The demand for road-based passenger mobility in India: 1950-2030 and relevance for developing and developed countries

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The main aim of the paper is to estimate the demand for road-based passenger mobility in India and subsequently project the energy demand and CO_2 emissions resulting from the same. Based on a data set of the four major motorized modes of transport – buses, cars (including jeeps and taxis), two-wheelers, and auto-rickshaws from 1950-51 to 2000-01, long-term trends in motorized traffic volume and modal split are projected up to the year 2030-31. It is found that the road-based traffic volume in India will increase from 3079 billion passenger-kilometers in 2000-01 to 12546 billion passenger-kilometers in 2030-31. Between 2000-01 and 2030-31, the aggregate share of private- and para-transit modes is projected to increase from 24.3% to 55.3% whereas the share of public transport mode is estimated to decrease from 75.7% to 44.7%. Based on the projected values of aggregate traffic volume, modal split, and modal intensities for energy demand and CO_2 emissions, the paper then estimated the level of energy demand and CO_2 emission from the road-based passenger transport sector in India. If there is no reduction in modal intensities, energy demand is projected to increase from 954 peta joules in 2000-01 to 5897 peta joules in 2030-31 whereas CO_2 emission is estimated to increase from 17.27 to 93.22 million metric tons of carbon equivalent during the same period. Even when we assume a reduction of 1% per year in energy and CO_2 intensity of all modes of transport, energy demand and CO_2 emission is projected to increase by a 4.6- and 4.0-fold respectively from 2000-01 to 2030-31.

Keywords: passenger transport in India; motorized mobility; energy demand; CO_2 emission; forecasting

1. Introduction

Road-based passenger mobility in India has increased tremendously over the years. From 1950-51 to 2000-01, passenger mobility increased from 36 billion passenger-kilometers (BPKm) to 3079 BPKm due to more than 30-fold increase in annual distance traveled by the people (from 100 in 1950-51 to 3021 Kms in 2000-01) and a 2.84-fold rise in population (from 359 million in 1950-51 to 1019 million in 2000-01). It is interesting to know that between 1980-81 and 2000-01, in light of a 50% population growth, motorized mobility by road in India has risen by 425% (from 585 to 3079 BPKm). Analysis of per capita mobility (i.e., passenger-kilometers per capita; PKm/cap) data shows that the average annual distance traveled by the people quadruples in every two decades. For example, between 1980-81 and 2000-01, per capita mobility increased from 862 to 3021 Kms (table 1).

Although large proportion of mobility need is still catered by the buses, there is a rapid increase in reliance on automobiles particularly during recent years. For example, during 1990s, per capita mobility by two-wheelers, auto-rickshaws and cars[1] increased by 124%, 130% and 97% respectively against the corresponding increase of 60% for buses. Due to this, mobility share of private- and para-transit modes[2] increased from 19.4% in 1990-91 to 24.3% in 2000-01.

Rapid increase in motorized mobility during the last two decades or so is primarily due to increase in household income, increase in commercial and industrial activities, availability of motorized transport, and improvement in road transport infrastructure. Per capita income and Gross Domestic Product (GDP) in India has increased by 100% and 200% respectively between 1980-81 and 2000-01. Latest figures from Central Statistical Organization (CSO), New Delhi reveals that per capita income in India has increased at the rate of 4.1% per annum from 1994-95 to 2004-05 whereas GDP has increased at the rate of 5.8% per annum during the same period. Besides rapid increase in income and economic activities, there has been significant change in automobile sector during the last two decades. Due to the liberalization of Indian economy during late 1980s and early 1990s, many new firms entered the automobile market to produce variety of cars and two-wheelers. Availability of variety of product and financing of durable product purchase at low interest rate has increased the sale of private vehicles substantially during 1990s and afterwards.[3] For example, during the year 2004-05, more than one million cars and six million two-wheelers were sold in the country.

As far as road infrastructure is concerned, total road network and National Highway (NH) increased by 67% and 55% respectively between 1990-91 and 2000-01. Presently, India has a vast road network of about 3.3 million km of which the national highway and the state highways together account for 195000 km length. Though the 65569 km long NH constitutes only 1.98 per cent of the total road length in the country, it carries around 40 per cent of road traffic. Recently, the central government has created a dedicated fund, called Central Road Fund (CRF)[4] from the collection of cess on petrol and diesel. The fund is distributed for

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[1] Cars include jeeps and taxis. This will be followed throughout this paper.

[2] Private- and para-transit modes include cars, two-wheelers, and auto-rickshaws.

[3] 60% of the cars bought in the last decade were through finance.

[4] The Central Road Fund Ordinance, 2000 was promulgated on November 1, 2000 to give statutory effect to the creation of Central Road Fund from the collection of cess on petrol and diesel. 50% of the cess on diesel will be allocated for the development of rural roads. The balance of amount of 50% on diesel and entire cess collected on petrol will be allocated for the development and maintenance of national highways (57.5%), for construction of road over/under bridges and other safety works at unmanned rail road crossing (12.5%) and development and

development and maintenance of NH, state roads, and rural roads. From last five years or so, the government has embarked upon a massive National Highways Development Project (NHDP) in the country. The main aim of NHDP, India's largest ever highways project, is to build high quality roads with uninterrupted traffic flow.

Although all these have contributed for change in modal-split structure where share of private- and para-transit modes is increasing, the equally important reasons are to be found in the public transport system itself. Speed, service quality, convenience, flexibility and availability favor adoption of private mode as the main mode of transport. Given the opportunity, people reveal widely divergent transport preferences, but in many places in the country transport authorities favor a basic standard of public transport services. Government regulation and control have exacerbated the poor operational and financial performance of publicly owned transport undertakings, which are the main provider of bus transport services in the country. It is increasingly becoming very difficult for loss making transport undertakings to augment and manage their fleet, which in turn leading to poor operational performance and deterioration in quality of services. As a consequence, those who can afford private vehicle are successively leaving public transport.

The main aim of the paper is to estimate the long-term trends in motorized traffic volume and modal split and subsequently, based on the projected values of traffic volume and modal split, estimate the level and growth of energy demand and CO_2 (carbon dioxide) emission from the road-based passenger transport sector in India.[5] Required data from 1950-51 to 2000-01 are used to estimate the long-term trends in motorized traffic volume and modal split. These data account for the four major modes of passenger transport namely cars, two-wheelers, auto-rickshaws, and buses. Appendix summarizes the data sources and their estimation methods. The statistical program Limdep version 8.0 is used for the required regression analysis. The paper projected the level and growth of energy demand and CO_2 emission from passenger transport sector in India using a scenario approach. Two scenarios, business as usual and efficiency gain, are discussed in the paper. In the business as usual scenario, both energy and CO_2 intensities of all transport modes are assumed to remain at 2000-01 levels whereas in the efficiency gain scenario, intensities are assumed to reduce at the rate of 1% per year in one case and 2% per year in another case from 2000-01 onwards.

The paper is organized into the following sections. Section 2 deals with the model to project future per capita mobility, model estimation, and projection of passenger mobility up to the year 2030-31. Section 3 presents estimation and projection of modal split changes. Using a scenario approach, Section 4 describes the energy demand whereas CO_2 emission estimates are presented in Section 5. Section 6 discusses the strategies to reduce energy demand and CO_2 emissions from the transport sector. The paper's findings are summarized in Section 7.

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maintenance of state roads including roads of economic importance (30%). The fund will be non-lapsable and will be used to fund the development of the total hierarchy of roads, right from national highways through state highways to rural roads.

[5] Refer Singh (2006) for another study on passenger transport sector in India. Singh (2006) focuses on land-based (i.e., rail plus road) passenger transportation and its impact on energy demand and carbon dioxide emission. Traffic mobility forecasting model in Singh (2006) uses GDP and population as the main explanatory variables rather than time trend. Also, time period for which forecasting has been done is relatively shorter. Unlike Singh (2006), this paper also examines the strategies to reduce energy demand and CO_2 emissions from road-based passenger transport sector in India.

Table 1. Absolute as well as per capita mobility in India

	BPKm (Road)	PKm/cap (Road)	BPKm (Bus)	PKm/cap (Bus)	BPKm (Two-wheeler)	PKm/cap (Two-wheeler)	BPKm (Car)	PKm/cap (Car)	BPKm (Auto-rickshaw)	PKm/cap (Auto-rickshaw)
1950-51	36	100	29	81	-	1	6	18	-	-
1955-56	59	151	51	129	-	1	8	21	-	-
1960-61	94	216	80	185	1	2	12	29	-	1
1965-66	145	298	123	254	2	4	18	38	1	2
1970-71	240	443	205	379	5	10	27	51	2	4
1975-76	353	581	307	506	10	17	31	51	5	8
1980-81	585	862	506	745	25	36	47	68	8	12
1985-86	908	1202	758	1003	59	78	71	95	20	26
1990-91	1487	1773	1198	1428	134	160	118	141	36	43
1995-96	2278	2455	1830	1972	220	237	168	182	60	64
2000-01	3079	3021	2330	2286	364	358	283	278	102	100

Note: All figures are rounded off to zero decimal place and (-) indicates negligible quantity.

2. Estimation of future road-based passenger mobility in India

2.1 The model to forecast per capita mobility

The growth in per capita mobility over time typically follows a sigmoid or *S*-shaped curve. There are a number of different functional forms that can describe *S*-shaped curves, for example, the logistic, Gompertz, logarithmic logistic, log reciprocal, etc.[6] Among these, the logistic and Gompertz functions are the two most widely used functional forms. Therefore, it is decided to use these two functions to model and forecast the development of per capita mobility in India. The logistic model can be written as:

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

where $\frac{PKm}{cap}$ is passenger-kilometers per capita (representing per capita mobility), α is the saturation level and ε_t is an error term at period t. All the parameters: α, β and γ are positive. Parameters γ and β determine the location and shape of the curve, respectively. The logistic function ranges from 0 to α as *time* ranges from -∞ to +∞. The logistic curve reaches its maximum growth rate αβ/4 when $\frac{PKm}{cap} = \frac{\alpha}{2}$, that is, at half of the saturation level of per capita mobility. Thus, the logistic curve is rotationally symmetric about its inflection point (the point at which maximum rate of diffusion takes place).
Similarly, the Gompertz model can be written as:

[6] An overview of such functional forms is given in Meade and Islam (1998), see also Tanner (1978), Bewley and Fiebig (1988), Meade and Islam (1995), Ramanathan (1998), Dargay and Gately (1999), Ramanathan and Parikh (1999), Singh (2000), Franses Philip Hans (2002), and Mohamed and Bodger (2005).

$$(\frac{PKm}{cap})_t = \alpha \exp(-\gamma \exp(-\beta (time)_t)) + \varepsilon_t \qquad (2)$$

where all the variables and parameters have their previous meaning and ε_t is an error term at period t. The Gompertz function also ranges from 0 to α as *time* ranges from -∞ to +∞. In this case, maximum growth rate αβ/e is achieved when $\frac{PKm}{cap} = \frac{\alpha}{e}$, that is, when per capita mobility reaches around 37% of its saturation level.

Both logistic and Gompertz models can easily be estimated using non-linear least square method. These two models can be estimated once by assuming no restriction on the saturation level and then by imposing restrictions on the saturation level. This should be done primarily because 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. Taking into account the saturation level in developed countries and the socio-economic characteristics (such as population density, rapid increase in teledensity, boom in information technology, high fuel prices, etc.) of India, 11000 PKm per capita appears to be the most appropriate saturation level.

Here, it would be useful to examine road-based PKm per capita in the United Kingdom (UK) from Europe and the United States (US) from America. Road-based per capita mobility in the UK has been relatively stable since 1990. According to the data published by the ECMT-Eurostat, it was around 11000 PKm per capita during the year 2000 which implies that the saturation level for the UK may be somewhere between 11000 and 12000 PKm per capita. The Bureau of Transportation Statistics, USA data shows that during the year 2000, PKm per capita by road in the United States was around 23000. The US is also approaching to its saturation level since growth in per capita mobility is slowing down over the recent years. There are many factors which explain the difference in the saturation level between the US and UK. Public transport is far more important for passenger travel in the UK than in the US. The US has far more extensive motorway networks, much cheaper fuel, and longer trip distances both within and between cities which encourage private vehicle use. Since transport availability characteristics (such as greater reliance on public transport, high fuel prices, etc.) in India is more close to the UK, we expect that the saturation level in India would be around 11000 PKm per capita.[7] Besides these, deterioration in air quality particularly in urban areas has forced Indian government to take various measures including adoption of market based instruments to reduce the usage of private vehicles. Measures such as cess on petrol and diesel, parking fee, congestion pricing, etc. are getting accepted in the country. Assuming that government policy will discourage the usage of private vehicles in forthcoming years due to environmental consideration, we expect that the mobility per capita in India will not follow the pattern of the US. Due to these reasons, our assumption about the saturation level of 11000 PKm per capita in India appears to be reasonable. However, both logistic and Gompertz models can be estimated for different saturation levels (e.g., 7000, 8000, 9000,

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[7] This is close to what has been estimated by Singh (2000). In his paper, Singh (2000) estimated that the saturation level for land-based (i.e., road and rail taken together) passenger mobility in India will be around 20000 billion PKm. Assuming that the Indian population will saturate at 1.65 billion and rail will supply between 8 and 10% of the total land-based travel demand, saturation level for road-based per capita mobility would be around 11000 Kms.

10000, 11000 and 12000 PKm/capita) not only to illustrate the different possible paths of per capita passenger mobility but also to find out the most appropriate saturation level. The Mean Absolute Percentage Error (MAPE)[8] over the sample period can be used to find out the most appropriate model and saturation level.

2.2 Model estimation

Both the models, logistic and Gompertz, are estimated for six different saturation levels (7000, 8000, 9000, 10000, 11000, and 12000 PKm/cap) along with without imposing any restriction on the saturation level using the econometric software Limdep version 8.0. Since we are interested in long-term forecast, it was decided to use five-yearly data of PKm/cap from 1950-51 to 2000-01 for the estimation of the models. The variable *time* is taken as 1 for 1950-51, 2 for 1955-56, 3 for 1960-61,……, and 11 for 2000-01. Table 2 reports the estimation results. According to the R^2 values, models fit the data very well. All the estimated parameters have the expected sign and most are highly significant. The MAPE, reported in table 2, is in the range of 3.13 to 7.99 for the logistic models and 9.81 to 32.13 for the Gompertz models. According to both R^2 and MAPE, logistic models fit the data better than the Gompertz ones. Among the logistic models, the one associated with 11000 PKm/cap saturation level is the best model since it has the lowest MAPE. As illustrated in the previous sub-section, this is in line with our expectation about the saturation level of road-based per capita mobility in India. Further analysis in this paper will primarily be based on the estimated logistic model at saturation level of 11000 PKm per capita as shown in equation (3).

$$\frac{PKm}{cap} = \frac{11000}{1 + 157.0214 e^{-0.3748(time)}} \quad (3)$$

where *time* is 1 for 1950-51, 2 for 1955-56, 3 for 1960-61,……, and 17 for 2030-31.

[8] The MAPE is commonly used in quantitative forecasting methods because it produces a measure of relative overall fit. The absolute values of all the percentage errors are summed up and the average is computed.

Table 2. Parameter estimates of the logistic and Gompertz models (with t-statistic in parentheses)

Model	Estimate
No restriction on the saturation level	
Logistic (1)	α = 6852.5 (6.7), β = 0.4226 (18.8), γ = 129.4445 (12.2); R^2 = 0.9982; MAPE = 7.99
Gompertz (2)	α = 167763.8 (0.7), β = 0.4226 (18.8), γ = 0.0669 (3.3); R^2 = 0.9969; MAPE = 9.81
Saturation level, α = 7000	
Logistic (1)	β = 0.4196 (51.8), γ = 129.8765 (12.9); R^2 = 0.9982; MAPE = 7.66
Gompertz (2)	β = 0.2092 (19.1), γ = 8.7228 (10.1); R^2 = 0.9867; MAPE = 32.13
Saturation level, α = 8000	
Logistic (1)	β = 0.4030 (50.4), γ = 134.5063 (13.0); R^2 = 0.9980; MAPE = 5.81
Gompertz (2)	β = 0.1917 (21.0), γ = 8.2357 (12.0); R^2 = 0.9888; MAPE = 30.17
Saturation level, α = 9000	
Logistic (1)	β = 0.3910 (48.0), γ = 141.0511 (12.7); R^2 = 0.9978; MAPE = 4.41
Gompertz (2)	β = 0.1786 (22.7), γ = 7.9300 (13.9); R^2 = 0.9902; MAPE = 28.55
Saturation level, α = 10000	
Logistic (1)	β = 0.3819 (45.7), γ = 148.6936 (12.3); R^2 = 0.9975; MAPE = 3.46
Gompertz (2)	β = 0.1683 (24.2), γ = 7.7270 (15.6); R^2 = 0.9913; MAPE = 27.18
Saturation level, α = 11000	
Logistic (1)	β = 0.3748 (43.7), γ = 157.0214 (11.9); R^2 = 0.9973; MAPE = 3.13
Gompertz (2)	β = 0.1599 (25.5), γ = 7.5869 (17.2); R^2 = 0.9921; MAPE = 26.02
Saturation level, α = 12000	
Logistic (1)	β = 0.3691 (42.1), γ = 165.8050 (11.7); R^2 = 0.9971; MAPE = 3.15
Gompertz (2)	β = 0.1531 (26.7), γ = 7.4876 (18.8); R^2 = 0.9927; MAPE = 25.01

2.3 Passenger mobility during the next three decades

Based on equation (3), road-based per capita mobility path has been projected (figure 1). Mobility trends in India shows that during the year 2030-31, average Indians will travel about thrice as many kilometers as they traveled during the year 2000-01 (table 3). Due to this, absolute passenger mobility in India at the end of year 2030-31 will be more than 12500 BPKm.[9] The traffic volume and per capita mobility in India is projected to increase at the rate of 6.72% and 5.16% per annum from 2000-01 to 2010-11, 4.69% and 3.45% per annum from

[9] To project the absolute mobility during the next three decades, we require population estimates up to the year 2030-31. Based on the *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, 1.11% per annum from 2015-16 to 2020-21, 0.94% per annum from 2020-21 to 2025-26, and 0.76% per annum from 2025-26 to 2030-31.

2010-11 to 2020-21 and 3.01% and 2.14% per annum from 2020-21 to 2030-31 respectively.[10]

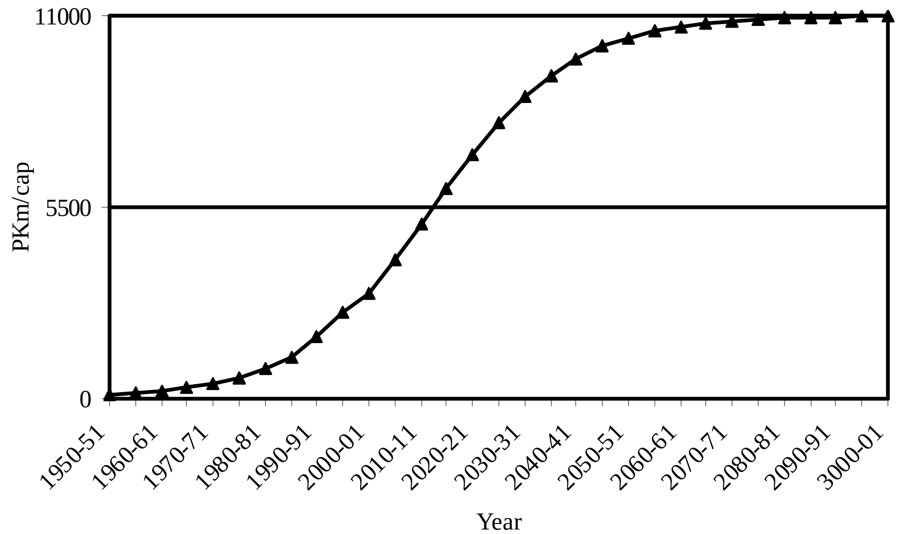

Figure 1. Projected path of road-based per capita passenger mobility in India

Table 3. Level as well as growth of road-based passenger mobility in India from 1950-51 to 2030-31

	Per capita mobility (PKm/cap)	CAGR in per capita mobility (since the previous period)	Population (million)	CAGR in population (since the previous period)	Absolute mobility (BPKm)	CAGR in absolute mobility (since the previous period)
1950-51	100	-	359	-	36	-
1960-61	216	8.06%	434	1.91%	94	10.13%
1970-71	443	7.45%	541	2.23%	240	9.84%
1980-81	862	6.88%	679	2.30%	585	9.34%
1990-91	1773	7.48%	839	2.14%	1487	9.77%
2000-01	3021	5.48%	1019	1.96%	3079	7.55%
2010-11	4996	5.16%	1181	1.49%	5900	6.72%
2020-21	7016	3.45%	1329	1.19%	9327	4.69%
2030-31	8673	2.14%	1447	0.85%	12546	3.01%

Note: Per capita mobility and absolute mobility figures have been rounded off to zero decimal place.

[10] Growth rate is calculated as compound annual growth rate (CAGR) rather than simple annual growth rate. This is followed throughout this paper.

3. Estimation and projection of modal split changes

Schafer (1998) shows that the time spent on travel per person per day (travel time budget) are virtually unchanged across the countries. Although, reason for this 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 time spent on travel remains constant. Time-use and travel surveys from numerous cities and countries throughout the world suggest that travel time budget is approximately 1 hour per person per day (Schafer and Victor, 2000). Stability in the travel time budget has an important implication for the change in modal split.

As shown in table 1, per capita motorized mobility in India is increasing over the years. Since the average person spends somewhat a fixed time (approximately 1 hour per day) on travel, mean travel speed has to increase with the increase in per capita mobility. Since 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 increases, traffic share of public transport mode (buses) decreases and share of private- and para-transit modes increases. For example, although, share of public transport mode in India increased initially up to the year 1975-76 primarily due to government provision of public transport, its share started declining afterwards when the level of per capita mobility crossed a critical limit (table 4).[11] The share of public transport mode went down from 87.0% in 1975-76 to 75.7% in 2000-01 as per capita mobility increased from 581 Km in 1975-76 to 3021 Km in 2000-01.

There is a predictable pattern in change in the modal split over time. The pattern of change in modal split from 1950-51 to 2000-01 and projection of the same up to the year 2030-31 has been presented in figure 2. It is projected that the share of public transport (buses) in India would be around 44.7% during the year 2030-31 (figure 3). As is the case in developed as well as in many developing countries, India will also experience greater reliance on private- and para-transit modes in forthcoming years. It is estimated that the aggregate share of

[11] After independence, in view of the increasing importance of road transport, the Government of India passed the Road Transport Corporation Act 1948, which was subsequently replaced by the Act of 1950. This Act enables the State Governments to form corporations for progressive nationalization of bus industry in the country. The undertakings established under this Act, as well as others formed under other kinds of incorporation, are usually described as State Transport Undertakings (henceforth, STUs). The STUs were set up by the several States, and during the last four to five decades some of them have grown into giant-sized organizations. STUs are the main provider of bus transport services in the country. The work culture in most of the STUs has become strong impediments in their healthy growth. Continuous losses and liberal subsidy by the Central and State Governments never provided the STUs a chance to learn the basics of financial discipline which eventually made the STUs highly inefficient. The STUs also failed to learn from the market. Operating schedules for eight hours according to the convenience of the crew became more important than meeting the actual demand of customers. Since the Motor Vehicle Act 1988 introduced deregulation and liberalization in the market, STUs are finding it difficult to compete with private bus operators, intermediate public transport, and personalized transport. Currently, bus population in the country is increasing at the rate of around 5% per year mainly due to demand from private bus operators whereas private- and para-transit vehicles are increasing at the rate of more than 10% per year. Clearly, transport demand for all modes is increasing but it’s increasing at higher rate for private and para-transit modes. It is expected that as mobility demand (PKm per capita) goes up, the share of public transport mode will go down.

private- and para-transit modes will increase from 24.3% in 2000-01 to 55.3% in 2030-31 (figure 3). We also projected the share of individual private- and para-transit modes up to the year 2030-31 (figure 4). Since, the mobility share of cars, two-wheelers, and auto-rickshaws within the private- and para-transit modes is virtually unchanged from 1993-94 onwards at 38%, 48.5%, and 13.5% respectively, we assumed that the same pattern will be followed up to the year 2030-31.[12] Based on this assumption, the share of individual private- and para-transit modes has been projected. It is estimated that, during the year 2030-31, 21.0% of the road-based traffic mobility in India will be provided by the cars, 26.8% by the two-wheelers, and remaining 7.5% by the auto-rickshaws.

Table 4. Change in modal split from 1950-51 to 2000-01

	Traffic share of public transport mode (%)	Traffic share of private- and para-transit modes (%)	Road-based PKm per capita
1950-51	81.2	18.8	100
1955-56	85.3	14.7	151
1960-61	85.5	14.5	216
1965-66	85.2	14.8	298
1970-71	85.4	14.6	443
1975-76	87.0	13.0	581
1980-81	86.4	13.6	862
1985-86	83.5	16.5	1202
1990-91	80.6	19.4	1773
1995-96	80.3	19.7	2455
2000-01	75.7	24.3	3021

[12] This assumption is made because growth rate of car, two-wheeler, and auto-rickshaw is more or less same from 1993-94 to 2003-04 which is not expected to change significantly in near future. It is important to note that per capita vehicle ownership in India is still among the lowest in the world and it can easily sustain high growth path for these categories of vehicles for long period.

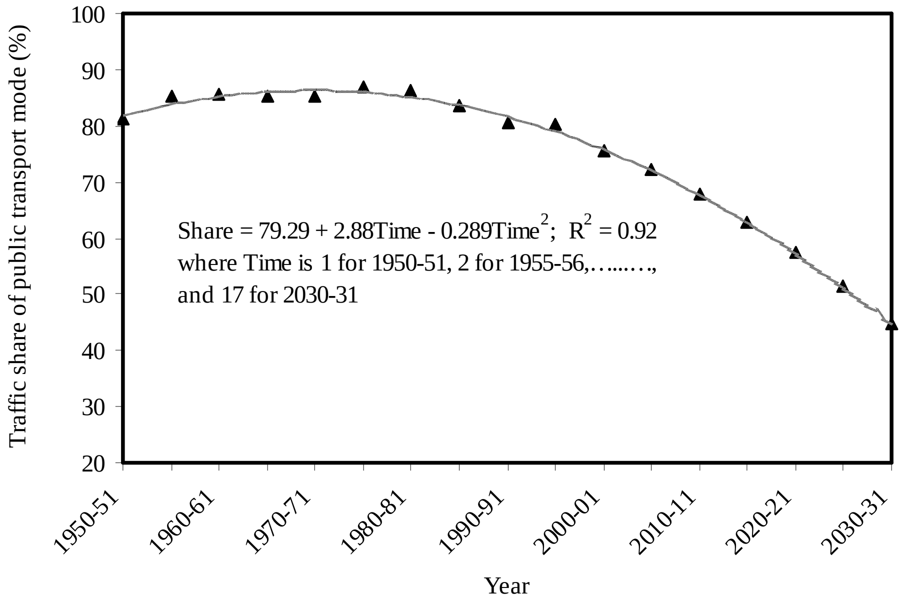

Figure 2. Projection of traffic share of public transport mode (buses) up to the year 2030-31

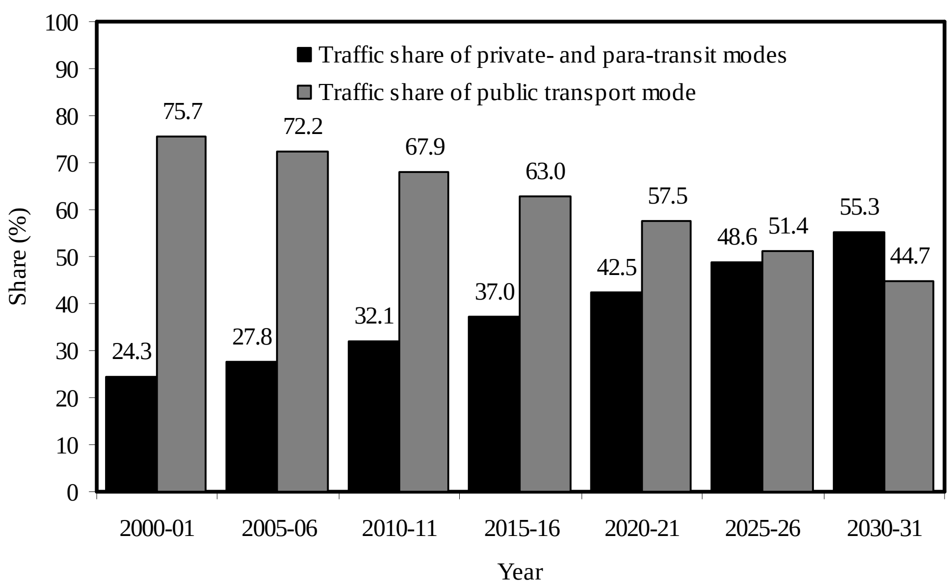

Figure 3. Projected modal split changes during the next three decades

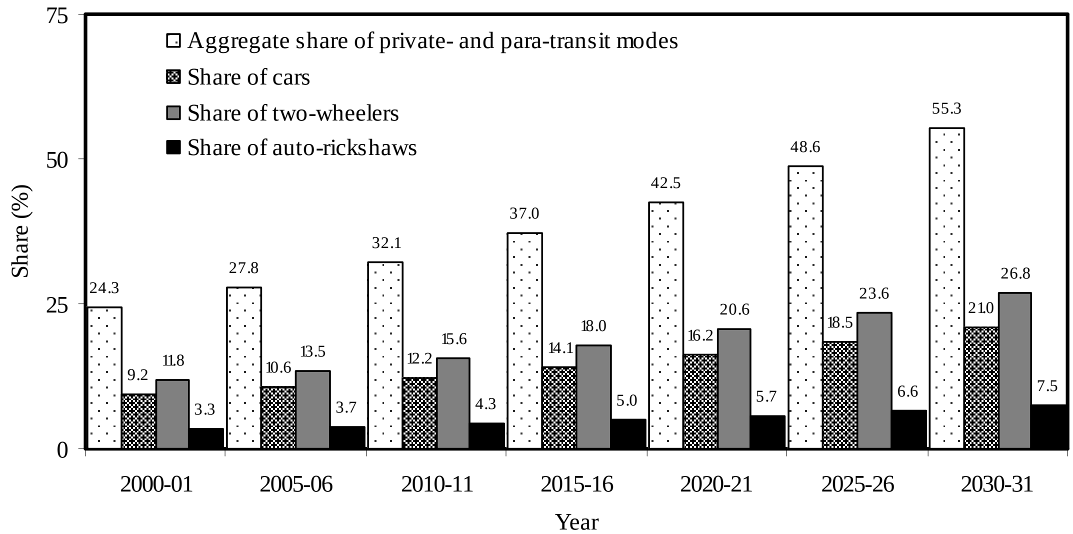

Figure 4. Projected share of private- and para-transit modes (cars, two-wheelers, and auto-rickshaws) during the next three decades

4. Projection of energy demand

The road transport sector in India is a major energy-consuming sector, particularly of petroleum products such as diesel and petrol. Passenger transport accounts for the significant proportion of energy consumed in the sector. The aim of this section is to estimate the present as well as future energy demand from road-based passenger transportation in the country. For this, we have to estimate the modal energy intensities of all major passenger transport modes. The estimated modal energy intensities for 2000-01, 2010-11, 2020-21 and 2030-31 are presented in table 5.[13] For these years, two scenarios are presented for energy intensities in the sector.

First, business as usual scenario, the 2010-11, 2020-21 and 2030-31 energy intensities of all transport modes are assumed to remain at 2000-01 levels. Although, this scenario may appear optimistic, historically there has not been a significant change in fuel efficiency of automobiles in many countries over the years. In addition, it is expected that average occupancy may decline with increase in mobility. Therefore, even if automobile fuel efficiency improves, energy intensity of individual modes may not change significantly.

Second, efficiency gain scenario, the energy intensities of all transport modes are assumed to decline at the rate of 1% per year in one case and 2% per year in another case up to the year 2030-31. In other words, in efficiency gain scenario, we assumed a reduction in energy intensity of all modes by 26% in one case and 45% in another in a span of 30 years. There is no doubt that the government has to play a key role in achieving the efficiency gain scenario.

[13] The energy intensities by mode (in Mega Joules per PKm; MJ/PKm) in 2000-01 have been estimated by the author. The mileage for car, two-wheeler, auto-rickshaw, and bus has been assumed to be 12, 45, 35, and 4.5 kilometers per litre of fuel (petrol/diesel) respectively. The average occupancy has been assumed to be 3.18 for cars, 1.5 for two-wheeler, 1.76 for auto-rickshaw, and 41.6 for bus. The energy equivalent value for 1 litre of fuel (petrol/diesel) is taken as 35.85 MJ.

Energy efficiency of passenger transport system can be improved by tackling traffic congestion problem particularly in urban areas (through measures such as improvement in traffic flow, removal of encroachment on roads, restraint on parking in congested areas, infrastructure improvement, etc.), introducing adequate inspection and maintenance program for in-use vehicles, discouraging the usage of private vehicles (through increasing the price of petrol and diesel using taxation mechanism, parking fee, congestion pricing, etc.), providing tax concession to fuel efficient vehicles, encouraging public transportation, etc. Although it is beyond the scope of this paper to estimate the efficiency gain potential of different measures, we can safely assume that the government policy can reduce the energy intensities of all modes anywhere between 1% and 2% per year from 2000-01 to 2030-31.

4.1 Energy demand in business and usual scenario

In the business as usual scenario, average energy intensity of the road-based passenger transport sector in India is expected to increase by around 52% in a span of 30 years from 0.31 MJ/PKm in 2000-01 to 0.47 MJ/PKm in 2030-31 (table 5). Increase in average energy intensity of the sector is because of increased dependence on automobiles to meet the travel demand in future. Due to increase in average energy intensity and aggregate transport demand, energy use in the sector is projected to increase from 954 peta joules in 2000-01 to 5897 peta joules in 2030-31 (table 6). Furthermore, energy demand is expected to increase at the rate of 8.0% per year from 2000-01 to 2010-11, 6.1% per year from 2010-11 to 2020-21, and 4.7% per year from 2020-21 to 2030-31. On an average, energy demand will increase at the rate of 6.3% per year from 2000-01 to 2030-31. Table 6 also presents the per capita energy consumption from 2000-01 to 2030-31. Energy consumption per person is projected to increase from 937 mega joules in 2000-01 to 4075 mega joules in 2030-31. It is projected that the energy use per person for road-based passenger transportation will increase at the rate of 6.4% per year from 2000-01 to 2010-11, 4.8% per year from 2010-11 to 2020-21, and 3.8% per year from 2020-21 to 2030-31.

Table 5. Modal share and energy intensities from 2000-01 to 2030-31; business as usual scenario

Mode of transport	2000-01		2010-11		2020-21		2030-31	
	Modal share (%)	Energy intensity (MJ/PKm)	Modal share (%)	Energy intensity (MJ/PKm)	Modal share (%)	Energy intensity (MJ/PKm)	Modal share (%)	Energy intensity (MJ/PKm)
Car	9.2	0.94	12.2	0.94	16.2	0.94	21.0	0.94
Two-wheeler	11.8	0.53	15.6	0.53	20.6	0.53	26.8	0.53
Auto-rickshaw	3.3	0.58	4.3	0.58	5.7	0.58	7.5	0.58
Bus	75.7	0.19	67.9	0.19	57.5	0.19	44.7	0.19
Total (weighted average)	100.0	0.31	100.0	0.35	100.0	0.40	100.0	0.47

Table 6. Transport energy demand in India; business as usual scenario

Mode of transport	2000-01			2010-11			2020-21			2030-31		
	BPKm	Energy demand (PJ)	Energy use per person (MJ)	BPKm	Energy demand (PJ)	Energy use per person (MJ)	BPKm	Energy demand (PJ)	Energy use per person (MJ)	BPKm	Energy demand (PJ)	Energy use per person (MJ)
Car	283	266	261	720	677	573	1511	1420	1069	2635	2477	1712
Two-wheeler	364	193	190	920	488	413	1921	1018	766	3362	1782	1232
Auto-rickshaw	102	59	58	254	147	125	532	308	232	941	546	377
Bus	2330	443	434	4006	761	645	5363	1019	767	5608	1066	736
Total	3079	954	937	5900	2065	1749	9327	3731	2807	12546	5897	4075

Note: Sum of modal energy demand may not be equal to the total of the sector since energy intensity figures have been rounded off to 2 decimal places. Also, PJ stands for peta joules (1 peta joule = 10^{15} joules) and MJ stands for mega joules (1 mega joule = 10^{6} joules).

4.2 Energy demand in efficiency gain scenario

In the efficiency gain scenario, it is assumed that energy intensity of all modes will decrease at the rate of 1% per year in one case and 2% per year in another case from 2000-01 to 2030-31. When we assume 1% per year reduction in energy intensity of all modes, energy intensity of the sector is expected to increase from 0.31 MJ/PKm in 2000-01 to 0.35 MJ/PKm in 2030-31 due to increase in share of automobiles and decline in share of buses in forthcoming years (table 7). In this case, energy requirement in 2030-31 is estimated to be 4391 peta joules, around 1500 peta joules less than that in the business as usual scenario. When we assume 2% per year reduction in energy intensity of all modes up to the year 2030-31, energy requirement during the year 2030-31 is projected to be 3262 peta joules, 2635 peta joules less than that in the business as usual scenario. This is mainly because there will be reduction in energy intensity of the sector from 0.31 to 0.26 MJ/PKm in a span of 30 years when energy intensity of all modes is getting reduced at the rate of 2% per year.

Similarly, per capita energy consumption in 2030-31 is projected to be 3036 mega joules in 1% per year case and 2255 mega joules in 2% per year case rather than 4075 mega joules in the business as usual case. One should note that even when there is a reduction in energy intensity of all modes by 2% per year, road-based passenger transport energy demand in India will increase at the rate of 4.2% per year from 2000-01 to 2030-31. If we assume 1% per year reduction in energy intensity of all modes, which is more achievable than the 2% per year case, transport energy demand will increase at an average rate of 5.2% per year during the next three decades.

Table 7. Transport energy demand in India; efficiency gain scenario

	2000-01	2010-11		2020-21		2030-31	
		1% per year reduction in energy intensity of all modes	2% per year reduction in energy intensity of all modes	1% per year reduction in energy intensity of all modes	2% per year reduction in energy intensity of all modes	1% per year reduction in energy intensity of all modes	2% per year reduction in energy intensity of all modes
Energy intensity (MJ/PKm)	0.31	0.32	0.29	0.33	0.27	0.35	0.26
BPKm	3079	5900	5900	9327	9327	12546	12546
Energy demand (PJ)	954	1888	1711	3078	2518	4391	3262
Energy use per person (MJ)	937	1599	1449	2315	1894	3036	2255

5. Projection of CO_2 emissions

This Section presents CO_2 emissions from road-based passenger transportation in India from 2000-01 to 2030-31. To estimate the present as well as future CO_2 emissions, we have to estimate the CO_2 emission intensity of the sector. Based on the CO_2 emission intensities of all the major modes, CO_2 emission intensity of the sector is computed from 2000-01 to 2030-31.[14] In this case also, two scenarios are discussed in line with the scenarios presented in the previous section. First is business as usual scenario in which 2010-11, 2020-21 and 2030-31 CO_2 intensities of all passenger transport modes are assumed to remain at 2000-01 levels. Second is efficiency gain scenario in which modal CO_2 intensities are assumed to decline at the rate of 1% per year in one case and 2% per year in another case up to the year 2030-31.

5.1 CO_2 emissions in business and usual scenario

Table 8 presents the estimated CO_2 intensities for 2000-01 and their projected values for 2010-11, 2020-21, and 2030-31 in the business as usual scenario. In this scenario, CO_2 intensity (in grams of carbon equivalent per PKm) of the sector is projected to increase from 5.61 in 2000-01 to 6.07 in 2010-11, 6.68 in 2020-21, and 7.43 in 2030-31. This increase in CO_2 intensity is happening primarily due to change in modal split towards private- and para-transit modes. In the business as usual scenario, CO_2 emission is projected to increase from 17.27 to 93.22 million metric tons of carbon equivalent in a span of 30 years between 2000-01 and 2030-31 (table 9). It is projected that the average annual rate of growth in CO_2 emission will be 7.6% from 2000-01 to 2010-11, 5.7% from 2010-11 to 2020-21, and 4.1% from 2020-21 to 2030-31. If we consider the period from 2000-01 to 2030-31, CO_2 emission from road-based passenger transportation in India is expected to grow at an average rate of 5.8% per year up to 2030-31. figure 5 presents the per capita CO_2 emission from road-based passenger transportation from 2000-01 to 2030-31. In the business as usual scenario, CO_2 emission per person is projected to increase at the rate of 4.5% per year from 16.95 kilograms of carbon equivalent in 2000-01 to 64.44 kilograms of carbon equivalent in 2030-31.

[14] Based on the data provided by Ramanathan and Parikh (1999), modal CO_2 intensities for 2000-01 have been estimated by the author.

Table 8. Modal share and CO_2 intensities from 2000-01 to 2030-31; business as usual scenario

Mode of transport	2000-01		2010-11		2020-21		2030-31	
	Modal share (%)	CO_2 intensity (grams of carbon equivalent per PKm)	Modal share (%)	CO_2 intensity (grams of carbon equivalent per PKm)	Modal share (%)	CO_2 intensity (grams of carbon equivalent per PKm)	Modal share (%)	CO_2 intensity (grams of carbon equivalent per PKm)
Private- and para-transit modes (car, two-wheeler, and auto-rickshaw)	24.3	10.05	32.1	10.05	42.5	10.05	55.3	10.05
Bus	75.7	4.19	67.9	4.19	57.5	4.19	44.7	4.19
Total (weighted average)	100.0	5.61	100.0	6.07	100.0	6.68	100.0	7.43

Table 9. The level of CO_2 emission from road passenger transport in India; business as usual scenario

Mode of transport	2000-01		2010-11		2020-21		2030-31	
	BPKm	CO_2 emission (million metric tons of carbon equivalent)	BPKm	CO_2 emission (million metric tons of carbon equivalent)	BPKm	CO_2 emission (million metric tons of carbon equivalent)	BPKm	CO_2 emission (million metric tons of carbon equivalent)
Private- and para-transit modes (car, two-wheeler, and auto-rickshaw)	749	7.53	1894	19.03	3964	39.84	6938	69.73
Bus	2330	9.76	4006	16.79	5363	22.47	5608	23.50
Total	3079	17.27	5900	35.81	9327	62.30	12546	93.22

Note: Sum of modal CO_2 emission may not be equal to the total of the sector since intensity figures have been rounded off to 2 decimal places.

5.2 CO_2 emissions in efficiency gain scenario

In this scenario, once again, it is assumed that there will be continuous efforts to improve efficiency to reduce the CO_2 intensities of all modes. It is important to note that energy efficiency improvement measures, as discussed in Section 4 and 6, will have huge potential to reduce modal CO_2 intensities since CO_2 emission is directly linked with energy consumption. In particular, we assumed that the CO_2 intensity of all modes will decrease at the rate of 1% per year in one case and 2% per year in another case from 2000-01 to 2030-31. When we assume 1% per year reduction in CO_2 intensity of all modes, CO_2 intensity of the sector will virtually be same from 2000-01 to 2030-31 due to increase in share of automobiles and decline in share of buses in forthcoming years. In this case, CO_2 emission in 2030-31 is estimated to be 69.00 million metric tons of carbon equivalent, around 24 million metric tons of carbon equivalent less than that in the business as usual scenario (table 10). When we assume 2% per year reduction in CO_2 intensity of all modes up to the year 2030-31, CO_2

emission during the year 2030-31 is projected to be 50.81 million metric tons of carbon equivalent, around 42 million metric tons of carbon equivalent less than that in the business as usual scenario. This is mainly because there will be reduction in CO_2 intensity of the sector from 5.61 to 4.05 grams of carbon equivalent per PKm in a span of 30 years when CO_2 intensities of all modes are getting reduced at the rate of 2% per year.

Similarly, per capita CO_2 emission in 2030-31 is projected to be 47.70 kilograms of carbon equivalent in 1% per year case and 35.12 kilograms of carbon equivalent in 2% per year case rather than 64.44 kilograms of carbon equivalent in the business as usual case (figure 5). One should note that even when there is a reduction in CO_2 intensity of all modes by 2% per year, CO_2 emission from the sector will increase around 3-fold in a span of three decades from 17.27 in 2000-01 to 50.81 million metric tons of carbon equivalent in 2030-31. If we assume 1% per year reduction in CO_2 intensity of all modes, which is more achievable than the 2% per year case, CO_2 emission is projected to increase by 4-fold in a span of three decades.

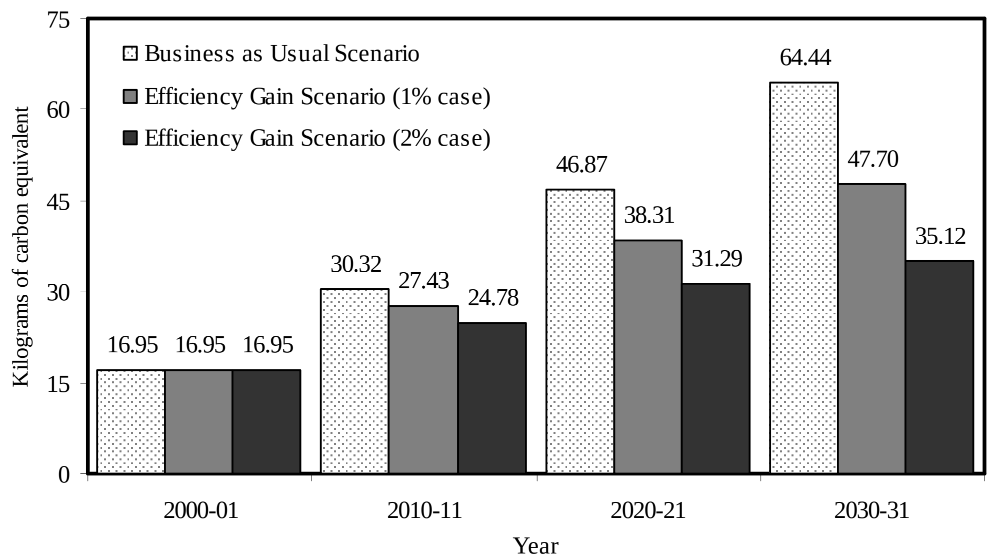

Figure 5. Per capita CO_2 emission from road passenger transport in India

Table 10. The level of CO_2 emission from road passenger transport in India; efficiency gain scenario

	2000-01	2010-11		2020-21		2030-31	
		1% per year reduction in CO_2 intensity of all modes	2% per year reduction in CO_2 intensity of all modes	1% per year reduction in CO_2 intensity of all modes	2% per year reduction in CO_2 intensity of all modes	1% per year reduction in CO_2 intensity of all modes	2% per year reduction in CO_2 intensity of all modes
CO_2 intensity (grams of carbon equivalent per PKm)	5.61	5.49	4.96	5.46	4.46	5.50	4.05
BPKm	3079	5900	5900	9327	9327	12546	12546
CO_2 emission (million metric tons of carbon equivalent)	17.27	32.39	29.26	50.93	41.60	69.00	50.81

6. Strategies to reduce energy demand and CO_2 emissions

The transport sector is one of the fastest growing sectors in terms of energy demand and CO_2 emissions not only in India but also in many other countries. The sector is also causing increasing environmental damage beyond emissions of CO_2, including air pollution, congestion, erosion of landscapes and land use. To ensure that the transport sector makes a contribution to climate protection and CO_2 reduction, there is a need to find a way of achieving a greater degree of mobility combined with lower levels of energy use and CO_2 emissions from transport. This Section presents a package of different instruments and measures which can be used to reduce energy demand and CO_2 emissions from the transport sector not only in India but also in many other countries facing rapid increase in transport demand.

6.1 Promoting regional economies to reduce the need for travel

There is a need to promote regional economies in such a way so that it reduces the need for long-distance transport. This would involve providing support for a great depth of production within a region and promoting regional marketing of products. The promotion of regional economies should be complemented by the creation of compact settlement structures with the provision of shopping, services and recreational facilities and work opportunities close to where people live, so that the trip distance is kept short. In other words, wherever possible, “towns of short distances” should be promoted.

6.2 Focusing on public transport

A comparison of different modes of transport shows that public transport has lower external costs vis-à-vis private modes. Both energy and CO_2 intensity is far lower in case of public transport than private modes such as cars and two-wheelers. Therefore, transport plans should specially emphasize on public transport system. Although rail based transport services in India are available for inter-city transportation, they hardly play any role in meeting the transport demand for intra-city transportation. Considering the financial health of various levels of governments (central, state, and local governments) and investment requirement to improve the rail-based public transport system, it is evident that bus transport will have to play a major role in providing passenger transport services in Indian cities in the future.

There is a need for variety of public transport services. Given the opportunity, people reveal widely divergent transport preferences, but in many places authorities favor a basic standard of public transport services. Presently, it is increasingly difficult to achieve good market acceptance with a single type of product. Rail as well as bus transport operators in India still believe that the vast majority of its users make the same type of commuting trips everyday, and so promotes package that essentially assume this regularity. It may be possible that current users of public transport have such regular pattern of use, but certainly many of those that have left it had varying mobility needs that they felt poorly satisfied either by the services themselves or by the price deals available. Therefore, it is required to segment the supply of public transport system to provide different services for different people and even to the same person at different occasions.

Rail- as well as road-based public transport services in India are mainly provided by the publicly owned transport companies. Government regulation and control have exacerbated the poor operational and financial performance of these companies. As cost of operation rises, transport system comes under financial pressure to raise fares, but politicians are under pressure to keep fares at existing levels. Unless the system is subsidized, it has to eliminate some of its less profitable or loss making services. In democracy, politicians are bound to yield to pressure from those whose services are threatened and to insist on maintaining money-losing operations. Due to this, transport companies find it difficult to raise their revenue sufficient enough to meet the cost of operation. In addition, they have to provide concessional travel facilities to various groups such as freedom fighters, journalists, students, etc. besides often paying a high level of different kinds of taxes.[15] It is increasingly becoming very difficult for loss making publicly owned transport companies to improve operational and financial performance. Furthermore, publicly owned transport companies often lack the flexibility of organization, the ability to hire and fire staff, or the financial discretion needed to adapt to changing conditions. Therefore, there is an urgent need for restructuring of public transport system in India to enhance both quantity as well as quality of services. (Singh, 2005).

6.3 Integrating different modes of transport

There is crying need for a transportation system, which is seamlessly integrated across all modes. The various modes of public transport including intermediate public transport have to work in tandem. The main aim of system integration should be to offer an attractive and easier to use transport system, leading to a better use of existing resources and improvement in the efficiency of service delivery and comfort for commuters. Integrated transport system has potential to attract people away from the private cars and two-wheelers and thus can contribute for congestion relief and environmental preservation.

[15] During the year 2000-01, on an average, every bus operated by publicly owned bus transport undertakings in India paid more than Rs. 100,000 in the form of motor vehicle tax, passenger tax, etc. On the other hand, private vehicle owners have to pay one time nominal tax.

6.4 Encouraging *green* modes

Transport strategy should also encourage the need for developing *green* modes like bicycles, cycle rickshaws, pedestrians, etc. The potential of *green* modes is often underestimated since they are used primarily for short distances. But, large fraction of journeys made by cars and two-wheelers are mainly for short distances say less than 6 km, a distance over which use of motor vehicle does not provide significant time advantage. Moreover, motor vehicle emissions are high for short distance travel because fuel consumption is high due to cold engine and because the catalyst is not yet working at full efficiency. Due to this reason, the use of *green* modes in place of motor vehicles for short distances has huge potential for pollution reduction. To promote *green* modes, first of all, the safety concerns of cyclists and pedestrians have to be addressed adequately. For this purpose, there has to be a segregated right of way for bicycles and pedestrians. Apart from improving safety, this will help improve traffic flow, increase the average speed of traffic and reduce emissions resulting from low speeds. In order to enable longer trip lengths to be undertaken on bicycles, there is a need to improve bicycle technology. Lighter bicycles with gears and tubeless tyres would be handy for longer trip. Government may promote the development and commercialization of lighter and efficient bicycles (Singh, 2005).

6.5. Promoting car sharing

Car sharing is when two or more people share a car and travel together. It allows people to have the convenience of the car, but at the same time helps to reduce congestion and pollution through reduction in vehicle kilometers. Car sharing may be organized through affinity groups, large employers, transit operators, neighborhood groups, or large car-sharing businesses (Shaheen et al., 1998). Car sharing provides the potential to reduce the costs of vehicle travel to the individual as well as society. In order to promote car sharing, it is important to ensure that sufficient parking places are allocated to vehicles belonging to car sharing groups at nominal or no parking fee.

6.6 Implementing demand side management measures

In general, India has not made much progress in implementing the demand side management measures, such as congestion pricing, parking fee, etc. Although policy measures that involve restraining the use of private cars and two-wheelers are likely to be unpopular, a gradualist approach of progressively introducing restraints on road use, while at the same time improving public transport, is more likely to lead to greater acceptance. It is believed that improved public transport and more efficient management of demand would help to combat the trend away from public transport vehicles towards greater use of personalized modes.

6.7 Restraining the use of polluting vehicles and fuels

A large fraction of the two- and three-wheelers in India operate with two stroke engine, which creates more pollution in terms of Particulate Matter (PM), Hydrocarbons (HC), and CO_2. Similarly, many new diesel cars have come up in the market primarily because diesel price in India is far less than the petrol price. Government encourages this price differential primarily to help farmers and bus and truck operators. This price benefit is not meant to be available for personal cars. Diesel fuel has higher energy content per liter than petrol and during combustion generates approximately 13% higher CO_2 emissions.[16] Diesel cars have serious impact on public health due to their higher level of Particulate Matter (PM) emissions particularly in densely populated metropolitan cities. Government should use market based instruments to promote cleaner technology and fuel. For example, a relatively high annual motor vehicle tax, which may be increasing with the age of vehicle, may be imposed on two stroke two-wheelers and all vehicles that are more than say 10 years old. Similarly, cars that use diesel could be discouraged in million plus cities by levying cess on diesel in those cities. Congestion pricing, parking fee, fuel tax, etc. could effectively be used to restrain the usage of all personalized modes.

6.8 Tightening vehicle emissions standards and inspection and maintenance programs

Appropriate vehicle emissions standards for new and in-use vehicles and a well-designed and operated Inspection and Maintenance (I/M) program are important elements of an overall strategy to reduce vehicle emissions and air pollution. Stringent emission regulations and their effective implementation have produced good results in many developed countries. However, emission standards in India are very lax compared to current Euro standards. At the present time, India lags behind the European new vehicle standards and fuels requirements by approximately a decade (table 11). Hence, there is a need to review the emission standards of India and make them more stringent. It is required to set a goal to achieve parity with Europe, United States or Japan by the year 2010 at the latest.

It has been estimated that at any point of time, new vehicle comprise only 8 to 10% of the total vehicle population in India. Currently, only transport vehicles, that is, vehicles used for hire or reward are required to undergo periodic fitness certification. The large population of personalised vehicles is not yet covered by any such mandatory requirement. Modern vehicles equipped with advanced pollution controls are even more dependent on properly functioning components to keep pollution level low. Minor malfunctions in the air, fuel, or spark management system can increase the emissions significantly. Therefore, tightening of new vehicle emissions standards should be followed by a similar tightening of in-use vehicle emission standards.

The inspection and maintenance system, comprising inspection, maintenance, and certification of vehicles, is crucial for regulating pollution for the large fleet of in-use vehicles. At present in India, there is no regular fitness checking program for in-use private vehicles. Simple Pollution Under Control (PUC) checks came into existence in 1991 for all on road vehicles. Commercial vehicles are required to undergo simple fitness checks in addition to PUC checks. However, these are isolated checks and are grossly inadequate.

Government needs to consider (i) whether it has adopted the appropriate in-use vehicle emissions standards and test procedures on which to base I/M, (ii) whether the institutional capacity and willingness to enforce an I/M program exists, and (iii) whether the repair sector is sufficiently trained to carry out repair work on vehicles which fail the tests. If any of these aspects are found to be deficient, government should take appropriate measures to rectify the problems. To ensure the public acceptance and their participation in I/M program, public awareness campaign should be strengthened by the government. (Asian Development Bank, 2003).

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[16] Reducing CO2 Emissions in the Transport Sector, a status report by the Federal Environmental Agency, Umweltbundesamt Berlin, Berlin, Sept. 2003, pp. 25. Also available at http://www.umweltbundesamt.org/fpdf-l/2607.pdf.

Table 11. Emission standards for new vehicles (light duty) in selected countries

<table>
<tr><th>Country</th><th>2000</th><th>2001</th><th>2002</th><th>2003</th><th>2004</th><th>2005</th><th>2006</th><th>2007</th><th>2008</th><th>2009</th><th>2010</th></tr>
<tr><td>India (entire country)</td><td></td><td colspan="4">Euro 1</td><td colspan="5">Euro 2</td><td>Euro 3</td></tr>
<tr><td>India (Delhi and other cities)</td><td colspan="5">Euro 2</td><td colspan="6">Euro 3</td></tr>
<tr><td>Thailand</td><td>Euro 1</td><td colspan="3">Euro 2</td><td colspan="5">Euro 3</td><td colspan="2">Euro 4</td></tr>
<tr><td>Hong Kong, China</td><td>Euro 2</td><td colspan="5">Euro 3</td><td colspan="5">Euro 4</td></tr>
<tr><td>European Union</td><td colspan="5">Euro 3</td><td colspan="3">Euro 4</td><td colspan="3">Euro 5</td></tr>
</table>

Source: Asian Development Bank, (2003), “Vehicular Emissions Standards and Inspection and Maintenance”, Asian Development Bank, Manila, Philippines.

6.9 Adopting supply side management measures

It is desirable to introduce supply side management measures as well, if the ultimate objective is to secure improved levels of air quality and reduction in CO_2 emission. They range from simple traffic engineering interventions (one way traffic system, coordinated signals, traffic engineering improvement measures for road network and inter-sections, etc.) and traffic restraints (parking controls, exclusive pedestrian zones, bus priority lane, etc.) in the short-run to road infrastructure improvement measures (new road alignments, hierarchy of roads, provision of service roads, bye passes, ring roads, bus bays, wide medians, intersection improvements, construction and repair of footpaths and roads, removal of encroachments, good surface drainage, etc.) in the medium-run. In the long-run, technology upgradation and introduction of high speed, high capacity public transport system particularly along high-density traffic corridors can be taken as supply side management measures.

6.10 Introducing public awareness program

Public attitudes influence politicians and policy makers and increase the political will to tackle problems. The adverse health effect of air pollution and climate change due to vehicular emission need to be better understood and communicated as a means of influencing public attitudes. Media, NGOs and research institutions should be encouraged to highlight the issues, conduct independent analysis, and advocate possible solutions to policy makers and implementing agencies. At the same time, fair and equitable procedures for public complaints should be instituted. These can enhance awareness and understanding, influence public attitudes and public support, and create the necessary political will to tackle the problem of air pollution and climate change.

At the same time, public awareness programs should also be initiated to communicate the benefits of public transportation, efficient vehicles and fuels, economical driving, etc. One should remember that an economical driving alone can bring about fuel savings of up to 25% per vehicle. The fact that fuel consumption can be influenced by economical driving is not widely communicated to the public. The public should be given better information about the same. To promote economical driver training for individuals as well as companies, government should positively think to provide financial subsidies to driver training schools.

6.11 Strengthening institutions

India is struggling to address the transportation problem in general and vehicular emission problem in particular mainly because of lack of appropriate institutional capacity. The functional responsibilities for transport are fragmented among central, state and local level governments where no one seems to be in charge of overall coordination. For example, management of urban areas is primarily a responsibility of the state governments in India. However, several key agencies those play an important role in urban transport planning work under the central government, with no accountability to the state or local government. Central government is directly involved in the provision of suburban rail service through Indian Railways in mega cities. Ministry of Road Transport & Highways, Government of India, is responsible for the national highways, including the stretches within urban areas, and local governments have no role in the operations and management of these stretches though they are heavily used for urban transport. State governments independently control local land use policies, motor vehicle and sales tax rates, bus transport systems, policies for private sector participation, etc. Although, Urban Local Bodies (ULBs) in India have been empowered by the Constitution (74th Amendment) Act, 1992 to assume responsibilities for development of urban transport, but most of them have failed to do so due to the lack of financial resources. Therefore, there is an urgent need to strengthen the existing institutions and to establish linkages among them for an effective communication through say setting up of an apex body.

7. Concluding remarks

This study estimated the future traffic mobility, energy demand, and CO_2 emission from road-based passenger transport sector in India. The traffic mobility in India increased at the rate of 7.55% per year between 1990-91 and 2000-01 and is expected to increase at the rate of 6.72% per year between 2000-01 and 2010-11, 4.69% per year between 2010-11 and 2020-21, and 3.01% per year between 2020-21 and 2030-31. Due to this, the traffic volume is projected to increase from 3079 BPKm in 2000-01 to 12546 BPKm in 2030-31. As is the case in developed world, India will also experience greater reliance on private- and para-trasit modes in forthcoming years. It is estimated that during the year 2030-31, 26.8% of the road-based traffic mobility will be provided by the two-wheelers, 21.0% by the cars, 7.5% by the auto-rickshaws, and rest by the buses. Increase in traffic mobility and adverse modal split will have huge implications for energy demand and CO_2 emissions.

In the business as usual scenario, energy demand from the sector is projected to increase at the rate of 8.0% per year from 2000-01 to 2010-11, 6.1% per year from 2010-11 to 2020-21, and 4.7% per year from 2020-21 to 2030-31. Overall road-based passenger transport sector energy use in 2030-31 is projected to be 5897 peta joules. When we assume 1% per year reduction in energy intensity of all modes, energy requirement in 2030-31 is estimated to be 4391 peta joules. Even when we assume 2% per year reduction in energy intensity of all modes, energy requirement will increase from 954 to 3262 peta joiles between 2000-01 and 2030-31. Assuming that the refined oil will continuously fuel the road-based passenger transport sector, CO_2 emission will grow more or less in the same proportion as energy demand. In the business as usual scenario, CO_2 emission is projected to increase from 17.27 to 93.22 million metric tons of carbon equivalent between 2000-01 and 2030-31. CO_2 emission in 2030-31 is projected to be 69.00 million metric tons of carbon equivalent when CO_2 intensity of all modes is assumed to decline at the rate of 1% per year from 2000-01 onwards and 50.81 million metric tons of carbon equivalent when decline in intensity is assumed to be 2% per year. One should note that even when there is a reduction in CO_2 intensity of all modes by 2% per year, CO_2 emission from the sector will increase around 3-fold in a span of three decades.

India's ability to protect environment will depend on its success in promoting policies that keep the economy growing while fulfilling the energy demand in a sustainable manner. Policy should be designed in such a way that it reduces the need to travel by personalized modes and boosts public transport system. This could be achieved by enhancing quantity as well as introducing variety of public transport services. At the same time, there is a need to integrate different modes of public transport, segment supply of public transport system to provide different services for different group of people, enhance productive efficiency of public transport system, and adopt optimal pricing strategies. Since public transport services in India are mainly provided by publicly owned transport companies, there should be an effort to restructure the functioning of these companies. Improving public transport system in isolation may not be very effective tool to reduce energy demand and thus vehicular emission. Demand as well as supply side management measures should be used in such a way so that it encourages people to use public transport. Government needs to use market based instruments to promote cleaner technology and fuel. People should also be encouraged for walking and cycling and government should support investments that make cycling and walking safer. Global warming and health impact of air pollution need to be better understood and communicated to the people to influence public attitude. One should note that public attitudes influence politicians and policy makers and increase the political will to tackle the problems holistically.

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Appendix: Data descriptions

Time series data of road-based passenger traffic volume in India from 1950-51 to 2000-01 has been estimated on the basis of transport services provided by cars (including jeeps and taxis), two-wheelers, auto-rickshaws, and buses. Table A1 reports the population of these vehicles from 1950-51 to 2000-01. The traffic mobility provided by these 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; and Report of Steering Group on Transport Planning (1987), Planning Commission, 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 the main text (see, table 1). 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 are presented in table A2. 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 table 1 in the main text.

Table A1. Passenger vehicle population in thousand and its compound annual growth rate in % age since previous period (in parentheses)

Year	Cars	Two-wheelers	Auto-rickshaws	Buses
1950-51	159.3 (-)	26.9 (-)	1.7 (-)	34.4 (-)
1955-56	203.2 (5.0)	41.0 (8.8)	2.5 (8.8)	46.5 (6.2)
1960-61	309.6 (8.8)	88.4 (16.6)	6.2 (19.9)	56.8 (4.1)
1965-66	455.9 (8.0)	225.6 (20.6)	16.1 (20.8)	73.2 (5.2)
1970-71	682.0 (8.4)	576.0 (20.6)	36.7 (17.9)	91.4 (4.5)
1975-76	779.0 (2.7)	1057.0 (12.9)	59.4 (10.1)	114.2 (4.6)
1980-81	1160.0 (8.3)	2618.0 (19.9)	142.1 (19.0)	153.9 (6.2)
1985-86	1780.0 (8.9)	6245.0 (19.0)	336.9 (18.9)	227.6 (8.1)
1990-91	2954.0 (10.7)	14200.0 (17.9)	617.4 (12.9)	331.1 (7.8)
1995-96	4204.0 (7.3)	23252.0 (10.4)	1009.0 (10.3)	449.0 (6.3)
2000-01	7058.0 (10.9)	38556.0 (10.6)	1725.4 (11.3)	560.0 (4.5)

Source: Statistical Abstract India, various issues; Published by CSO, GOI, New Delhi.

Table A2. Growth of Indian bus industry; 1950-51 to 2000-01

Year	Bus population (thousand)	Average annual utilization (Kms)	Occupancy ratio (percent)	BPKm
1950-51	34.4	36000	45	29
1955-56	46.5	41000	51	51
1960-61	56.8	46000	59	80
1965-66	73.2	54000	60	123
1970-71	91.4	59000	73	205
1975-76	114.2	68000	76	307
1980-81	153.9	79000	80	506
1985-86	227.6	80000	80	757
1990-91	331.1	87000	80	1198
1995-96	449.0	98000	80	1830
2000-01	560.0	100000	80	2330

Note: BPKm figure is rounded off to zero decimal place.
Source: Data compiled and estimated by the author from various sources such as: (1) Singh and Kadiyali (1990), (2) State Transport Undertakings: Profile and Performance published by the CIRT, Pune, India; various issues, and (3) TERI Energy Data Directory & Yearbook (TEDDY) published by the TERI, New Delhi; various issues.