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16. Abstract

The present report was designed to analyze the traffic safety situation in India, and to identify countermeasures for areas in which the total harm caused by crashes can be substantially and readily reduced. The report focuses on two aspects of traffic safety in India: challenges and opportunities. The first part of the report provides a comprehensive analysis of the current traffic safety situation in India. It is pointed out in this analysis that fatality rates have increased both on highways and in urban areas during the past few years. Theoretical models suggest that the number of fatalities in India is not likely to start to decline for many years to come unless new policies are implemented. Based on the present analysis, the following six areas are identified as having potential for substantially reducing fatalities in India: (1) pedestrians and other non-motorists in urban areas, (2) pedestrians, other non-motorists, and slow vehicles on highways, (3) motorcycles and small cars in urban areas, (4) over-involvement of trucks and buses, (5) nighttime driving, and (6) wrong-way drivers on divided highways. The second part of the report outlines several promising countermeasures for each of these six areas. The third part of the report presents a brief comparison of major traffic safety challenges in India and China.

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Dinesh Mohan's contribution was prepared while he was a visiting research scientist at UMTRI from the Transportation Research and Injury Prevention Programme, Indian Institute of Technology Delhi, New Delhi, India.

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CHALLENGES: ROAD SAFETY IN INDIA

Introduction

According to official statistics, 105,725 people were killed in road traffic crashes in India in 2006 (NCRB, 2007). The situation in India has worsened in recent years. Traffic fatalities increased by about 5% per year from 1980 to 2000, and since then have increased by about 8% per year for the four years for which statistics are available (Figure 1). This is attributable partly to an increase in the number of vehicles on the road, and partly to the absence of a coordinated official policy to control the problem. The fatality rate has increased from 36 fatalities per million persons in 1980 to 95 fatalities per million persons in 2006.

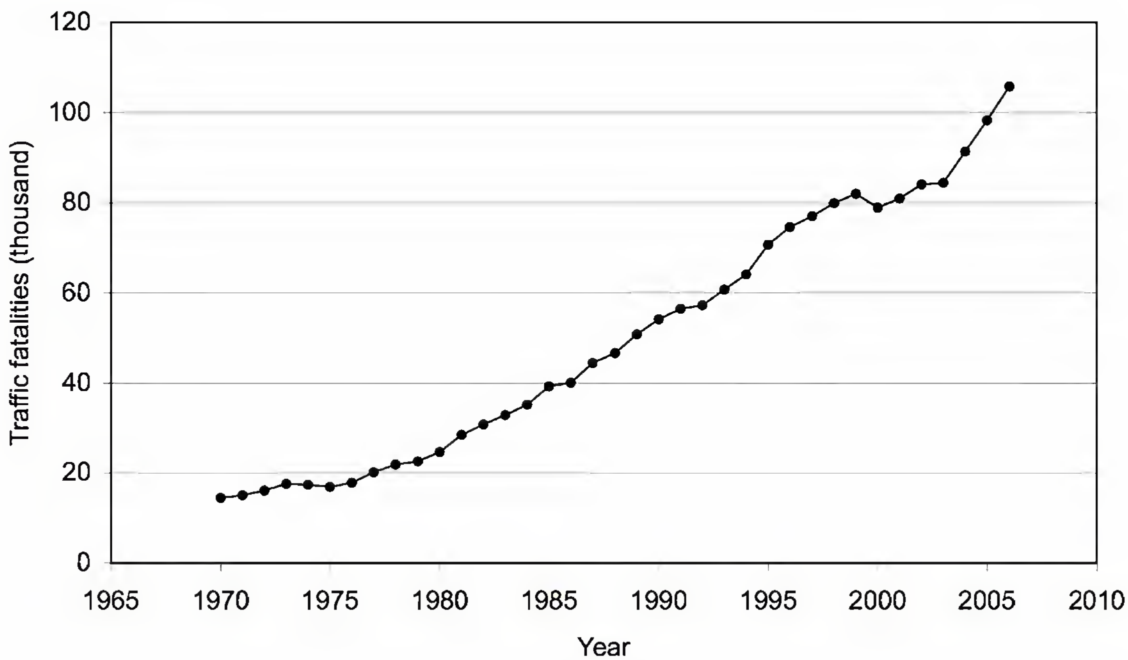

Figure 1. Traffic fatalities, 1970 through 2006.

The total motor vehicle population has increased from about 300,000 in 1951 to about 73,000,000 in 2004 (see Figure 2). (The actual number of motor vehicles in the country may be 20-30% lower, as registration procedures do not remove many of the out-of-service vehicles from the records. This issue is dealt with in more detail in a later section.) The numbers and percents of various types of vehicles registered (in 2004) and sold (in 2007) in India are given in Table 1. Most notably, motorcycles are more than five times as numerous as cars. It is also interesting that the total of buses, trucks, and other vehicles is similar in magnitude to the number of cars. These proportions of vehicle types are different from those in the high-income countries and can influence fatality rate patterns. In the U.S. in 2005, for example, passenger cars constituted 66% of vehicles on the road; trucks, and vans constituted 30%; motorcycles were only 3%; and buses 1%.

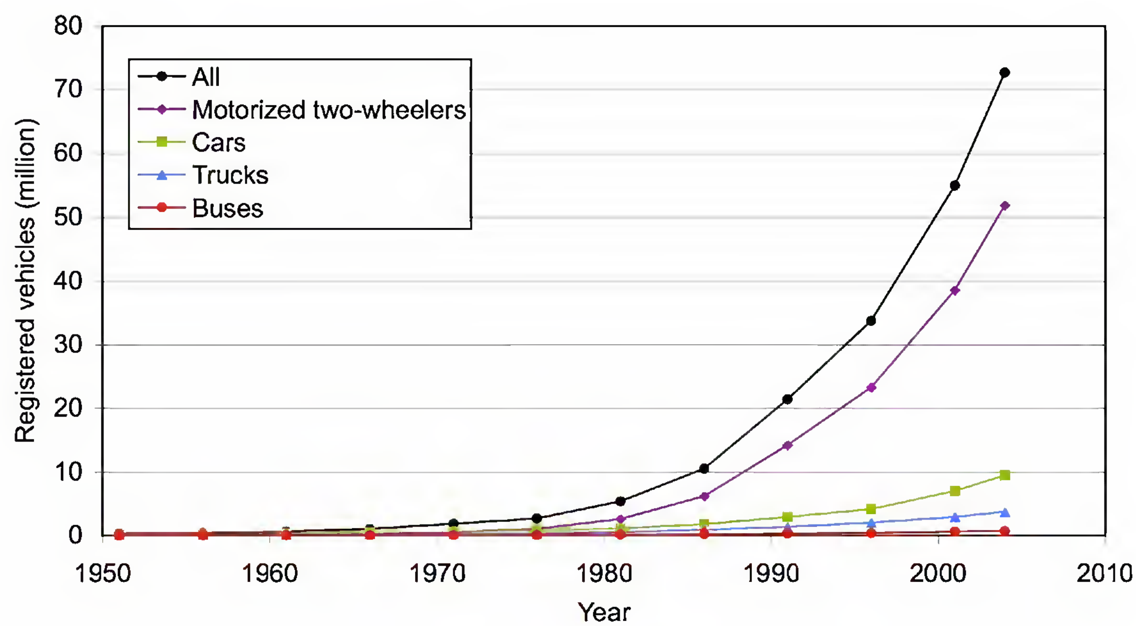

Figure 2. Registered vehicles, 1951 through 2004 (Department of Road Transport and Highways, 2008a).

Table 1
Vehicle fleet by type.

<table>
<tr><th rowspan="2">Vehicle type</th><th colspan="2">Registered (2004)*</th><th colspan="2">Sold (2007)**</th></tr>
<tr><th>Number (million)</th><th>Percent</th><th>Number (million)</th><th>Percent</th></tr>
<tr><td>Motorized two-wheeler</td><td>51.92</td><td>71</td><td>7.42</td><td>78</td></tr>
<tr><td>Car</td><td>9.45</td><td>13</td><td>1.27</td><td>13</td></tr>
<tr><td>Bus</td><td>0.77</td><td>1</td><td rowspan="2">0.48</td><td rowspan="2">5</td></tr>
<tr><td>Truck</td><td>3.75</td><td>5</td></tr>
<tr><td>Other</td><td>6.83</td><td>9</td><td>0.38</td><td>4</td></tr>
<tr><td>Total</td><td>72.72</td><td>100</td><td>9.55</td><td>100</td></tr>
</table>

* Department of Road Transport and Highways (2008a).
** Society of Indian Automobile Manufacturers (2008).

The gross national income per capita in India in 2006 was US$ 820 (or US$ 2,460 in purchasing power equivalent), while the corresponding values for the U.S. were US$ 44,710 and 44,070 (World Bank, 2008). The Indian economy has been growing at about 8% per year for the past five years and is expected to grow at an average of 8-10% per year over the next five years (Planning Commission, 2006). Car and motorized two-wheeler sales have averaged 16% and 9% annual growth rates, respectively, over the past five years. The trends are illustrated in Figure 3. Although the recent global economic turmoil is likely to affect sales, we can expect some level of sales growth to continue into the future. However, major increases in fuel prices are likely to have a greater negative influence on sales of cars than on sales of motorized two-wheelers.

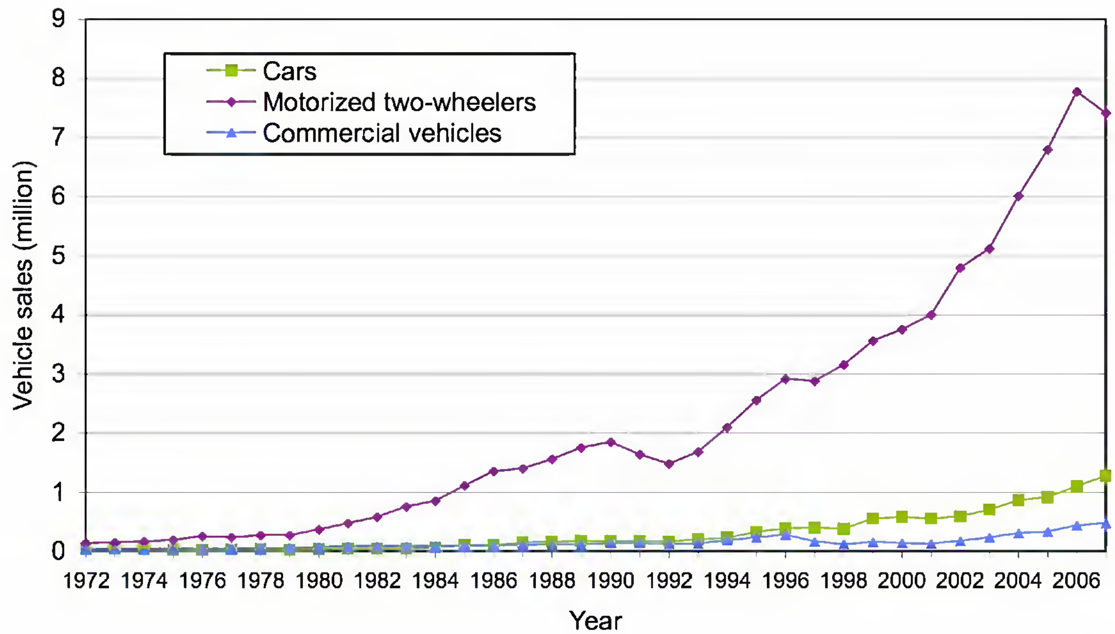

Figure 3. Vehicle sales, 1972 through 2006 (Society of Indian Automobile Manufacturers, 2008).

India has a rural road network of over 3,000,000 km, and urban roads total more than 250,000 km. The national highways, with a total length of 65,569 km, serve as the arterial network across the country. Roads carry about 61% of the freight and 85% of the passenger traffic. Highways total about 66,000 km (2% of all roads) and carry 40% of the road traffic. The ongoing project of four-laning the 5,900-km Golden Quadrilateral connecting Delhi, Mumbai, Chennai, and Kolkata is nearing completion. The ongoing four-laning of the 7,300-km North-South East-West corridor is to be completed by December 2009. The National Highway Development Programme, involving a total investment of US$ 55 billion up to 2012, has been proposed for constructing 1,000 km of new expressways, six-laning 6,500 km of the four-lane highways comprising the Golden Quadrilateral and certain other high-density stretches, four-laning the Golden Quadrilateral and NS-EW corridors, four-laning 10,000 km of high-density national highways, and upgrading 20,000 km of smaller rural roads into two-lane highways (Committee on Infrastructure, 2008; Department of Road Transport and Highways, 2008b).

In urban areas, road development has been helped by a national urban renewal mission program, through which the central government assists city governments with federal funds (Ministry of Urban Development, 2006). With a combination of higher investments in urban and rural road infrastructure, increasing sales of motor vehicles, and 7-10% growth rates in the economy, the trend of increasing road traffic fatalities may be exacerbated if corrective policies are not put in place on an urgent basis. The government of India has indicated its concern by accepting the Report of the Committee on Road Safety and Traffic Management, which has recommended that a National Road Safety Agency be established in India through specific enabling legislation on road safety (Committee on Infrastructure, 2007). This proposal is under consideration by the national government.

The goal of the present report is to identify major road safety problems in India and to discuss countermeasures that have promise to address these specific road safety problems. A similar report for the situation in China was recently completed (Zhang, Tsimhoni, Sivak, and Flannagan, 2008). The first part of the present report examines the available crash data and identifies a limited number of important areas that are especially characteristic of the current road safety situation in India, and for which relatively specific countermeasures are available. The second part discusses several promising countermeasures. In this discussion, we have organized the treatment of countermeasures in terms of an analysis that describes the total harm from road crashes as the product of three components: exposure, risk, and consequences (Thulin and Nilsson, 1994; Sivak and Tsimhoni, 2008).

Analysis of national data, trends, and distributions

As indicated above, according to official statistics, 105,725 people were killed and 452,922 people were injured in road traffic crashes in India in 2006 (NCRB, 2007). However, a study done in Bangalore shows that while the number of traffic crash deaths recorded by the police may be reasonably reliable, the total number of injuries is grossly underestimated (Gururaj, 2006). According to that study, deaths were underestimated by 5% and the number injured who needed treatment in hospitals was underestimated by more than a factor of two. In that study, the ratio of injured people reporting to hospitals versus those killed was 18:1. It is important to note that even this ratio would be an underestimate, as many of the injured would not have gone to a hospital, but would have taken treatment at home or from private medical practitioners. Another detailed study done in rural northern India recorded all traffic-related injuries and deaths through bi-weekly home visits to all households in 9 villages for a year and showed that the proportional numbers of critical, serious, and minor injuries were 1:29:69 (Varghese and Mohan, 2003). In 2006 in the U.S., 42,642 people were reported killed and 2,575,000 injured, giving a ratio of 1:60 for recorded fatalities to injuries (NHTSA, 2008). Other studies report ratios among deaths, serious injuries, and minor injuries as 1:13:102 (Martinez, 1996) and 1:14:80 (Evans, 1991).

Using the epidemiological evidence from India and other countries where better records are available, a conservative estimate can be made that the ratios among deaths, injuries requiring hospital treatment, and minor injuries in India are likely about 1:15:70. If the estimate of road traffic fatalities in India in the year 2006 is taken as 110,000, then the estimate of serious injuries requiring hospitalization would be 1,650,000, and that for minor injuries would be 7,700,000. For a national population of 1,120 million in 2006, this gives rates of 98, 1,474, and 6,876 fatalities, serious injuries, and minor injuries per million persons, respectively. In this report we use fatality figures for most analyses because they are much more reliable than injury statistics.

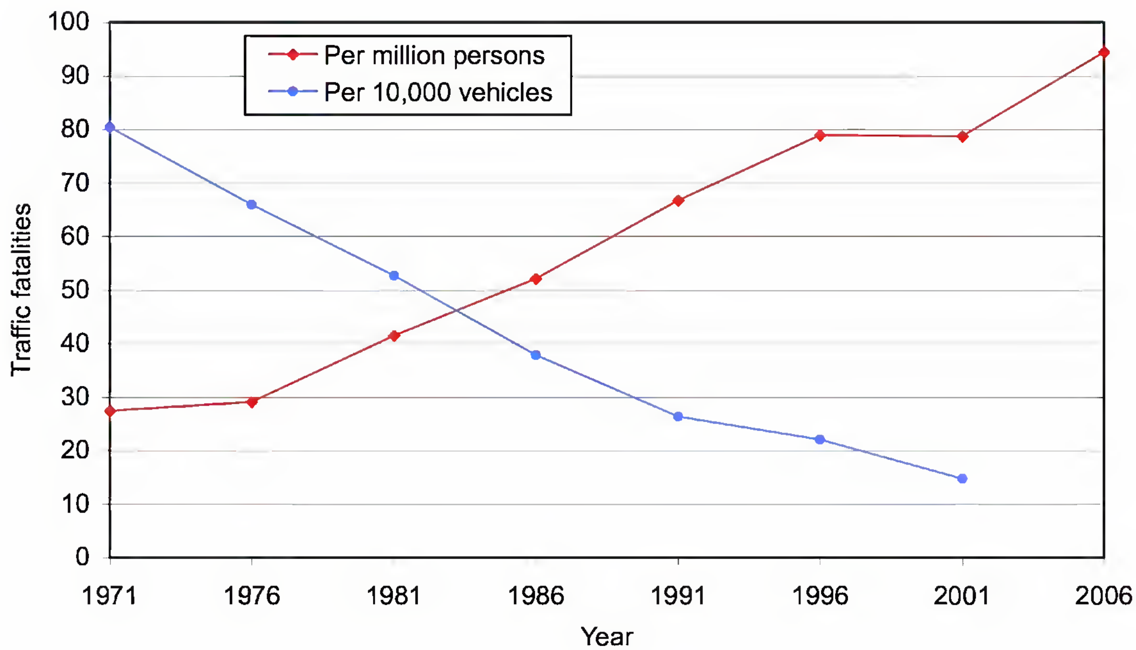

Figure 4. Traffic fatality rates, 1971 through 2006 (NCRB, 2007).

Figure 4 shows the trends for fatalities per million persons and per 10,000 vehicles in India. Fatalities per million persons indicate the national health burden of traffic crashes. For India, this ratio has been increasing continuously for the last four decades, reaching 98 in 2006. The number of fatalities per 10,000 vehicles has decreased from about 80 in 1970 to 15 in 2004. However, this reduction in fatalities per vehicle does not necessarily indicate improvement in safety conditions on the road. As the per-capita availability of motor vehicles increases, fatalities per vehicle always decrease (Smeed, 1972; Kopits and Cropper, 2005), and therefore, a decrease in this ratio is not necessarily an indicator of road safety conditions. What matters is the risk per trip, even at the individual level, as most trips are necessary for human activity. The need for trips to work places, educational institutions, and destinations for socializing/shopping does not change substantially with income levels. Although modes of transportation may change, the number of trips per person remains approximately constant over time and income (Knoflacher, 2007). Therefore, traffic fatalities per unit population can be taken as a rough indicator of risk faced by individuals. In this report, we use traffic fatalities per unit population as an indicator of the health of the society at the city, region, or national level.

Figure 5 shows fatality rates in various countries as a function of per-capita income. The Indian fatality rate (represented by the red square) is in the middle of the range for low-income countries (Mohan, 2004). The fatality rates in mid-income countries range between half that of India to five times greater. As incomes in India increase along with motor-vehicle use, the present trends in India and the experience of some mid-income countries suggest that fatalities could see a dramatic rise before they start to drop, consistent with the so-called Kuznets curve (e.g., McManus, 2007). However, future trends may be altered if vehicle design, road building, and traffic management policies include the latest scientific countermeasures.

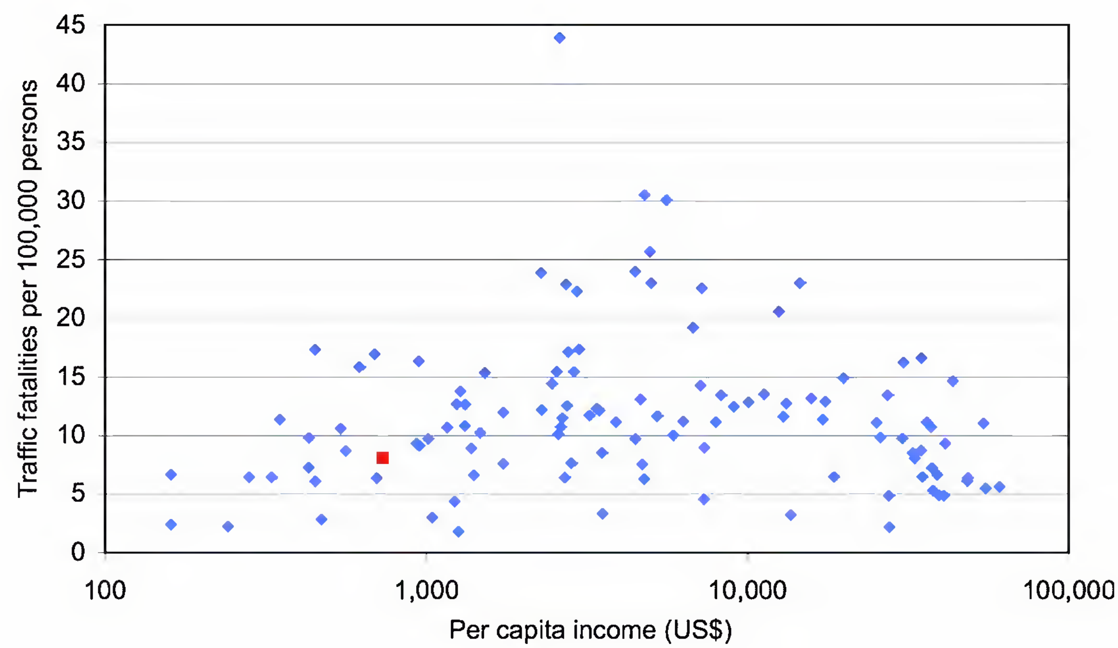

Figure 5. Traffic fatality rates per 100,000 persons in 115 countries. India is represented by the red square.

Age and sex distribution

Figure 6 shows the age distributions of population (projection; Census of India, 2001) and traffic fatalities in India (NCRB, 2007) in 2006. Children age 14 years and younger comprise only 7% of the fatalities, though their share in the population is 32%. The proportion of fatalities in the age groups 15-29 and greater than 60 years is similar to their representation in the population, but the middle-age groups 30-44 and 45-59 are overrepresented by about 70%. The overrepresentation is likely because people in these age groups are in their prime working years, and are thus more likely to be present on the road.

The low representation of children (2 fatalities per 100,000 persons) (NCRB, 2007) is curious because a significant number of children walk and bicycle to school unescorted, both in urban and rural areas. In comparison, children account for 4.4% of the total fatalities in the U.S. (FARS, 2008), and 20% of the total population (U.S. Census Bureau, 2008). Though the exposure numbers for India are not available, children's presence on the road unsupervised is not insignificant. The reasons for this low involvement rate need to be investigated further.

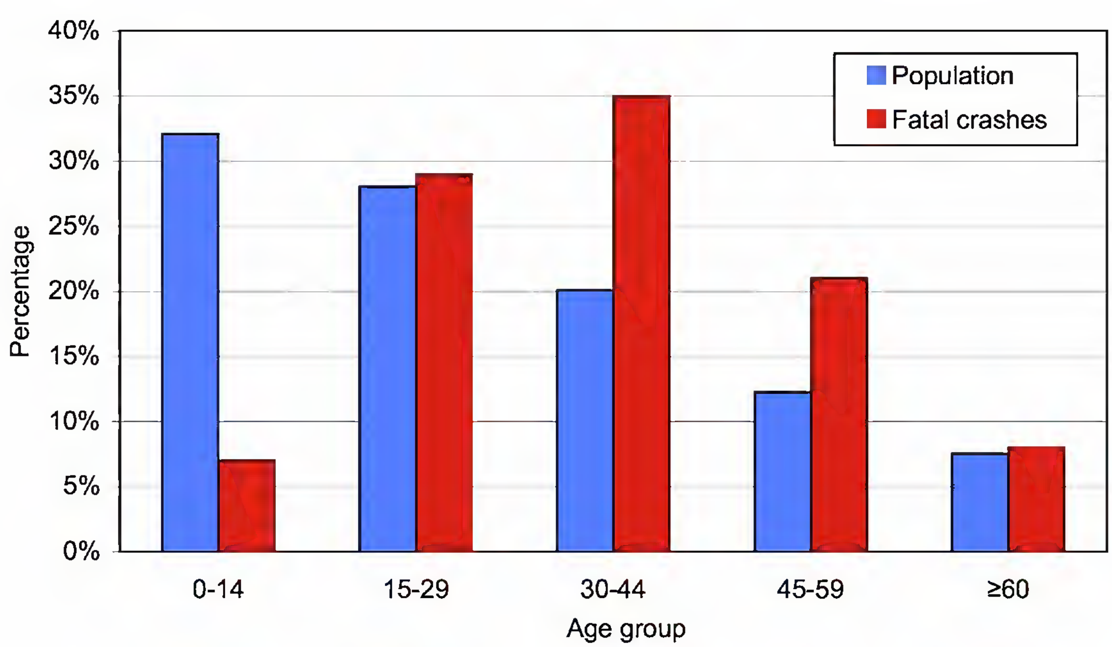

Figure 6. Age distribution of population and traffic fatalities, 2006.

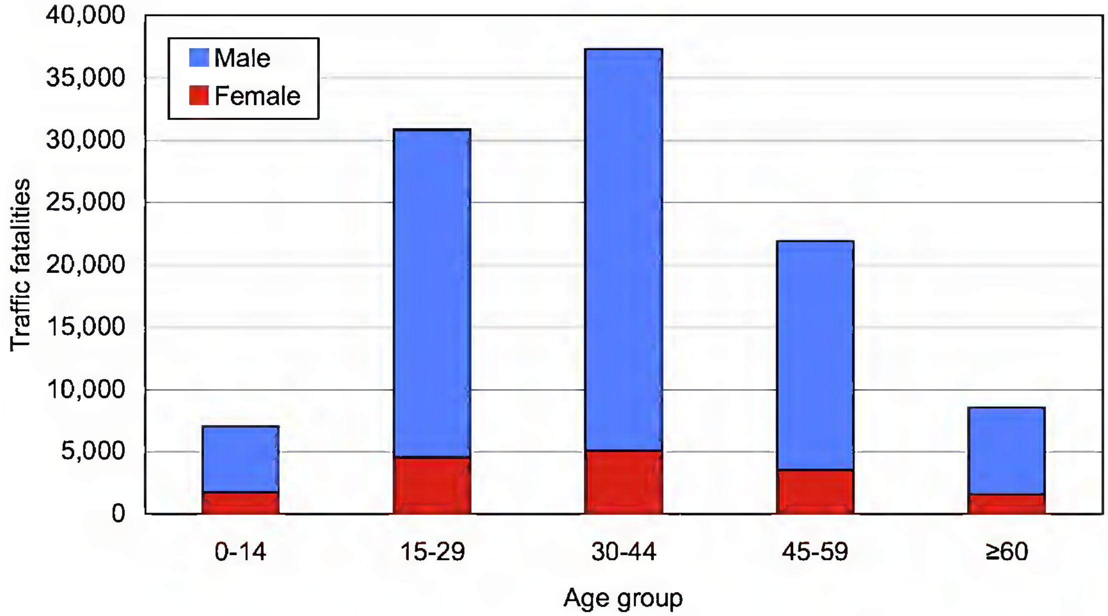

Figure 7. Traffic fatalities by gender, 2006.

Figure 7 shows fatalities by age for males and females (NCRB, 2007). Among children, the male fatality rate is greater than that of females by a factor of 2.8, whereas among older groups the male-to-female ratio ranges between 4:1 and 6:1 (which may be partly explained by the exposure of older groups on rural and urban roads). The primary and secondary school enrollment ratios for males to females are reported to be 1.07:1 and 1.26:1, respectively (UNICEF, 2007). However, this does not fully explain the difference. The male-to-female ratio of adult literacy rate in India is 1.5:1 (UNICEF, 2007), and the male-to-female ratios of labor force in rural and urban areas are 1.7:1 and 3.5:1, respectively (National Sample Survey Organisation, 2005). This may partly account for the exposure of males and females on urban and rural roads. In the U.S., by comparison, the fatal crash involvement rate per 100,000 persons in 2006 was almost three times higher for male drivers than for females (NHTSA, 2008). Males accounted for 70% of all traffic fatalities, 69% of all pedestrian fatalities, and 88% of all bicyclist fatalities in 2006. For all traffic fatalities, the male-to-female ratio of 2.3:1 in the U.S. is lower than that in India. Higher female participation in the work force and presence on the roads may partly account for this difference.

Temporal factors

Figure 8 shows fatalities by month and Figure 9 shows fatalities by time of day (NCRB, 2007). For the country as a whole, monthly variations are not substantial, but hourly variations are. The fatalities remain relatively constant and high during working hours, and low during early hours of the morning. However, no detailed information is available to analyze the contributing factors.

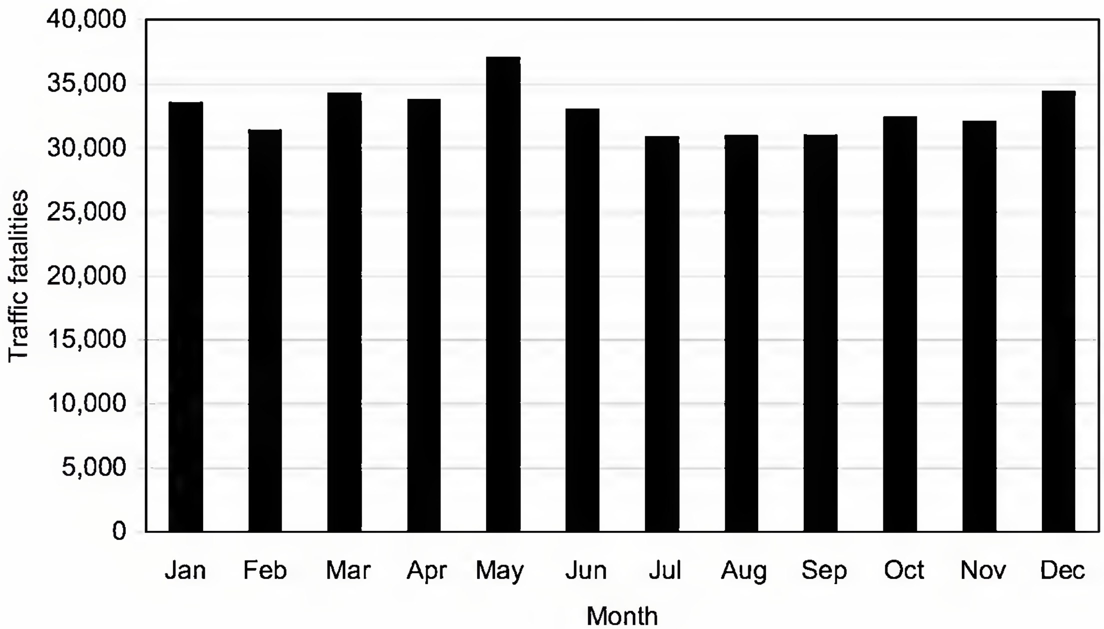

Figure 8. Traffic fatalities by month, 2006.

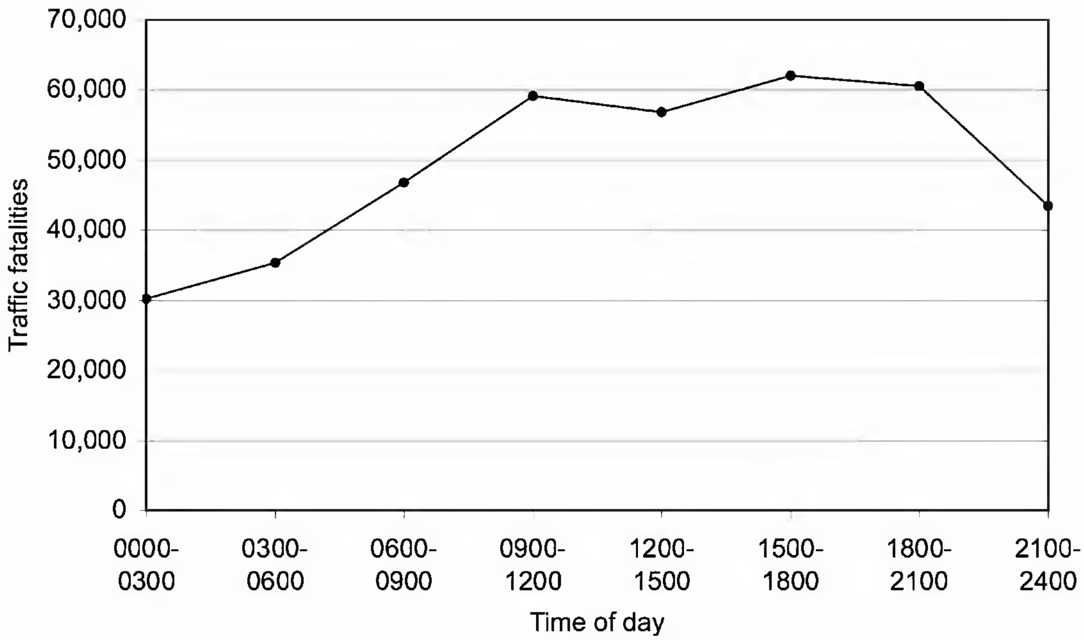

Figure 9. Traffic fatalities by time of day, 2006.

Road users killed in traffic crashes

Data for road user types killed are not available at the national or state levels in India. Some cities maintain such details locally, but data are not available for all cities in the country. Proportions of road users killed in the late 1990s in the cities of Mumbai and Delhi and selected highway locations are given in Table 2 (Mohan and Tiwari, 2000). These data show that car occupants were a small proportion of the total fatalities. Pedestrians, bicyclists, and motorized two-wheeler riders accounted for 60-90% of all traffic fatalities. This pattern is very different from that obtained in all high-income countries.

Table 2
Traffic fatalities by road user and type.

Type of road user	Location (percent)		
	Mumbai	Delhi	Highways*
Truck	2	2	14
Bus	1	5	3
Car	2	3	15
Three-wheeled scooter taxi	4	3	-
Motorized two-wheeler	7	21	24
Human and animal powered vehicle	0	3	1
Bicycle	6	10	11
Pedestrian	78	53	32
Total	*100*	*100*	*100*

* The data are for 14 selected locations, and thus might not be representative for the entire country. (Tractor fatalities are not included.)

Analysis of state-level data

India is divided into 28 states and 7 union territories, the latter being administered by the central government. Among the states, Sikkim has the smallest population (540,493) and Goa the smallest area (3,702 km^2), whereas Uttar Pradesh has the largest population (166,052,859) and Rajasthan the largest area (342,239 km^2). The union territories are relatively smaller: Lakshadweep has the smallest population (60,595) and area (32 km^2), Delhi (capital of India) has the largest population (13,782,976), and Andaman and Nicobar Islands the largest area (8,249 km^2). Among the states, Arunachal Pradesh (13 persons per km^2) and West Bengal (904 persons per km^2), and among the union territories, Andaman and Nicobar Islands (43 persons per km^2) and Delhi (9,294 persons per km^2) have the lowest and highest population densities (Registrar General & Consensus Commissioner India, 2008; all statistics are for 2001). These data show that the various states have widely varying characteristics.

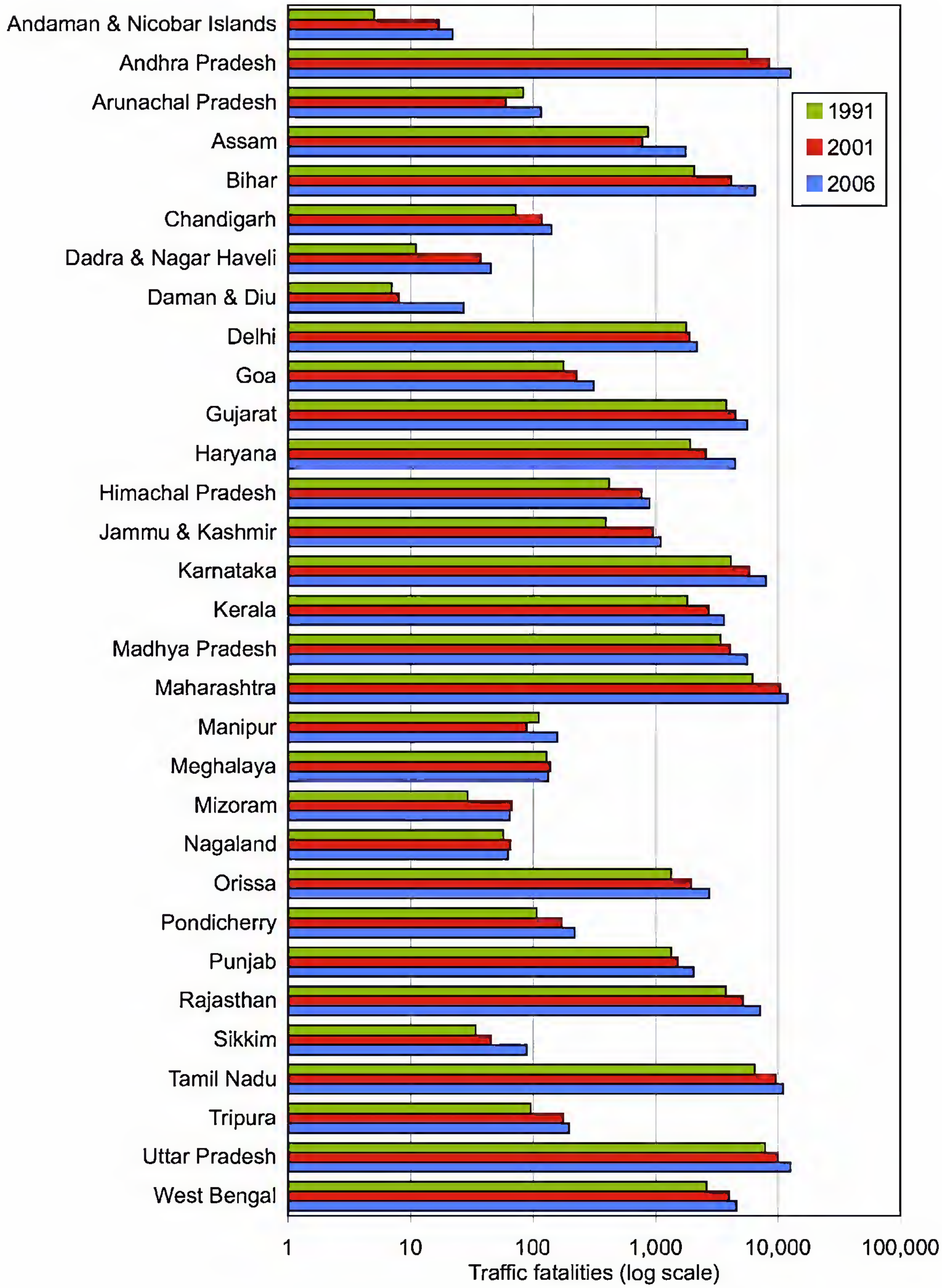

Figure 10. Traffic fatalities by state and territory (NCRB, 2007).

Figure 10 shows the total number of fatalities by state and territory from 1991 to 2006. Manipur, Meghalaya, Mizoram, Nagaland, and Tripura are small states with hilly terrain. Andaman and Nicobar Islands, Dadra and Nagar Haveli, Daman and Diu, Lakshadweep, Puducherry, Chandigarh and Delhi are union territories, which are generally small, and the last two are cities. Therefore, these regions can have different traffic and fatality patterns. Regardless, the total number of fatalities increased by more than 70% in most regions between 1991 and 2006.

Figure 11 shows the fatalities per million population and Figure 12 the ratios between fatalities per million population in 2006 and 1991. Fatality rates per million population also increased in most regions except in the northeastern hilly states and the city of Delhi. The increase was 50% or more in 11 states and union territories. Figure 13 shows the fatality rate (per million persons) as a function of the population density in states and territories. There does not seem to be a strong correlation of fatality rates with population density.

Figure 14 shows the association between fatalities per 100,000 persons (2003) and income per-capita of states (expressed in 2003 US$) (Ministry of Statistics and Programme Implementation, 2008). Figure 15 shows the relationship between increasing incomes and vehicle ownership. These data show that states with higher per-capita incomes generally have higher vehicle ownership and higher fatality rates. Many policy makers identify this increasing vehicle ownership as the cause for higher fatality rates. However, increasing vehicle ownership need not result in increased fatality rates if adequate safety measures are implemented.

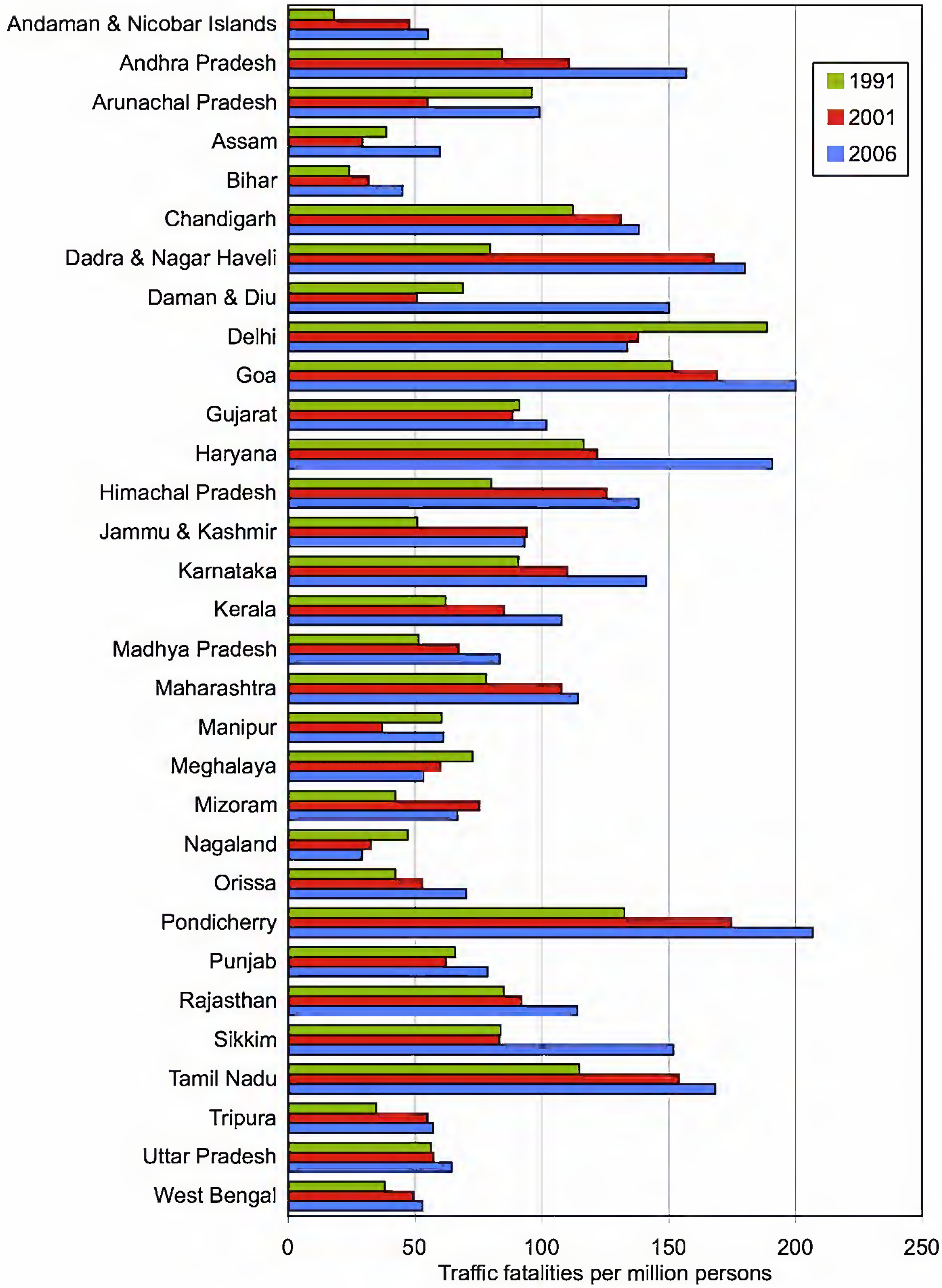

Figure 11. Traffic fatality rates per population by state and territory (NCRB, 2007).

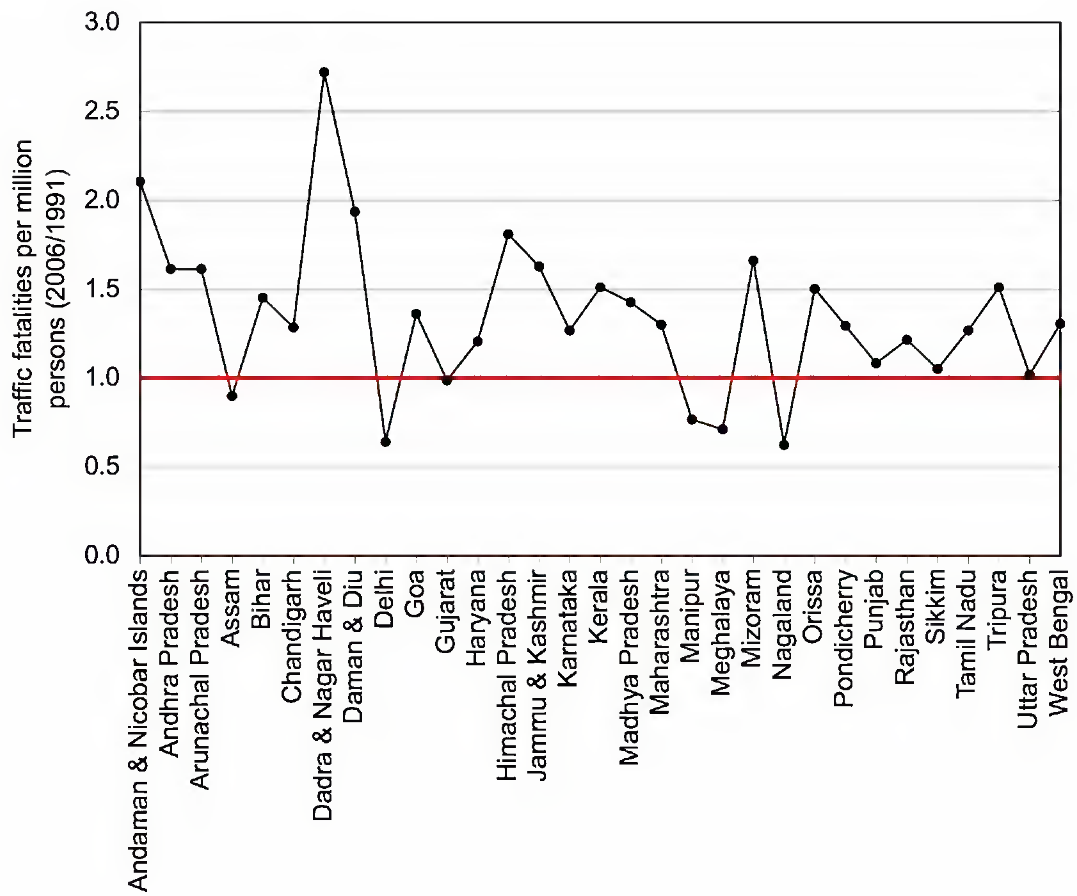

Figure 12. Change in traffic fatalities per population from 1991 to 2006 by state and territory.

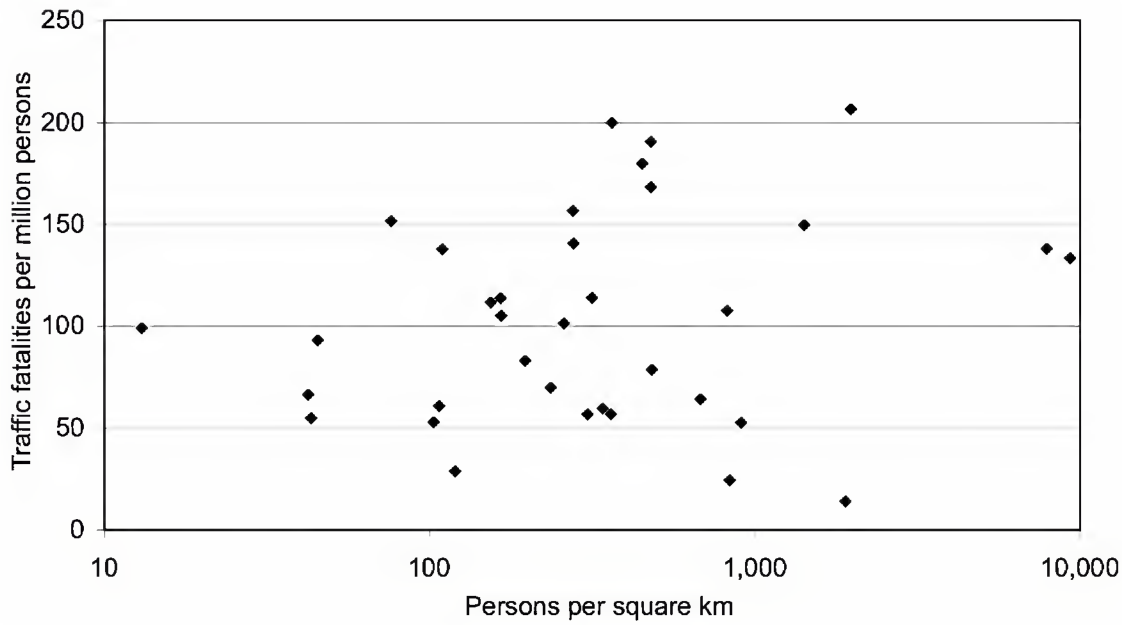

Figure 13. Relationship between traffic fatalities per million persons and population density for states and territories in 2006 (NCRB, 2007).

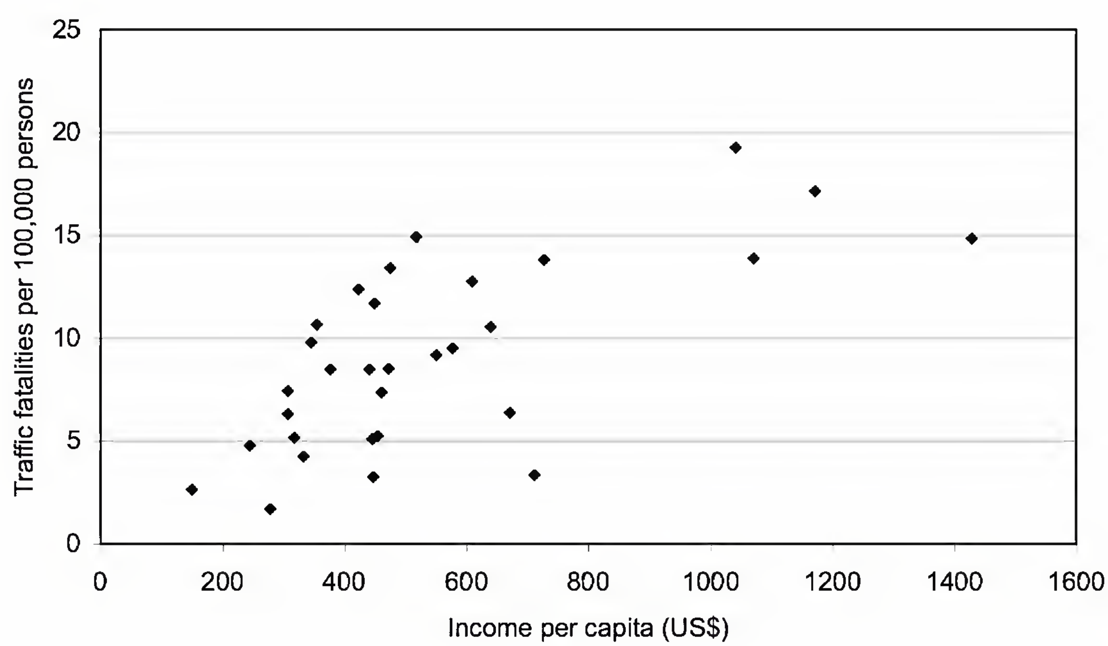

Figure 14. Traffic fatalities per 100,000 persons vs. income per capita for states and territories, 2003 (Ministry of Statistics and Programme Implementation, 2008; NCRB, 2007).

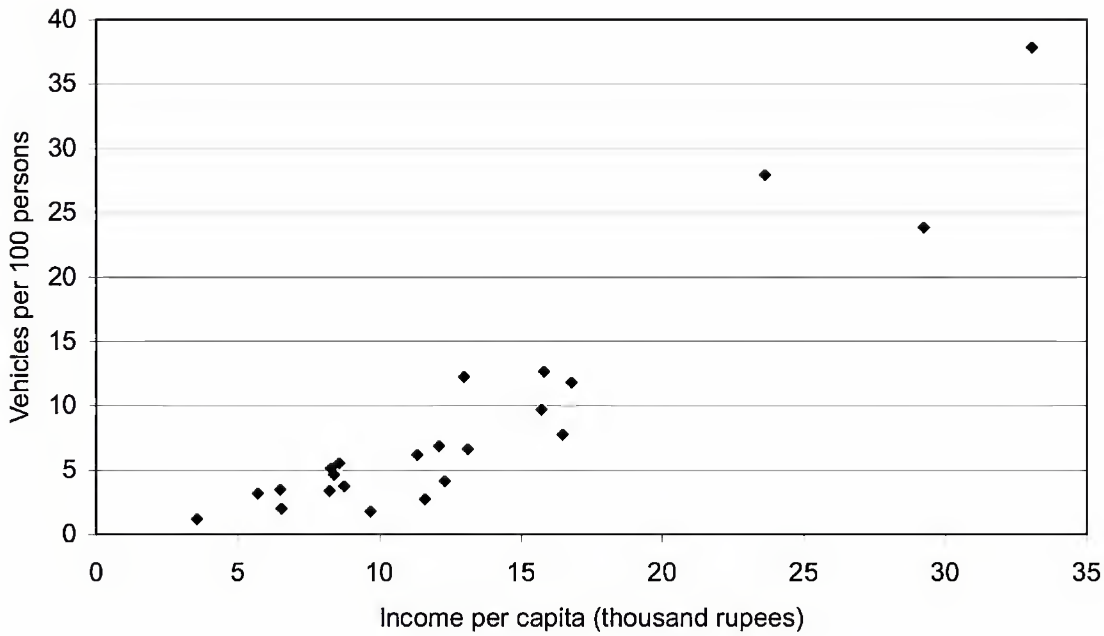

Figure 15. Vehicle ownership vs. income per capita for states and territories, 2003 (Department of Road Transport and Highways, 2008a; Ministry of Statistics and Programme Implementation, 2008).

Many countries with higher vehicle ownership rates than India have lower fatality rates (Table 3), but all of these countries with lower fatality rates have high incomes (IRF, 2007). Kopits and Cropper (2005) suggest that the income per-capita at which the motor vehicle fatality rate begins to decline is approximately $6,100 (1985 international dollars) when a common time trend is assumed for all countries, and $8,600 when separate time trends are used for each geographic region. Koornstra (2007), using a cyclically modulated risk decay function model, predicts that countries like India are unlikely to see declining rates before 2030. The income per-capita in India was estimated at US$ 820 in 2006 (World Bank, 2008). At an average growth rate of 8% per year, the per capita income of India in 2030 would be US$ 5,200. Therefore, if we depend on current traffic management and road design policies, Indian states can expect increasing death rates into the foreseeable future according to both scenarios. This is clearly not desirable.

Table 3
Fatality rates in selected countries, 2005.

Country	Vehicles per 100 persons	Fatalities per 100,000 persons
Sweden	51	4.9
Netherlands	48	4.9
United Kingdom	51	5.3
Switzerland	56	5.5
Norway	55	5.6
Denmark	44	6.1
Iceland	72	6.4
Germany	58	6.5
Japan	59	6.6
India*	7	9.5

** Estimates for 2006*

Safety policies depend on changes in vehicle design, road infrastructure, and enforcement to bring down injury and fatality rates. Because car occupants are a small proportion of all fatalities, and are likely to remain so in the near future, improvements in car design are not likely to have as large an effect on overall fatalities as they had in high-income countries in the past 30 years. In any event, a large proportion of cars sold in India already conform to international standards, and safety regulations are expected to be fully aligned with the ECE by 2010 (Government of India, 2006).

Intercity roads

India has a total road network of 3.3 million km. The distribution of various categories of roads is shown in Table 4, and the share of national highways by road length is shown in Table 5 (Department of Road Transport and Highways, 2008c). The total length of access-controlled highways is less than 600 km at present. Although national highways constitute only about 2% of the total road network, about 40% of the total road traffic moves on these roads. The Ministry of Road Transport and Highways administers the national highway system, while state highways and other state roads are maintained by state public works departments, and other, more local roads are maintained by municipalities, districts, and villages.

Table 4
Total length of roads by category.

Road category	Total length (km)
National highway	66,754
State highway	128,000
District road	470,000
Rural road	2,650,000
Total	*3,314,754*

Table 5
Total length of national highways by width.

Highway width	Total length (km)	Percent
1 lane, intermediate lane	18,350	27
2 lanes	39,079	59
4-8 lanes	9,325	14

Figure 16 shows the proportions of fatalities on different categories of roads in Indian states. This figure shows that about two-thirds of the fatalities take place on national and state highways, which are mainly intercity roads (Ministry of Shipping, Road Transport and Highways, 2006). Fatality rates per 100 km of national highway in 2004 for states with largely non-hilly terrain are plotted in Figure 17 as a function of income per capita (Ministry of Shipping, Road Transport and Highways, 2006; Department of Road Transport and Highways, 2008c; Ministry of Statistics and Programme Implementation, 2008). Table 6 shows the fatality rates for states with hilly terrain. The average fatality rate for national highways in non-hilly states was 59 persons per km per year in 2004, whereas the same rate in hilly states was 16.

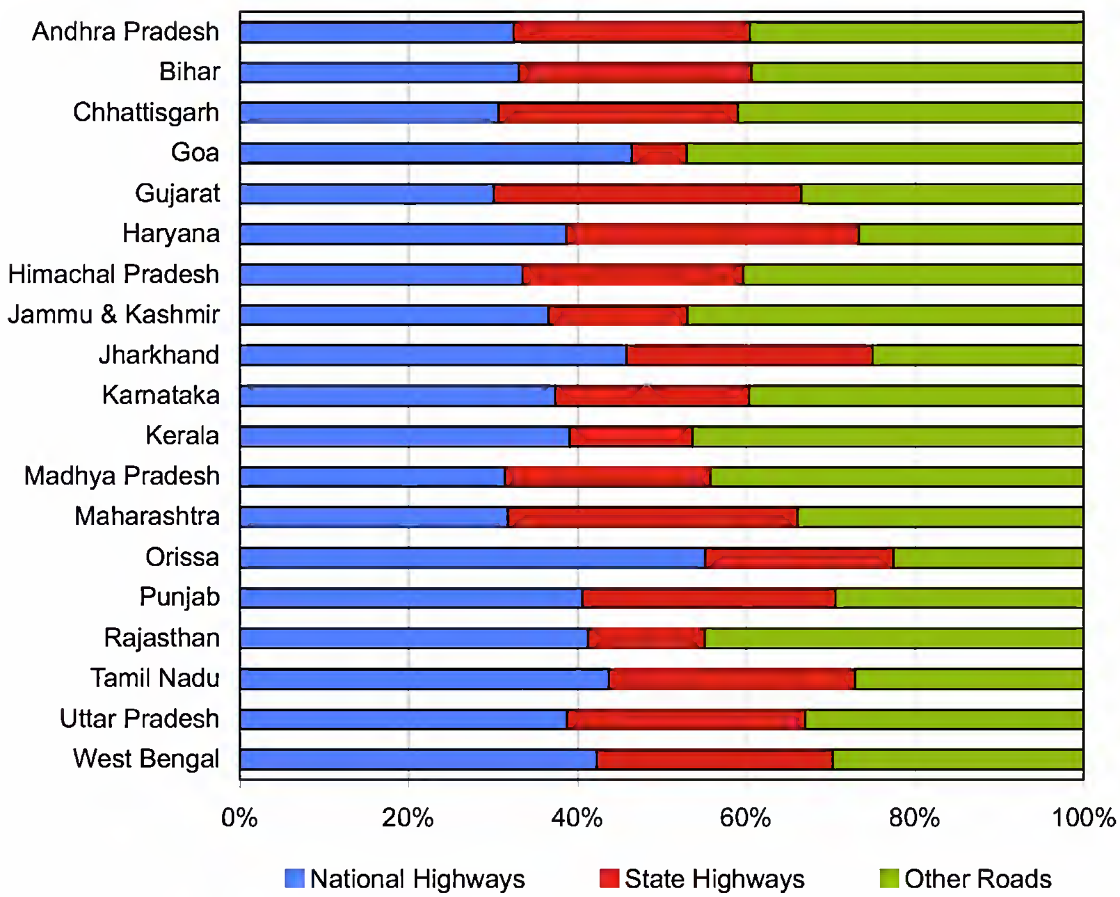

Figure 16. Percentages of traffic fatalities by road category and state or territory, 2004.

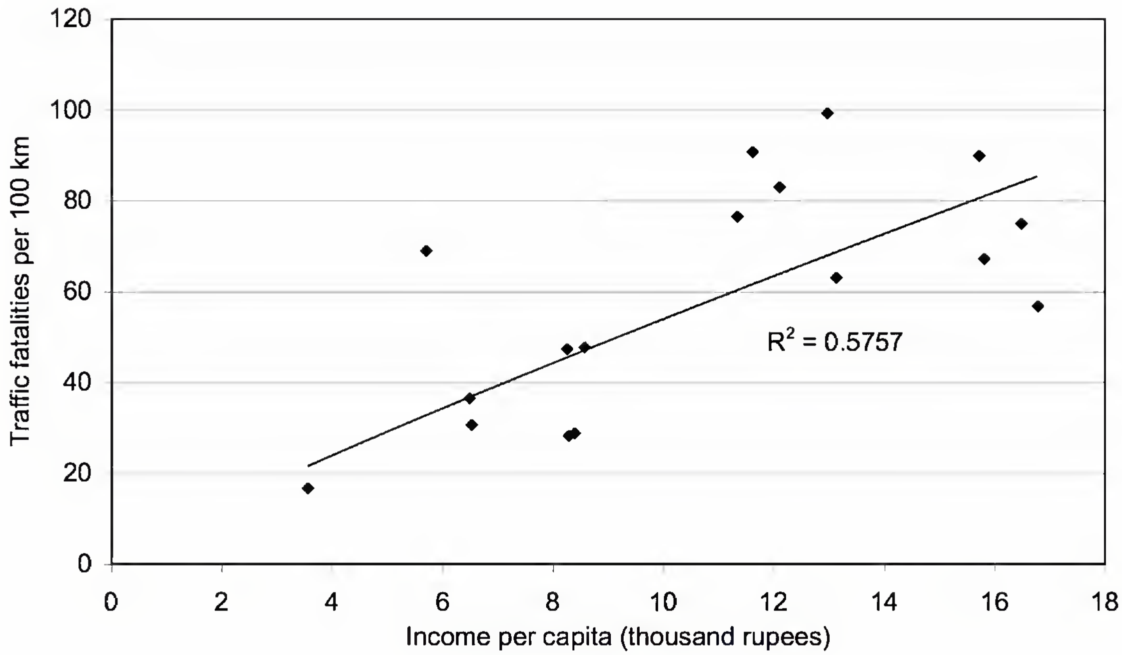

Figure 17. Traffic fatality rates on national highways in states with non-hilly terrain vs. income per capita, 2004.

Table 6
Fatalities on national highways in hilly states, 2004.

States	Fatalities, number	Length (km)	Fatalities per 100 km
Jammu & Kashmir	350	823	43
Himachal Pradesh	280	1,208	23
Uttaranchal	425	1,991	21
Arunachal Pradesh	67	392	17
Meghalaya	87	810	11
Nagaland	36	494	7
Manipur	53	959	6
Mizoram	36	927	4
		Mean	*16*

Detailed data are not available at the national or state level for crashes on national highways. A study sponsored by the Ministry of Road Transport and Highways collected data on modal shares, vehicle speeds, and traffic crashes on selected locations on national and state highways around the country in the late 1990s (Tiwari, Mohan, and Gupta, 2000). Figure 18 shows the type of road users killed on highways and the impacting vehicles, respectively. Two findings are of particular interest. First, the fatalities in this sample included 32% of motor-vehicle occupants and 68% of vulnerable road users. Though the motor vehicle fatalities were higher on highways than in urban areas, as would be expected, their proportion was not as high as in high-income countries. Second, trucks were the striking party in 65% of fatal crashes.

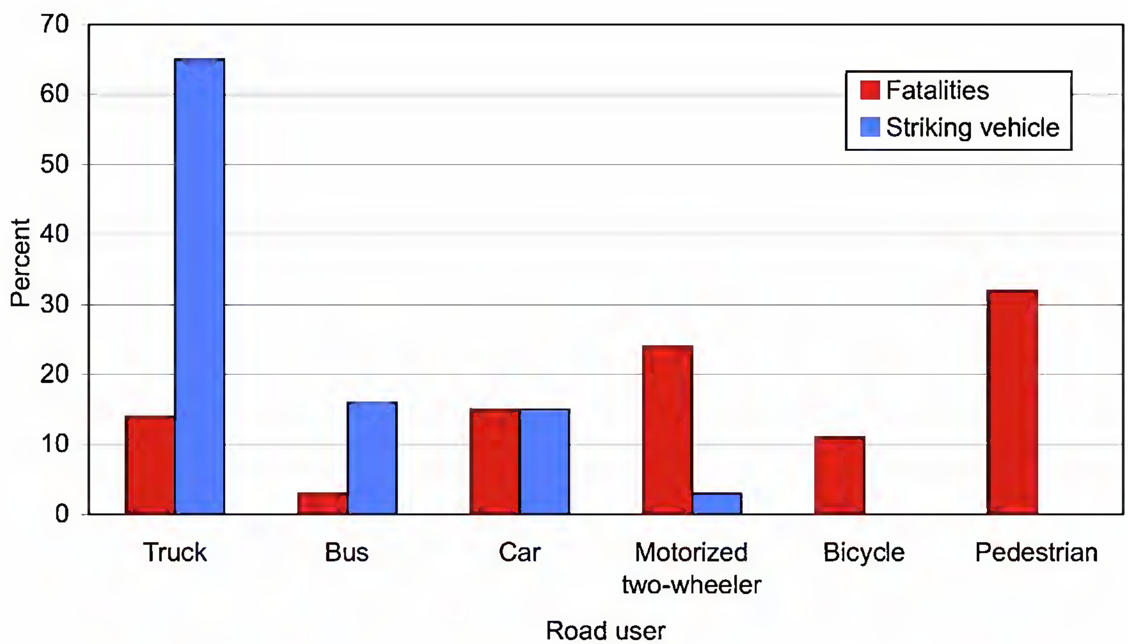

Figure 18. Traffic fatalities and striking vehicle by road-user type on national highways, 1999.

Table 7 shows the crash statistics by categories of highways (Tiwari et al., 2000). There were no major differences in rollover crashes on two-lane and four-lane roads. Similarly, there were no major differences in head-on collisions on different types of two-lane roads. However, it is surprising that 19% of crashes on four-lane divided roads were head-on collisions. This means that many vehicles were going the wrong way on divided highways.

Table 7
Fatal crashes by category at 14 selected highway locations by type, 1999.

Highway type	Fatal crashes (percent)						
	Rollover	Head-on	Angle	Rear-end	Pedestrian and bicycle	Fixed object	Other
1 lane, intermediate lane	-	13	13	13	-	13	48
2 lane, without shoulder	7	14	2	31	23	5	18
2 lane, with 1.5 m paved shoulder	5	11	-	16	45	11	16
2 lane, with 2.5 m paved shoulder	5	17	2	25	19	13	17
4 lane, divided	4	19	7	19	35	2	13

Rear-end collisions (including collisions with parked vehicles) were high on all types of highways, including four-lane highways. This shows that although more space is available on wider roads, rear-end crashes are not reduced there. Impacts with pedestrians and bicycles have a high rate on all roads, including four-lane divided highways. Collisions with fixed objects were infrequent only on four-lane divided highways. Speeds of cars averaged 60-70 km/h and heavy vehicles 50-60 km/h on four-lane divided highways (with no access control). This means that many vehicles on these highways would have been traveling at speeds in excess of 80 km/h in mixed traffic, with some vehicles at speeds less than 50 km/h, and the presence of pedestrians and bicyclists.

Saija, Patel, and Upadhyay (2000) and Shrinivas (2004) analyzed road traffic crash data obtained from police records for the states of Gujarat and Tamilnadu, respectively, at a macro level but considered national highway data in combination with other roads. Kumar, Venkatramayya, and Kashinath have done a study of crashes on the Dindigul-Palani section of National Highway 209 and report that about 50% of the crashes involved buses, 25% of the victims were pedestrians, and two stretches of the highway had a higher number of crashes than other sections (Kumar and Venkatramayya, 2004). A study of crashes on National Highway 8 passing through Valsad District found that crashes were increasing at a rate of 3.9%, rear-end crashes were 40% of total crashes, and heavy vehicles were involved in the largest number of cases (Saija and Patel, 2002). These studies inform us that highways do have some stretches that can be identified as being associated with a higher number of crashes than other locations, heavy vehicles are involved in a larger number of crashes than lighter vehicles, and vulnerable road users are a significant proportion of those killed on national highways. However, none of these studies provides information on speeds, modal shares, and highway design or their association with road traffic fatalities.

Shaheem et al. have published two detailed studies on road traffic crashes on the Aluva-Cherthala and Pallichal-Kaliyikkavila sections of National Highway 47 in Kerala (Shaheem and Das Gupta, 2005; Shaheem, Mohammed, and Rajeevan, 2006). For the Pallichal-Kaliyikkavila section, the authors evaluated the impact of four-laning of 38.5 km of the highway on road traffic crashes. They also reported that heavy vehicles had a high involvement, and pedestrians and cyclists were 28% of the victims. The most important finding of this study is that the fatality rate per volume is more than three times higher on the four-lane section than on two-lane sections. The fatality rate based on population density of the associated regions was higher on the four-lane section compared to two-lane sections, and conversion of two-lane sections to four-lane sections increased the fatality rate from 41% to 51% on the high-crash-rate sections.

A recent study of crashes in the state of Punjab reported that 30% of the crashes took place in urban areas, with the rest in semi-urban and rural areas (Consulting Engineering Services (I) Pvt. Ltd, 2007). The crash rate was 2.4 fatalities/km on national highways and 0.9 on state highways. The distribution of fatal crashes on rural roads is given in Table 8. These figures include all kinds of roads in rural areas and so are not directly comparable with the data in Table 7. Bicycle crashes have not been reported separately and the definitions used for various categories would be different. However, two issues are similar: the incidence of rear-end crashes and the involvement of pedestrians on highways.

Table 8
Fatal crashes by type on rural roads in Punjab.

Crash type	Percent
Rollover	1.0
Head-on	31.2
Rear-end	11.8
Side swipe	1.1
Right angle	15.2
Pedestrian	13.0
Others	26.7
Total	*100.0*

Various studies suggest high involvement of trucks in fatal crashes on rural highways in India, but only one study quantified this (Tiwari et al., 2000). Figure 19 shows average modal shares of road users in 2006 obtained from the data collected by the Ministry of Road Transport and Highways at sample stations on national highways in different states (Department of Road Transport and Highways, 2008d). The average values for all states were as follows: 33% for cars and three-wheeled vehicles, 29% for motorized two-wheelers, 29% for trucks, 7% for buses, and 2% for tractors. These modal shares are different from those in high-income countries. This partly explains the high involvement of trucks and motorized two wheelers in crashes on Indian rural highways. Accurate estimates for non-motorized road user share on Indian roads are not available, but the data from the study done in late 1990s gives the following ranges: 4-25% on four-lane divided highways and 9-39% on two-lane highways (Tiwari et al., 2000). The presence of pedestrians and bicyclists in significant numbers on highways accounts for the high fatality rates for these groups, even on intercity roads.

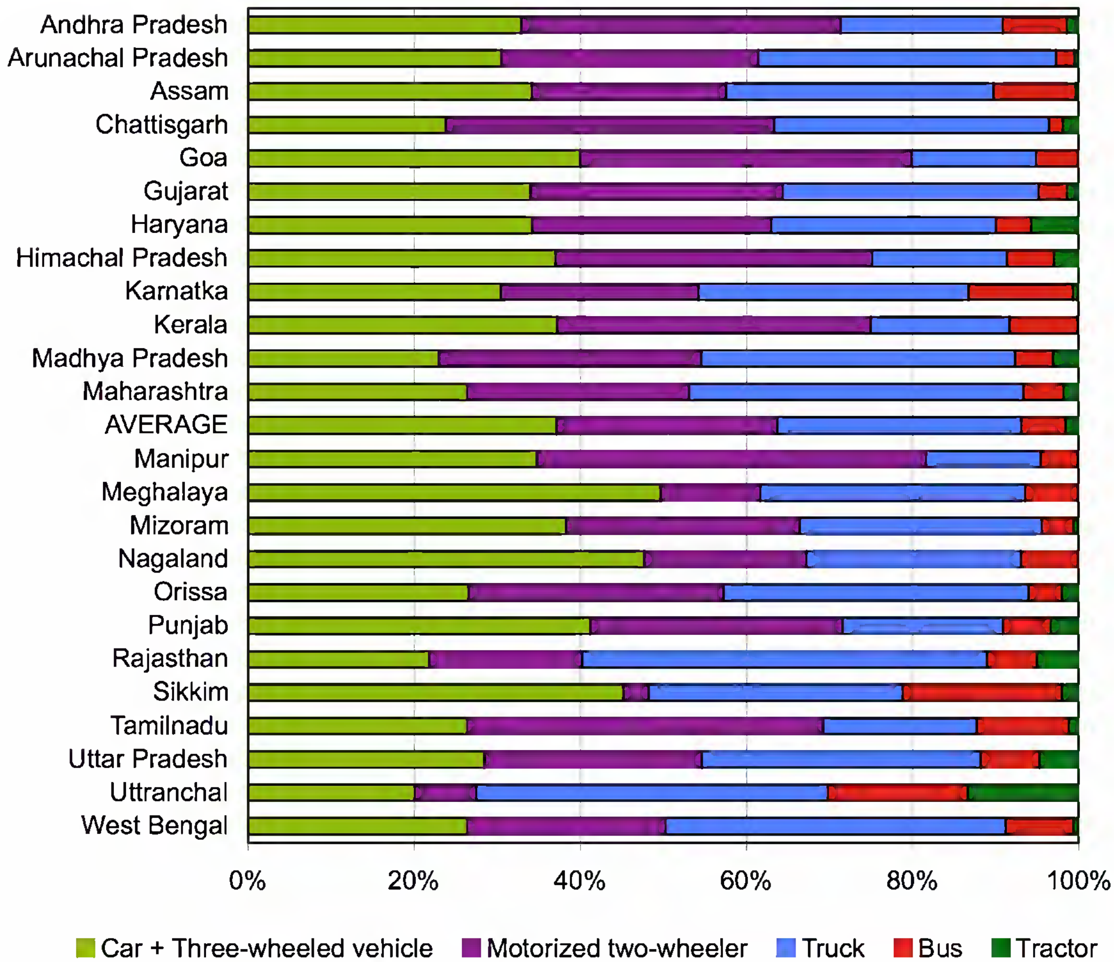

Figure 19. Percentages of road users on national highways by state and territory, 2006.

In summary, it is clear that crash rates on intercity roads are high. The construction of four-lane divided highways (without access control) does not seem to have reduced fatality rates, and vulnerable road users still account for a large proportion of fatalities. The presence of slow modes on highways creates serious problems, as speed differentials can account for significant increases in crash rates (Koornstra, 2007). High incidence of fatal rear-end crashes suggests a general lack of visibility with a possible contribution of poor conspicuity of parked vehicles. There is a clear case for redesign of intercity roads with separation of slow and fast modes. The needs of road users on local short distance trips will have to be accounted for to reduce the probability of head-on crashes (due to drivers going the wrong way on divided highways) by provision of continuous service lanes and safe road crossings at convenient distances. Solutions for many of these issues are not readily available, and research studies are necessary for the evolution of new designs.

City data

Million-plus cities

According to the 2001 census, 35 cities in India have populations of 1 million or more. Data for the total number of fatalities are available for these cities and are shown in Figure 20 (NCRB, 2007). Delhi had the highest number of fatalities in 2006 (1,794) with a rate of 140 per million population. The lowest rate was in Amritsar (33) and the highest in Agra (317), with an overall average of 142 fatalities per million persons for all these cities. In comparison, there were 245 cities with populations greater than 100,000 persons in the U.S. in 1998. For these cities, the average fatality rate was 98 per million persons, with Dallas having the highest rate (142) and New York the lowest (46). The average rate for million-plus cities is 45% higher in India than in the U.S., with the highest rate being 2.2 times higher.

A comparison of the fatality rates per million persons between 2001 and 2006 is shown in Figure 21. In this period of five years, only eight of the 35 cities did not experience an increase in fatality rates. The highest increase was 550% in Asansol, with an overall average for all cities of 5.5% compound per year. This is quite an alarming situation, as at this rate the city death rate per million persons will be doubled in 12 years. Since a vast majority of the victims in these cities are vulnerable road users, one possible cause could be increases in vehicle speeds. The probability of pedestrian death is estimated at less than 10% at impact speeds of 30 km/h and greater than 80% at 50 km/h, and the relationship between increase in fatalities and increase in impact velocities is governed by a power of four (Leaf and Preusser, 1999; Koornstra, 2007). Small increases in urban speeds can increase death rates dramatically.

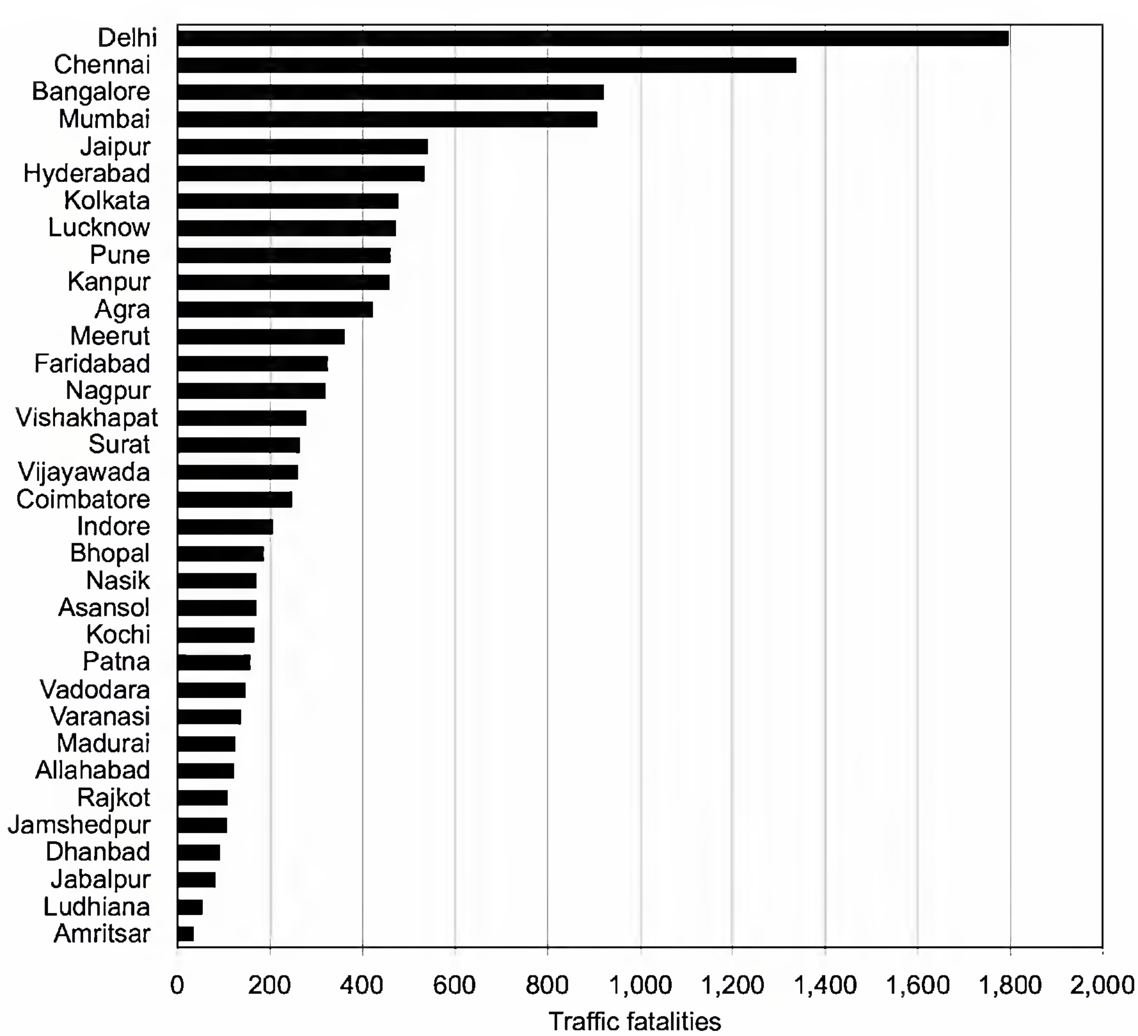

Figure 20. Traffic fatalities in cities with populations of at least one million, 2006.

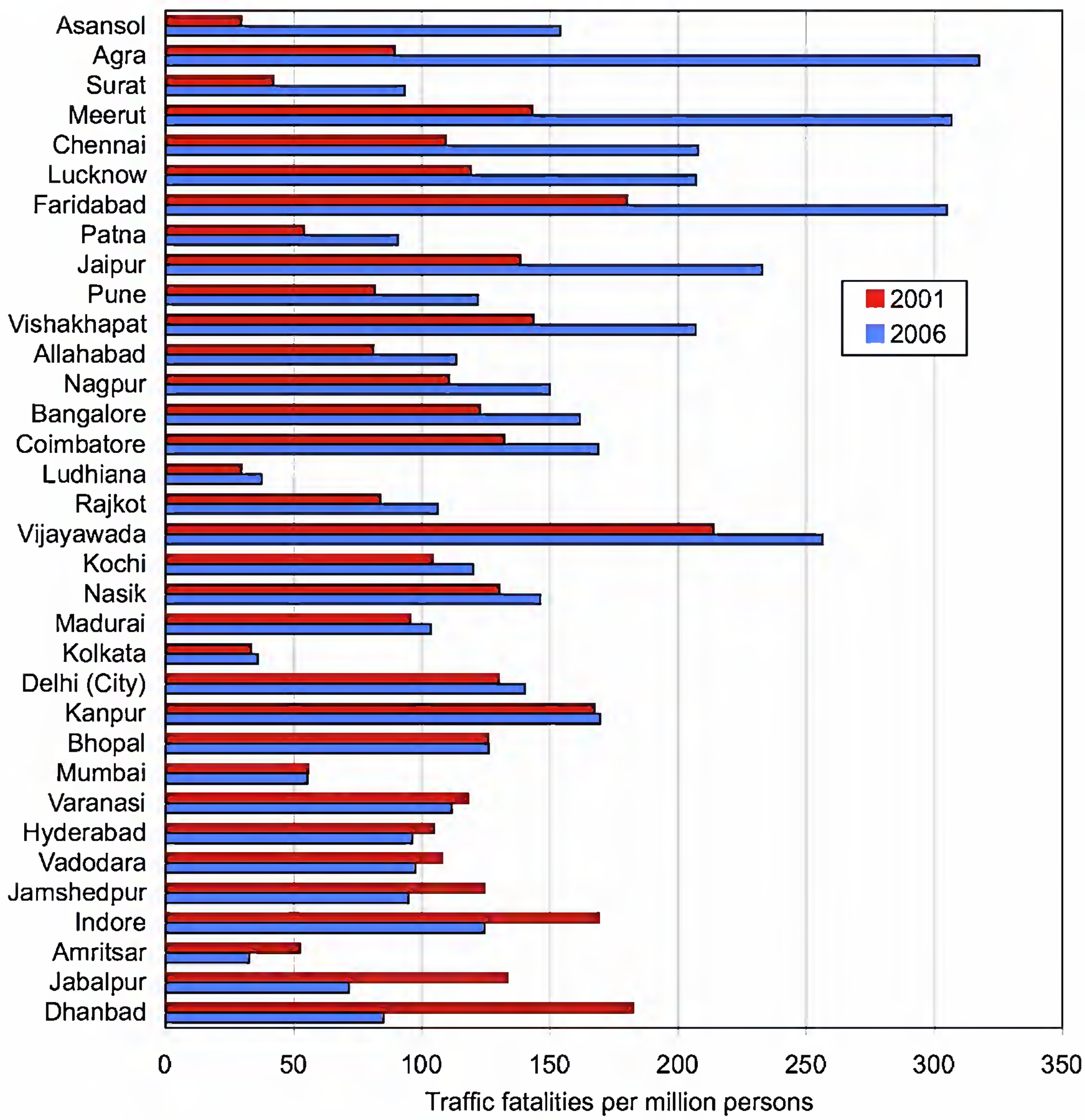

Figure 21. Traffic fatality rates in cities with populations of at least one million, 2001 and 2006 (NCRB, 2007). (The cities are listed in decreasing order of the ratio of the 2006 to 2001 fatality rates.)

Analysis for Delhi, Mumbai, and Kota

In this section, police data for traffic fatalities are analyzed for Mumbai (population 16.4 million), Delhi (population 13 million), and Kota (population 780,000). Mumbai is the financial capital of India with the largest population, and Delhi is the political capital with the third largest population. Mumbai is an older city with a strong central business district, and is not representative of the growing megacities of modern India in terms of city form and structure. The latter, including Delhi, have grown and developed in the last four decades and have multi-modal business districts. Delhi had the highest ownership of motor vehicles per capita in the country in 2004, with 6.5 cars and 13.3 motorized two-wheelers per 100 persons, and Mumbai had 2.0 cars and 3.1 motorized two-wheelers per 100 persons.

Figure 22 shows the car ownership statistics for different cities in India. (The total number of vehicles in each city was reduced by 30% from the official data for calculating these statistics. The official statistics overestimate the number of registered vehicles because owners do not have to register their vehicles every year. Therefore, out-of-use vehicles remain on the record. Recent studies have estimated that the actual number of private vehicles on the road in Delhi is 60-70% of the official statistic [Expert Committee, 2002; CRRI, 2007].) These data show that people in smaller cities have much higher ownership of motorized two-wheelers than cars. The ratio of motorized two-wheelers to cars in most cities with less than 10 million population ranges between 5 and 10; in the three largest cities (Kolkata, Mumbai, and Delhi), the ratio is between 1 and 2. Differences between cities in this ratio have strong influences on the fatality patterns.

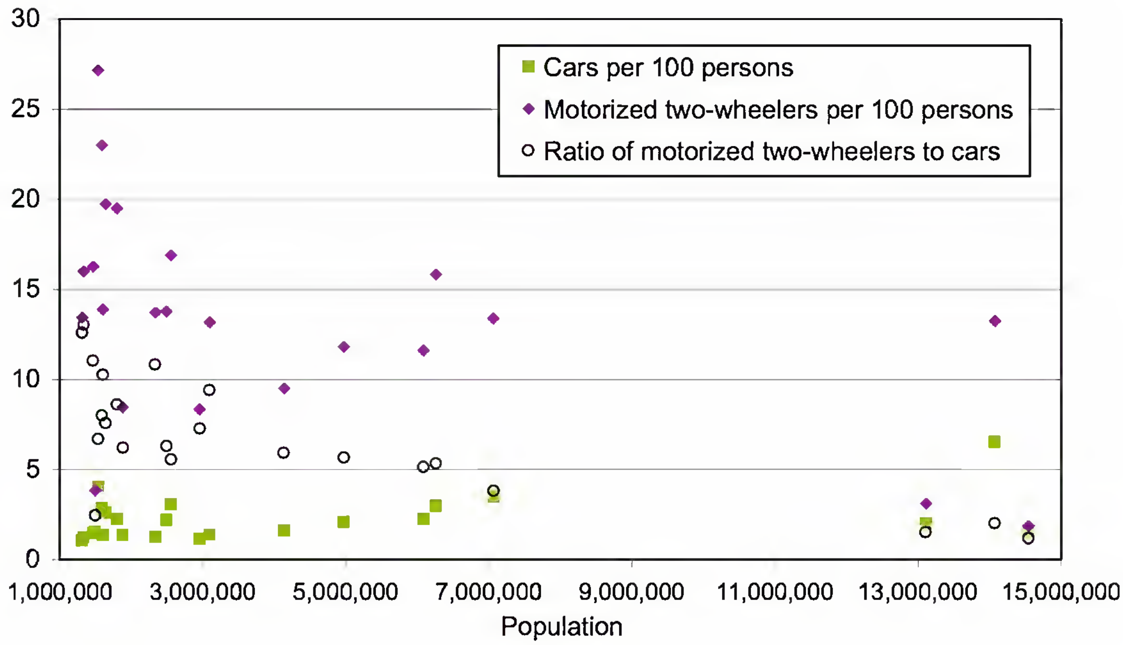

Figure 22. Vehicle ownership in cities with populations of at least one million, 2004 (Department of Road Transport and Highways, 2008a).

Fatality data from the city of Delhi were obtained for five years (from 2001 to 2005) from the Delhi police in the form of a consolidated spreadsheet used for preparing annual reports. The data consist of a list of incidents, identified by the time and location at which each incident occurred, the involved road user types and license plate numbers, the number of fatalities and injuries in the crash, a general categorization of the fatality by age (young/old) and gender, and whether a pedestrian was hit. The dataset provides a reliable view of some characteristics of fatalities that are not available otherwise at the state or national level. It is presented here to provide detail about the traffic situation in the capital of India, with the understanding that while Delhi is not a perfect representation of other cities and towns in India, it would reflect patterns in other large cities that have grown in the last few decades.

The data for the city of Mumbai were obtained for 1996 and 1997 for a project in which police crash reports were coded specially for a detailed analysis of the road safety situation in the city (Tiwari, Mohan, and Muskaug, 1998). For the purpose of the current report, only summary data are presented.

Finally, a complete dataset of fatalities from the city of Kota, Rajasthan were obtained from the Kota police department for 2007. Kota, with a population of about 780,000, is substantially smaller than Delhi or Mumbai. Although fewer fatalities occur in Kota, an analysis of the situation in Kota adds a different perspective that may be useful for making inferences about smaller cities with lower car ownership and much higher motorcycle ownership than megacities.

Figure 23 shows the distribution of fatalities by road user in the three cities. It excludes fatalities for which no information was available and focuses on road user fatalities that were influenced by another road user. For example, it includes pedestrians that were hit by various types of other road users, and includes crashes involving non-motorized and motorized vehicles that were hit by another road user and that resulted in a fatality.

In all three cities, a majority of the fatalities were pedestrians, bicyclists, other non-motor road users, and riders of motorized two-wheelers: 86% in Delhi, 93% in Mumbai, and 67% in Kota. Mumbai differs substantially in having fewer fatalities among riders of motorized two-wheelers. This may be partly because Mumbai has a much lower ownership rate of motorized two-wheelers. Kota appears to have a much higher proportion of car involvement, but this is misleading because for Kota the category "cars" included all kinds of shared-route taxis that consist of cars, jeeps, and three- and four-wheeled locally manufactured vehicles. These taxis carry a much larger number of passengers than can be accommodated by the available seats. This practice ensures low, affordable fares and is common in smaller cities of India, as organized public transport is not available. It should be noted that private cars accounted for only 5.5% of the total number of fatalities, and 17% of those listed in the car group. Thus, occupants of private cars constitute a very small proportion of fatalities, and people outside the car constitute the vast majority of fatalities in all cities irrespective of size. Only the relative proportions of pedestrians, bicyclists, and motorized two-wheeler fatalities differ, depending on city characteristics.

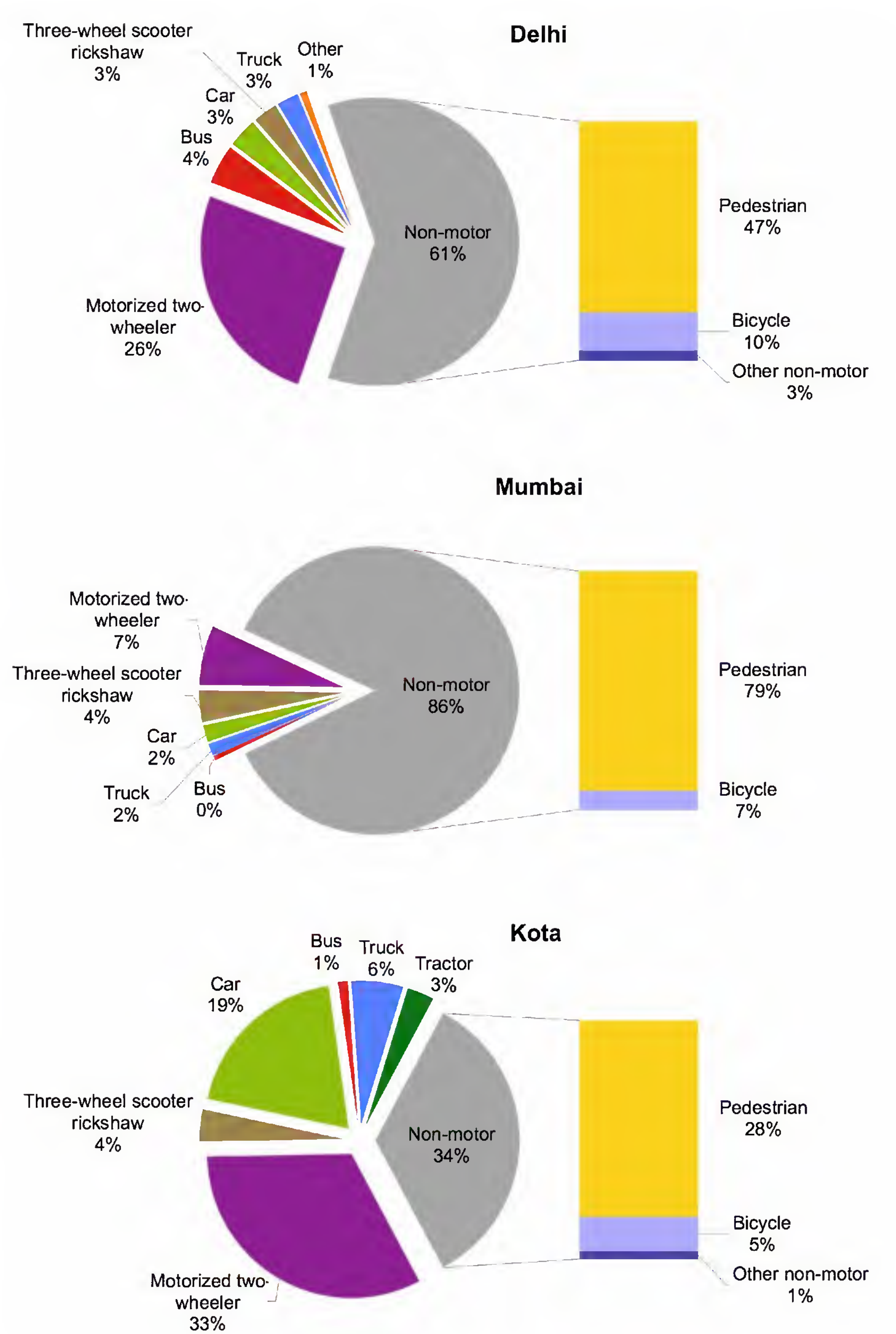

Figure 23. Fatalities by road user in Delhi (2001-2005), Mumbai (1996-1997), and Kota (2007).

Figure 24 examines the types of road users that were the striking components of the crashes in each of the three cities. Trucks and buses together are associated with more than 40% of the fatalities in urban areas in all three cities. This is in comparison with 14% in the U.S. (FARS, 2008). Buses are a smaller component in Kota, which has very limited public bus service. Buses are replaced by jeep taxis (included in the "car" category) and other vehicles transporting passengers as route taxis. The other difference between Kota and the large cities is the involvement of tractors in crashes. This is probably because small cities have greater business involvement with the surrounding rural areas, and farmers bring their produce for sale into the city, using tractors as personal transport. The high involvement of trucks is due to the fact that intercity highways go through populated parts of the city and are not separated from the rest of the road users. Large cities can restrict passage of trucks through the city in the daytime, but this is not possible in the smaller cities. The high involvement of buses and trucks has been investigated in a detailed conflict-analysis study (Tiwari, Mohan, and Fazio, 1998). The authors report that these vehicles have to use the curbside lane in the city and often come into conflict with pedestrians, bicyclists, and motorized two-wheelers, as they are present in the same space on the road. This results in frequent involvement of vulnerable road users in fatal crashes because of the absence of dedicated bicycle paths and adequate space for pedestrian movement.

The involvement of motorized two-wheelers, though not very high, is significant because it can be associated with pedestrian, bicyclist, and other motorcycle fatalities. Of particular interest is the pattern of fatalities in which the striking vehicle is classified as unknown. Many such cases are hit-and-run incidents. This is probably because the presence of traffic police is limited at night and offenders can get away undetected. This is particularly true for Delhi. Since it is more difficult for buses and trucks to escape after a crash than it is for cars, it is possible that many in the unknown category could be the latter. If that is true, then the involvement of cars would be higher than is shown in the figure. This also suggests that policing of roads should be done around the clock, for more complete data to be available and for control of drivers.

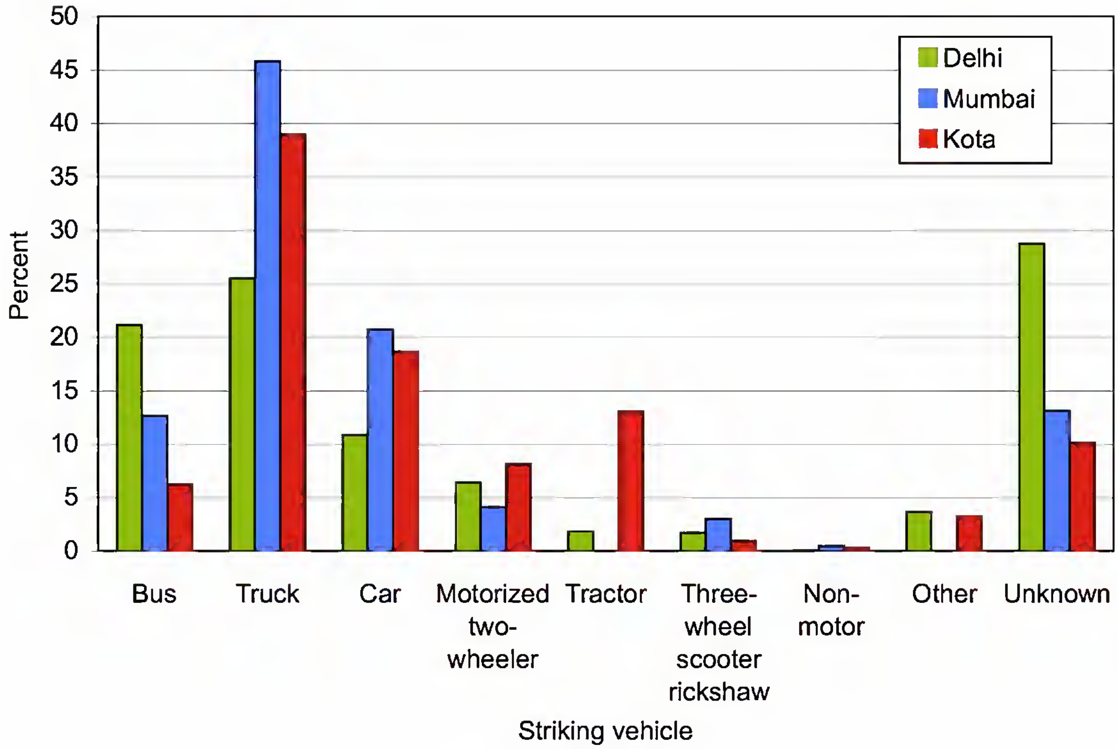

Figure 24. Striking vehicle in fatal crashes in Delhi (2001-2005), Mumbai (1996-1997), and Kota (2007).

Figure 25 shows involvement of different categories of road users by time of day in Delhi. There are four main features of the data. First, despite the fact that nighttime exposure is likely to be substantially lower than daytime exposure, nighttime crashes account for a large proportion of fatalities. Second, trucks have high involvement in both daytime and nighttime. Third, buses feature prominently from about 07:00 until about 21:00. Fourth, the proportion of unknowns is substantial, especially during nighttime.

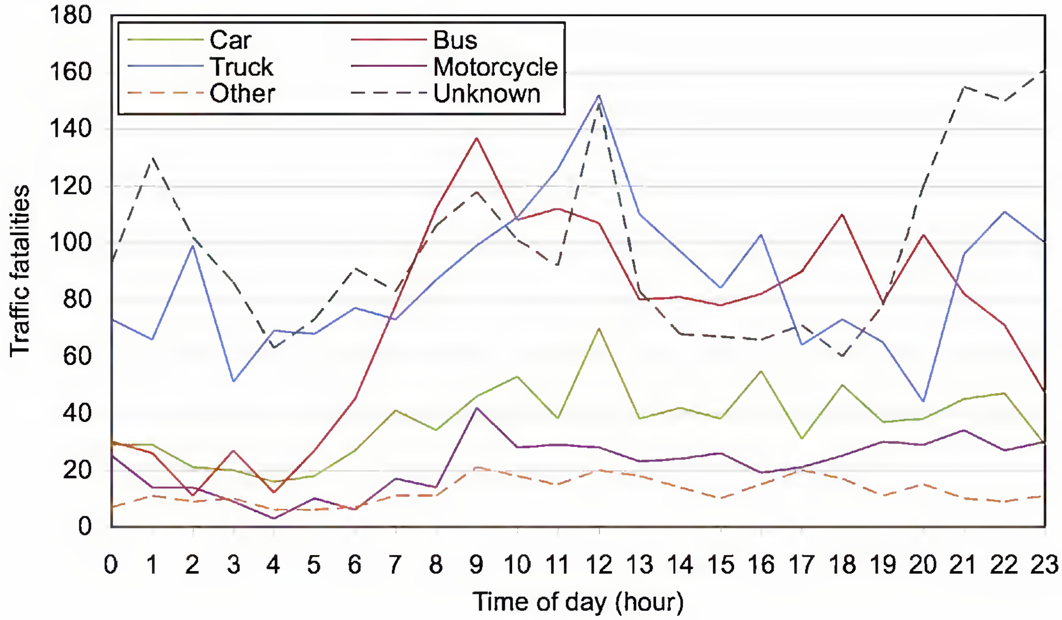

Figure 25. Fatalities by striking vehicle and time of day in Delhi, 2001-2005.

Figures 26 and 27 present the distribution of fatalities in Delhi as a function of time of day and month of the year. The seasonal pattern of pedestrians, bicyclists, and non-motorized vehicles is somewhat different from that of motorized vehicles. While the peaks between 10:00 and 15:00 are similar for motorized and non-motorized users, the nighttime peaks are not. Motorized users have a relatively high number of crashes between 22:00 and 01:00, while non-motorized users do not. This could be because of the differential exposure of these two groups at night, higher speeds of vehicles at night due to low density, and/or higher frequency of driving under the influence of alcohol at night. Evidence for increased use of alcohol comes from a hospital study in Delhi where 29% of the riders of motorized two-wheelers admitted to alcohol consumption before the crash (Mishra, Banerji, and Mohan, 1984). In Bangalore, a hospital-based study showed that alcohol was involved in 22% of nighttime crashes, and that 35% of randomly checked drivers on the road at night were under the influence of alcohol (Gururaj, 2006).

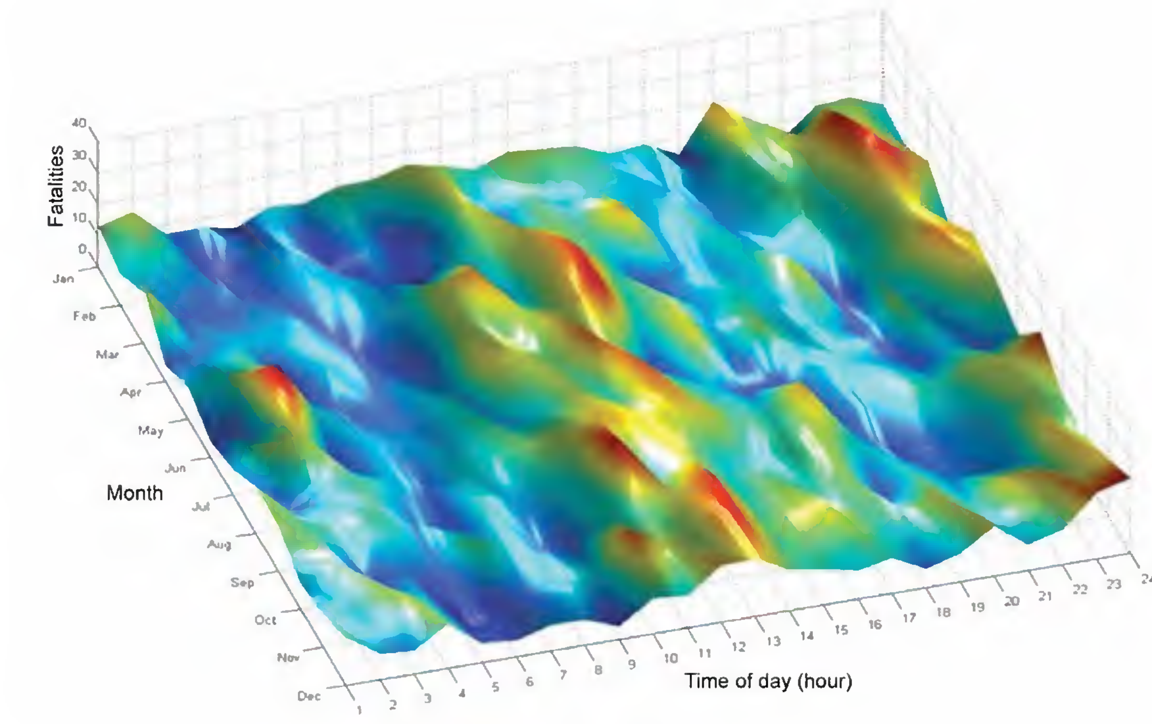

Figure 26. Fatalities in motorized vehicles by month and time of day in Delhi, 2001-2005.

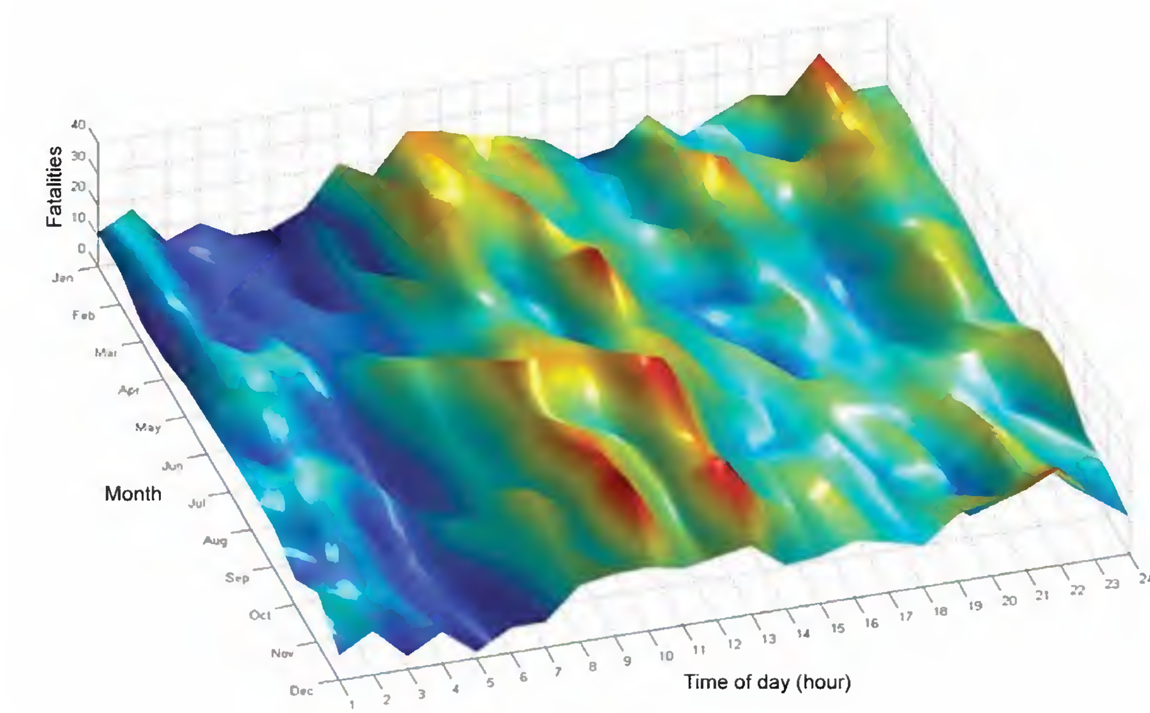

Figure 27. Fatalities of unprotected road users by month and time of day in Delhi, 2001-2005.

Another difference between the motorized and non-motorized users is the increase in fatalities among the non-motorized users during the winter months between 17:00 and 19:00, which is not present for the motorized road users. In Delhi, sunrise and sunset are at around 05:00 and 18:30, respectively, in midsummer, and at 07:00 and 17:30 in mid-winter. These higher fatality rates could be due to the lack of conspicuity of pedestrians and bicyclists when the sun starts setting early in the winter.

Figure 28 shows the distribution of all traffic fatalities in Delhi and Kota and pedestrian fatalities in Mumbai, and their representation in the population. As shown earlier, in the data for all of India, children are underrepresented in all three cities, whereas pedestrians in Mumbai are overrepresented for ages greater than 45 years. The data are shown with reference to location in Figure 29. The fact that a vast majority of crashes take place mid block and involve adults of all ages suggests that vulnerable road users have a high possibility of conflict with motor vehicles and that the velocities of these vehicles are high enough to cause fatalities. Therefore, urban safety policies should give the highest priority to pedestrian and bicycle separation from motor vehicles, speed control on main arterial roads, and traffic calming on all other roads.

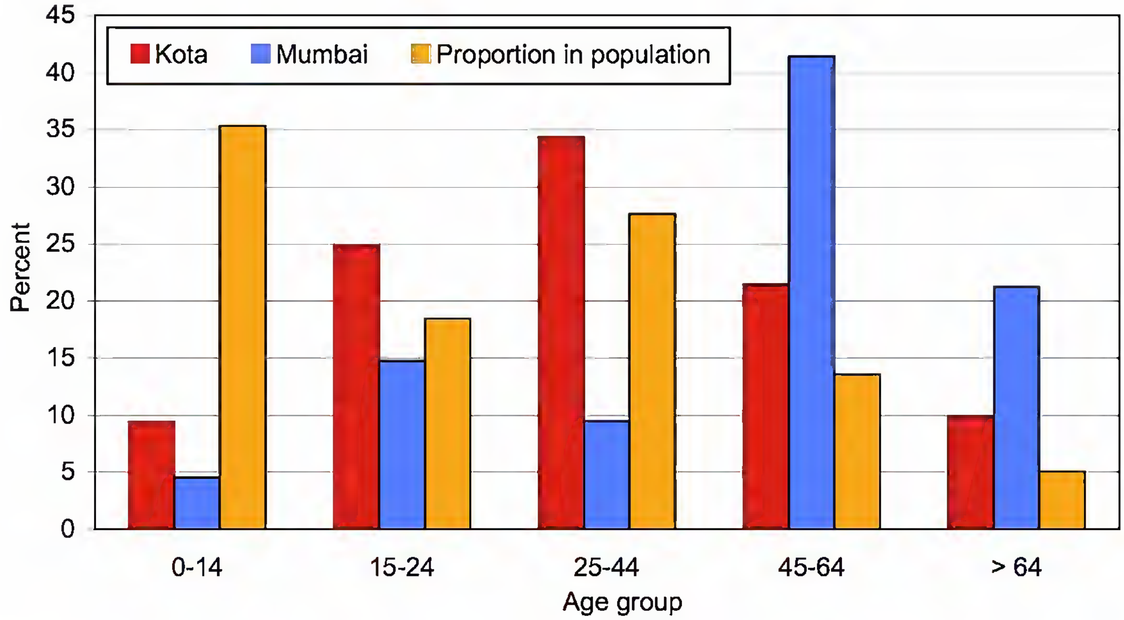

Figure 28. Traffic fatalities by age group in Kota (2007; all traffic fatalities) and Mumbai (1996-1997; pedestrians only).

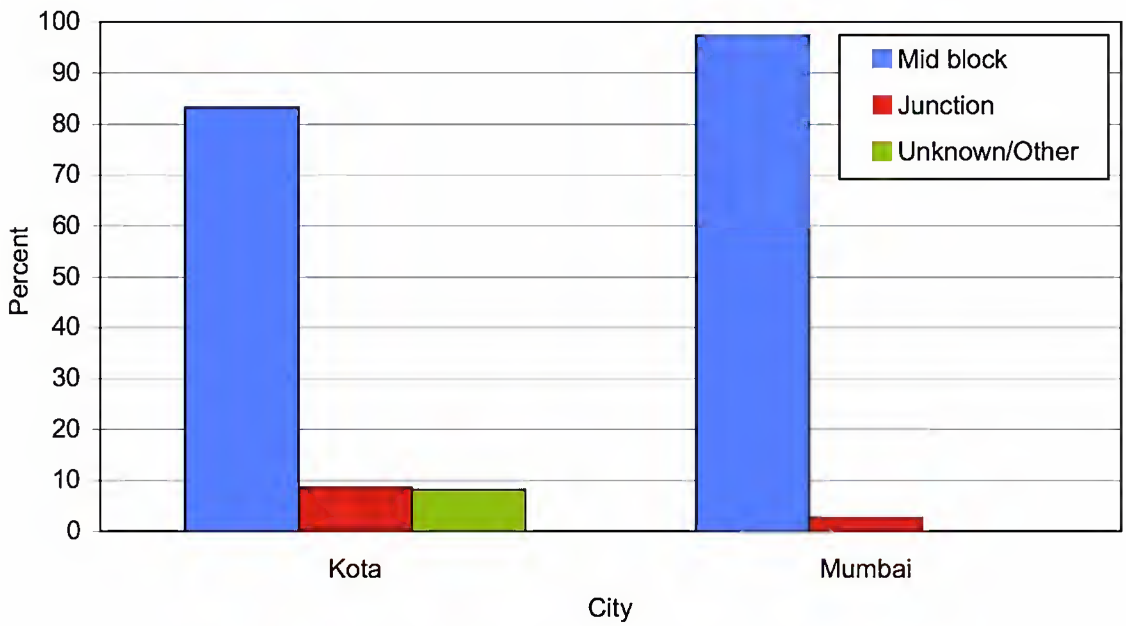

Figure 29. Locations of fatal crashes in Kota (2007) and Mumbai (1996-1997).

Conclusions

The data presented in this report indicate that road traffic fatalities have been increasing at about 8% annually for the last ten years and show no signs of decreasing. Two modeling exercises have attempted to predict the time period when we might expect fatality rates to start to decline in a range of countries, consistent with the so-called Kuznets curve (Kopits and Cropper, 2005; Koornstra, 2007; McManus, 2007). Kopits and Cropper used the experience of 88 countries to model the dependence of the total number of fatalities on fatality rates per unit vehicle, vehicles per unit population, and per-capita income of the society. They predicted that fatalities in India would reach a total of about 198,000 before starting to decline in 2042. Koornstra, using a cyclically modulated risk decay function model that incorporates the cyclically varying nature of a society's concerns for safety, predicted an earlier date of 2030 for the peak traffic fatalities in India. In the past few years, traffic fatalities have grown at 8% per year, while averaging 5% in earlier years. If we assume that the present growth rate of 8% per year declines in a linear manner to 0% by 2030, then we can expect about 260,000 fatalities in 2030. Neither of these projected dates (2042 and 2030) can be accepted as road safety goals for the country.

Both the above models use the experience of high-income countries over the past decades in calculating relationships between vehicle ownership levels and risk of death per vehicle. Therefore, the models predict the onset of decline at specific per-capita income levels if the past road safety policies of high-income countries are followed in the future in countries like India. If this is true, then the only way the decline of road safety fatalities can be brought forward in time is to implement additional India-specific road safety policies that are new and more effective. Existing road and vehicle design and enforcement policies can at best only fulfill the predictions of Koornstra or Kopits and Cropper.

Based on the analysis above, we selected six areas in which to examine countermeasures in the next part of this report. Successfully dealing with these six areas is likely to bring about substantial improvement in road safety in India.

(1) Pedestrians, bicyclists, and other non-motorists in urban areas. This group of road users currently accounts for about 60% of all fatalities in urban areas, substantially more than in most high-income countries.

(2) Pedestrians, other non-motorists, and slow vehicles on national highways. Evidence suggests that a high percentage (about 20-40%) of fatalities on highways consist of pedestrians, bicyclists, other non-motorists, and occupants of slow vehicles. The problems associated with pedestrians and other non-motorists on highways are inherently different from the problems in urban areas. Therefore, it is appropriate to deal with these two problems separately.

(3) Motorcycles and small cars in urban areas. Motorcyclists represent a large portion of urban fatalities (about 25%). The expected partial shift of motorcyclists to small cars is of concern, because although small cars provide more protection to the occupants, they are expected to be more harmful than motorcycles to pedestrians, bicyclists, and other motorcyclists unless vehicle fronts are designed to be more forgiving.

(4) Over-involvement of trucks and buses in fatal crashes. Several studies indicate that the involvement of trucks in fatal crashes is greater than would be expected based only on their exposure.

(5) Nighttime driving: visibility, alcohol, and fatigue. Evidence suggests that, as is the case in other countries, nighttime driving in India is substantially riskier than daytime driving. Three aspects are of relevance here: conspicuity of road users, driving under the influence of alcohol, and fatigue of truck drivers. The available data do not allow us to quantify the individual contribution of each of these aspects.

(6) Wrong-way drivers on divided highways. A large proportion of fatalities on divided highways are from head-on collisions. One study found that such crashes accounted for 19% of all fatalities on four-lane, divided highways.

OPPORTUNITIES: PROMISING COUNTERMEASURES

In the first part of this report, we identified six areas that, with appropriate countermeasures, are likely to bring about substantial improvements in road safety in India. These areas are (1) pedestrians and other non-motorists in urban areas, (2) pedestrians, other non-motorists, and slow vehicles on national highways, (3) motorcyclists and small cars in urban areas, (4) over-involvement of trucks and buses in crashes, (5) nighttime driving, and (6) wrong-way drivers on divided highways. In this part of the report, we will outline several safety countermeasures for each of these areas.

General approach to identification of potential countermeasures

The approach that we used in this report is based on the concept of total harm (Thulin and Nilsson, 1994; Sivak and Tsimhoni, 2008, Zhang et al., 2008). As we discussed in Sivak and Tsimhoni (2008, p. 453),

> …total harm is conceptualized as a product of exposure, risk, and consequences. Exposure is the probability of a particular, potentially risky recent event (condition, situation) per distance traveled or per unit of time. Risk is the conditional probability of a crash, given the event in question. Consequence is the conditional probability of undesirable outcomes (i.e., fatality, injury, and property damage) given a crash that was precipitated by the event in question. For each event, the values along the three dimensions (exposure, risk, and consequences) define a three-dimensional space. The volume of this space is the total harm for this particular event.

The goal of traffic-safety countermeasures should be a reduction in total harm, based on influence on exposure, risk, or consequences.

Proposed countermeasures for India

Table 9 lists broad areas of intervention for each of the six problem areas discussed above. The countermeasures are classified by three components that contribute to total harm (exposure, risk, and consequences). Some countermeasures are known and have international applicability, whereas many other, India-specific, measures would have to be developed in the coming years. The latter will require intensive research and development efforts in India.

Table 9
Summary of promising countermeasures.

Problem area	Exposure	Risk	Consequences
Pedestrians and other non-motorists in urban areas	Separation of motorized and non-motorized traffic on arterial roads	Speed control Roundabouts Restrictions on free left turns	Pedestrian-friendly front ends of vehicles
Pedestrians, other non-motorists, and slow vehicles on highways	Special facilities for slow and local traffic all along highways	Pedestrian detection technology Forward collision warning systems	Pedestrian-friendly front ends of vehicles Crashworthiness of slow vehicles
Motorcycles and small cars in urban areas		Daytime running lights Improved lighting and signaling	Enforcement of helmet-use and seatbelt laws Introduction of passive measures like airbags Pedestrian/motorcycle impact standards for small cars
Over-involvement of trucks and buses		Speed control Rest regulations for truck drivers Improved vehicle conspicuity	Safer vehicle fronts
Nighttime driving		Improved headlighting Improved vehicle conspicuity Random alcohol breath testing Rest regulations for truck drivers	
Wrong-way drivers on divided highways	Highway designs incorporating local needs Enforcement	Forward collision warning systems	

Pedestrians and other non-motorists in urban areas. The countermeasures with high potential for major positive effects include separation of traffic on arterial roads and traffic calming in all other areas (starting in urban areas that have the highest exposure of non-motorists to other traffic), and improvement in the pedestrian friendliness of vehicle front ends. International guidelines for traffic calming will have to be modified to incorporate designs that are effective for motorcycles as well. Speed control, use of scientifically designed roundabouts instead of traffic lights, and restrictions on free left turns (India drives on the left) are internationally used measures that reduce urban road traffic injuries. Because of the expected future partial shift in India from motorized two-wheelers to small cars (Cather, 2007), making small cars more pedestrian friendly will be of increased importance

Pedestrians, other non-motorists, and slow vehicles on highways. The etiology of these crashes is somewhat different from the analogous crashes in urban areas. These crashes involve conditions with higher speeds and relatively lower frequency of exposure to non-motorists. Highway designs in India will have to be modified to separate slow vehicles and pedestrians all along the highway, and provide convenient road crossing facilities at frequent intervals for local traffic. The recommended focus for the future is on in-vehicle pedestrian-detection technology and pedestrian-friendly front ends of vehicles (for crashes involving non-motorists), and forward collision warning systems and improved crashworthiness of slow vehicles (for crashes of slow vehicles with other vehicles).

Motorcycles and small cars in urban areas. The following countermeasures are recommended: required daytime running lights for motorcycles, improved lighting and signaling on motorcycles, enforcement of motorcyclist helmet-use laws, and motorcycle-friendly front ends of vehicles (for crashes involving motorcycles), and improved crashworthiness of small cars (for crashes of small cars). Passive measures, like mandatory airbags for all cars, may prove to be cost effective when enforcement measures are lacking.

Over-involvement of trucks and buses. Two countermeasures, aimed at the driving performance of truck drivers, are recommended: speed control by use of data loggers and GPS systems, and implementation of rest regulations. Also recommended, for both trucks and buses, are safer vehicle fronts and improved vehicle conspicuity.

Nighttime driving. The available data do not allow quantification of the relative contribution of visibility, alcohol, and fatigue to the increased risk of nighttime driving in India. Consequently, the recommendation is to address all of these mechanisms with a combination of countermeasures: improved headlighting and conspicuity of all vehicles (including bicycles and other non-motorized vehicles), frequent and sustained random breath testing programs, and rest regulations for truck drivers.

Wrong-way drivers on divided highways. Again, the available data are not sufficiently detailed to provide information about the mechanisms that contribute to this type of crash. Nevertheless, anecdotal evidence suggests that these crashes often involve drivers who take shortcuts, often with slow vehicles such as farming equipment. In the short term, enforcement is the key approach for addressing this phenomenon. Research needs to be undertaken to understand the needs of local traffic and to develop standards for safer road crossings and the frequency at which they need to be provided. Additionally, collision warning systems would also contribute to a reduction of this type of crash.

As indicated above, detailed data are not available to suggest specific measures for all road safety issues in the country. Therefore, there is an urgent need to revamp police data collecting procedures so that necessary information is available for scientific analysis. Initially, this effort may be focused on all fatal crashes. Statistically valid conclusions are also difficult because a significant number of the crashes are classified as "hit and run." Information on such cases will be available only if enforcement is maintained twenty-four hours a day.

COMPARISON OF ROAD SAFETY IN INDIA AND CHINA

In a recent report on road safety in China (Zhang, Tsimhoni, Sivak, and Flannagan, 2008), we applied a similar approach for identification of potential countermeasures to reduce the number of traffic fatalities in China. India and China have the two largest populations in the world. The two countries have comparable social characteristics but different political structures. Table 10 provides a comparison of several relevant aspects related to traffic safety in India and China (Cather, 2007; CRTAS, 2007; Stevenson et al., 2007; Zhang et al., 2008). The most notable differences are that India has lower income per capita, proportionally more motorized two-wheelers, a higher fatality rate per population, more older people among the fatalities, proportionally fewer females among the fatalities, and a less advanced network of access-controlled expressways. Table 11 summarizes the major traffic safety problems in India (as discussed in this report) and in China (Zhang et al., 2008).

The information in Tables 10 and 11 indicates that the road-safety situations in India and China are similar. This is the case in spite of the fact that income per capita in China is roughly two and a half times greater than in India. Because it takes about 10 years for income to double at a sustained growth rate of 7% per year, this comparison highlights the fact that road traffic fatalities cannot be expected to decrease rapidly unless focused efforts with a sound scientific base are put in place with a sense of urgency.

Table 10
Comparison of India with China on several relevant features related to traffic safety. (Data are for 2006 and 2007.)

Aspect	India	China
Gross national income per capita, US$	820	2,000
Gross national income per capita, US$ purchasing power parity	2,460	4,660
Vehicle population	Cars: 13% Motorized two-wheelers: 72%	Cars: 14% Motorized two-wheelers: 55%
Traffic fatalities	Annually 95 per million persons National distribution by road user not known; estimates indicate pedestrians, bicyclists and motorized two-wheelers: > 60% Children (0-14): 7% Elderly (> 64): 8% Male to female ratio: 5.4	Annually 68 per million persons Pedestrians, bicyclists, and motorized two-wheelers: 59 % Children (0-15): 6% Elderly (> 65): 1% Male to female ratio: 3.2
Regulations	Seat belt use mandatory, but many states not enforcing the law. Where enforced, seatbelt use is ~70%. Helmet use mandatory, but many states not enforcing the law. Where enforced, helmet use > 90% in the daytime. Daytime headlight use is not mandatory for any type of motorized vehicle. Law against drinking and driving on the books, but not enforced strictly.	Seat belt use mandatory, but many provinces are not enforcing the law effectively. Where enforced, seat belt use ~70% in the daytime. Helmet use is not mandatory. Daytime headlight use is not mandatory for any type of motorized vehicle, except in fog. Zero alcohol tolerance, strictly enforced in urban areas.
Vehicle crashworthiness	By 2012, all cars sold in India will have to satisfy crashworthiness regulations similar to those in Europe.	No specific regulations, but *de facto* required for marketing due to customer demand.
Roads	Expressways: < 500 km. No separate lanes for bicyclists in urban areas.	Expressways: > 40,000 km. Dedicated bicycle lanes in many urban areas.

Table 11
Highlighted major problems areas in India (this report) and in China (Zhang et al., 2008).

India	China
Pedestrians and other non-motorist in urban areas	Pedestrians and other non-motorists
Pedestrians, other non-motorists, and slow vehicles on highways	
Motorcycles and small cars in urban areas	Motorcycles
Over-involvement of trucks	
Nighttime driving	Nighttime driving
Wrong-way drivers on divided highways	
	Vehicle passengers

SUMMARY

The present report was designed to analyze the traffic safety situation in India, and to identify countermeasures that would address areas in which the total harm caused by crashes can be substantially and readily reduced. The report focused on two aspects of traffic safety in India, challenges and opportunities. The first part of the report provided a comprehensive analysis of the current traffic safety situation in India. It was pointed out in this analysis that fatality rates have increased both on highways and in urban areas during the past few years. Theoretical models suggest that the number of fatalities in India is not likely to start to decline for many years to come unless new policies are implemented. Based on the present analysis, the following six areas were identified as having potential for substantially reducing fatalities in India: (1) pedestrians and other non-motorist in urban areas, (2) pedestrians, other non-motorists, and slow vehicles on highways, (3) motorcycles and small cars in urban areas, (4) over-involvement of trucks and buses, (5) nighttime driving, and (6) wrong-way drivers on divided highways. The second part of the report outlined several promising countermeasures for each of these six areas. The third part of the report presented a brief comparison of major traffic safety challenges in India and China.

There is an urgent need to revamp police data collecting procedures so that necessary information is available for scientific analysis. India specific countermeasures will be possible through continuous monitoring and research, which will require the establishment of road safety research centers in academic institutions. The proposed National Road Safety Board would be the obvious agency that could help move toward a safer future as outlined above.

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