	-	35.72	-	102.24	-
1955-56	62.90	-1.1	59.19	10.6	122.09	3.6
1960-61	77.67	4.3	93.76	9.6	171.42	7.0
1965-66	96.76	4.5	144.63	9.1	241.39	7.1
1970-71	118.12	4.1	239.65	10.6	357.77	8.2
1975-76	148.76	4.7	352.76	8.0	501.52	7.0
1980-81	208.56	7.0	585.40	10.7	793.96	9.6
1985-86	240.62	2.9	907.68	9.2	1148.30	7.7
1990-91	295.64	4.2	1487.27	10.4	1782.91	9.2
1995-96	342.00	3.0	2278.03	8.9	2620.03	8.0
2000-01	457.02	6.0	3078.49	6.2	3535.51	6.2