IATSS Research 39 (2016) 95–101

Contents lists available at ScienceDirect

IATSS Research

Research article

Urban traffic safety assessment: A case study of six Indian cities

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ARTICLE INFO

Article history:
Received 20 August 2015
Received in revised form 16 January 2016
Accepted 1 February 2016
Available online 11 February 2016

Keywords:
Road traffic injury
Indian cities
Urban safety
Risk

ABSTRACT

This study reports the results of fatal road traffic fatal crash data from six mid-sized cities in India: Agra, Amritsar, Bhopal, Ludhiana, Vadodara, and Vishakhapatnam. Relative to total road fatalities, the percentage of vulnerable road user deaths in all six cities range between 84% and 93%, car occupant fatalities between 2% and 4%, and TST occupants less than 5%. The largest proportion of fatalities for all road user categories (especially vulnerable road users) is associated with collisions with buses and trucks, followed by collisions with cars; however, the proportion of pedestrian fatalities associated with MTW collisions ranges from 8% to 25% of the total. The data indicate that the 0–14 age group is underrepresented in proportion to its share of the population, including children riding motorcycles. Occupant fatality rates per 100,000 vehicles for MTW and TST occupants are 2–3 and 3–5 times higher, respectively, than for cars. However, estimates of association with fatal crashes show that MTWs and cars pose a similar risk to society, with TSTs representing a slightly smaller risk. Confirming some of these results will require data with a higher level of detail.

1. Introduction

1n 1990, road traffic injuries (RTIs) corresponded to the tenth leading cause of death across the globe. In 2013, the global situation worsened, with RTI moving up to the fifth position after ischaemic heart disease, lower respiratory infections, cerebrovascular disease, and diarrhoeal diseases [1]. While the number of life years lost due to RTI has increased globally, the situation has improved in many of the OECD countries [2] but not in most low- and middle-income countries [3]. Among the low- and middle-income countries, India accounts for a large share of the deaths and disabilities contributed by RTI, owing partly to the country's large share of the world population [3] and a lack of appropriate road safety measures [4]. In 2014, RTI resulted in 141,526 fatalities in India, resulting in a rate of 11 deaths per 100,000 population as compared to rates of in more successful countries, where rates tended to be around 3 or 4 deaths per 100,000 population [5].

The high rate of RTI in India is also evident in its cities, where the fatality rates vary between 3 and 35 per 100,000 populations [4,5]. Interestingly, the low end of that spectrum compares well with some of the safest cities in the world, while the higher end ranks with some of the worst. Over the past decade, the fatality rate in some of these cities has increased by a factor of 4 or more. However, as details of RTI and crashes are not in the public domain for most cities, it is difficult to ascribe reliable reasons for these differences and the increases in fatalities over time.

Official road traffic crash data for most cities in India do not include fatalities by road user category. Such data are only available from a few cities and research studies done on selected locations on rural highways. Table 1 shows the traffic fatalities by road user category in Delhi, Mumbai, and selected locations on national and state highways [6–9]. These data show that car occupants represented a small proportion of the total fatalities: 4% and 3% in Mumbai and Delhi, respectively, and 15% on rural highways. Vulnerable road users (pedestrians, bicyclists, and motorised two-wheeler riders) accounted for 89% and 83% of the deaths in Mumbai and Delhi, respectively, and 47% to 76% of those on highways. This pattern is very different from those in high-income countries [10].

The high incidence of vulnerable road user fatalities has a negative influence on many conditions in urban life, including the freedom of children and the elderly to use the street and public transport. Safety on public transport access trips is one important issue. Unless walking trips are safe from accidents, harassment, and crime, people avoid using public transport. Therefore, safety emerges as a precondition for promoting public transport and active travel [11–15]. However, it would be difficult to promote effective road safety countermeasures all over the country in the absence of RTI details from more cities in India. The present study aims to establish an understanding of road

Peer review under responsibility of International Association of Traffic and Safety Sciences.

http://dx.doi.org/10.1016/j.iatssr.2016.02.001

Table 1
Modal share of road traffic fatalities in Mumbai, Delhi, and four rural highway locations in India.

Location		Fatalities by road user type, %						
		Pedestrian	Bicycle	Motorised two-wheeler	Car	Bus	Truck	Unknown & other
Urban	Mumbai (2008–2012)[1]	58	2	29	4	0	0	7
	Delhi (2013)[2]	47	10	26	3	4	3	7
Rural highways	Highways (1998)[3]	32	11	24	15	3	14	1
	2-Lane NH8 2 (2010–2014)[4]	20	2	42	14	9	13	1
	4-Lane NH24 (2010–2014)[4]	27	5	44	8	7	4	4
	6-Lane NH1 (2010–2014)[4]	34	3	10	6	5	41	1

Notes: (1) Average of data for 2008–2012, adapted from [9]; (2) source: [7]; (3) data for locations on 34 national and state highways in India, 1998 [6]; (4) source: [8].

traffic crash details in mid-size Indian cities and present the results of data collected from six cities with populations in the range of 1.0–2.0 million people.

2. Method

2.1. Selection of cities

Six cities with populations between 1.0 and 2.0 million and different RTI fatality rates were selected from different locations in India: Agra, Amritsar, Bhopal, Ludhiana, Vadodara, and Vishakhapatnam. Table 2 shows the population and fatality rate for each city [16,17]. These cities exemplify the type of growing urban agglomerations that observers expect to experience high growth rates over the next decade.

2.2. Data collection

Research assistants were sent to Agra, Amritsar, Bhopal, Ludhiana, Vadodara, and Vishakhapatnam to obtain primary data on vehicle registration, road traffic fatality cases, and other data available from secondary sources (such as transportation and city development plan studies commissioned by the respective city governments). Researchers visited all the city police stations and placed requests for copies of First Information Reports (FIRs) detailing fatal road traffic crashes for the period from 2008 to 2011. The data from these records were coded onto accident recording forms designed specifically for this project. The data from these forms were then entered into spreadsheets for computer analysis. The following variables were used for analysis:

- Victim gender
- Month, day, and time of the crash
- Road user type and crash vehicle type
- Type of road where the crash occurred
- Vehicles registered in the city
- Brief description of the crash as recorded by the police.

These were the only variables in the police files that were considered reliable. The data coders were also asked to note details of crashes that had any special characteristics and reports of crashes involving children. Fatality data could not be obtained for the full four-year period for all the cities. Table 3 shows the number of records obtained from each city. Vehicle registration data for Amritsar was not available.

3. Results and discussion

3.1. Vehicle registration

Table 4 shows the number of vehicles in 2011 for five of the six cities in the study. Data for Amritsar were not available. Fig. 1 shows an example of a three-wheeled scooter taxi (TST). The actual numbers of personal vehicles (cars and motorised two-wheelers) are estimated to be 60% of the official number for cars and 50% of the official number for motorised two-wheelers. These adjustments have been made because the official numbers of personal vehicles are inflated; in India, owners pay a lifetime registration tax upon purchasing a vehicle, but most owners do not de-register their vehicles when they stop using them. Our estimates of actual vehicle numbers are based on three survey studies that were conducted to determine the number of vehicles on the road in India [18,19].

Table 4 shows the relative proportions of vehicles registered in five of the cities in the study. Overall, the cities have similar vehicle proportions. However, Ludhiana has the highest number of cars and MTWs, while Vadodara and Vishakhapatnam have a much higher proportion of TSTs.

3.2. Modal share of RTI fatalities

Fig. 2 shows the proportions of road traffic fatalities by road user type in the six Indian cities. The total number of vulnerable road user deaths in all six cities ranges between 84% and 93%, with car occupant fatalities varying between 2% and 4%. TST occupants account for less than 5% of all deaths in all the cities besides Vishakhapatnam, where the proportion is 8%. These total proportions are similar to those in the megacities of Mumbai and Delhi. However, these smaller cities have lower relative proportions of pedestrian fatalities and higher relative proportions of MTW than the figures for the megacities. This may be because the proportion of MTW ownership is higher in the smaller cities than in the megacities [4]. Helmet use by MTW riders is not enforced in any of these cities, though helmet use is mandated by the Motor Vehicles Act 1988 of India [20]. The high rate of MTW fatalities could be reduced significantly if the existing mandatory helmet laws were enforced in all the cities and laws requiring MTWs to keep their lights on during the day were implemented [21–24].

Ludhiana and Amritsar have relatively high proportions of bicyclists. Anecdotal evidence suggests that these cities have higher rates of bicycle use than the other cities in the study, but we cannot confirm this conjecture. At present, we are unable to determine the reasons for a higher rate of MTW fatalities in Vishakhapatnam.

Table 2
Population and road traffic fatality data for six cities selected for the study [16,17].

	City					
	Agra	Amritsar	Bhopal	Ludhiana	Vadodara	Vishakhapatnam
2011 population	1,574,542	1,132,761	1,795,648	1,613,878	1,666,703	1,730,320
2011 road traffic fatalities	653	70	254	294	172	416
Fatalities per 100,000 persons	41	6	14	18	10	24

Table 3
Number of fatal crash records obtained for each city.

City	Fatal crash records obtained
Agra	674
Amritsar	265
Bhopal	685
Ludhiana	651
Vadodara	684
Vishakhapatnam	1164

Fig. 1. Three-wheeled scooter taxi (TST).

3.3. Road user victim type and impacting vehicle/object

Fig. 3 shows the data for the distribution of road traffic fatalities by road user category versus the respective impacting vehicles/objects for two of the six cities in the study (Agra and Bhopal). These two cities, whose figures are representative of the patterns in all six cities, were selected as they have different fatality rates per 100,000 population: 24 (Vishakhapatnam) versus 14 (Bhopal) in 2011. In both cities, the largest proportion of fatalities for all road user categories (especially vulnerable road users) is associated with collisions with buses and trucks, with cars coming in as the next leading vehicle type. This pattern holds true for the other four cities, as well. The most interesting finding to emerge from this analysis is that motorised two-wheelers are associated with a certain percentage of pedestrian fatalities in all six cities. The proportion of pedestrian fatalities associated with MTW collisions ranges from 8% to 25% of the total. The highest proportion was observed in Bhopal. The involvement of MTWs as impacting vehicles in VRU fatalities may be due to the fact that pedestrians and bicyclists lack adequate facilities on arterial roads in these cities and have to share road space (the curbside lane) with MTW riders.

3.4. Road traffic fatalities by road user type and time of crash

Fig. 4 covers the fatalities in Agra and Ludhiana by road user type and time of crash. Agra and Ludhiana were selected due to their divergent fatality rates and because traffic characteristics were studied in greater detail by us. According to the data, pedestrian and bicycle fatalities have higher rates earlier in the morning. This may be because pedestrians and bicyclists leave for work earlier in the morning than those using forms of motorised transport do. The total fatality rate remains relatively constant between the hours of 10 a.m. and 6 p.m. with no evidence of a strong bimodal distribution. This could be because school and work hours are reasonably staggered. The school day starts around 8 a.m. and ends at 2 p.m.; some schools also have second shifts. Private offices open between 8 a.m. and 9 a.m., government offices between 9 a.m. and 10 a.m., and shops around 11:00 a.m. Most shops stay open until 9 p.m., and restaurants generally serve customers until 11 p.m. The data also show that MTW and pedestrian deaths are relatively high between 8 p.m. and 11 p.m., a time frame when one would expect traffic volumes to be comparatively low. Although the details of risk factors for these elevated rates of vulnerable road user fatalities at night are not available for all the cities, surveys done in Agra and Ludhiana suggest that, due to the lower traffic volume levels, vehicles drive faster at night. Other factors include insufficient street lighting and limited drunk-driving countermeasures [25]. The conditions would likely be similar in the four other cities except for Vadodara, where the consumption of alcohol is illegal.

3.5. Victim age

In a vast majority of cases, the First Information Reports (FIR) available to us did not indicate victim age. Fig. 5 shows the known age distribution of fatal road traffic crash victims and the age-specific population distribution for India in 2011 [16,17]. These data indicate that the 0–14 age group is underrepresented in proportion to its share of the population. The data coders marked out the cases where “children” were mentioned as victims in the police reports. In general, these would be individuals under the age of 4. For Agra, Amritsar, Bhopal, and Vishakhapatnam (2788 total fatalities in the sample), a total of 78 cases (2.8%) fell into this category; 13 of the cases involved MTW occupants (0.5%), and 53 were pedestrians (1.9%). This is less than the national rate of 7% for the 0–14 age group. This may be partly because some individuals under the age of 14 may not have been classified as children. Lower exposure rates among children may be a factor, but this explanation does

Table 4
Vehicle registered in Agra, Bhopal, Ludhiana, Vadodara, and Vishakhapatnam in 2010.

Vehicle	No. of vehicles in 2011[a]				
	Agra	Bhopal	Ludhiana	Vadodara	Vishakhapatnam
MTW[b]	257,577 (72.4)	301,397 (72.9)	866,392 (76.8)	322,035 (69.2)	234,892 (71.7)
TST[c]	8501 (2.3)	11,500 (2.7)	14,562 (1.2)	33,239 (7.1)	21,994 (6.7)
Car	32,563 (9.1)	49,705 (12)	158,263 (14)	61,076 (13.1)	39,943 (12.1)
Taxi	3370 (0.9)	17,945 (4.3)	1701 (0.1)	7116 (1.5)	6331 (1.9)
Bus	1752 (0.4)	3275 (0.7)	2588 (0.2)	3717 (0.7)	3234 (0.9)
Truck	16,371 (4.6)	14,433 (3.4)	35,487 (3.1)	33,337 (7.1)	18,163 (5.5)
Tractor	35,616 (10)	14,977 (3.6)	48,571 (4.3)	4779 (1)	3001 (0.9)
Total	355,750 (100)	413,232 (100)	1,127,564 (100)	465,299 (100)	327,558 (100)

Numbers in parentheses represent the percent vehicles in each city.
[a] The numbers for cars and MTWs are estimates (see the text).
[b] Motorised two-wheelers.
[c] Three- and four-wheeled scooter taxis.

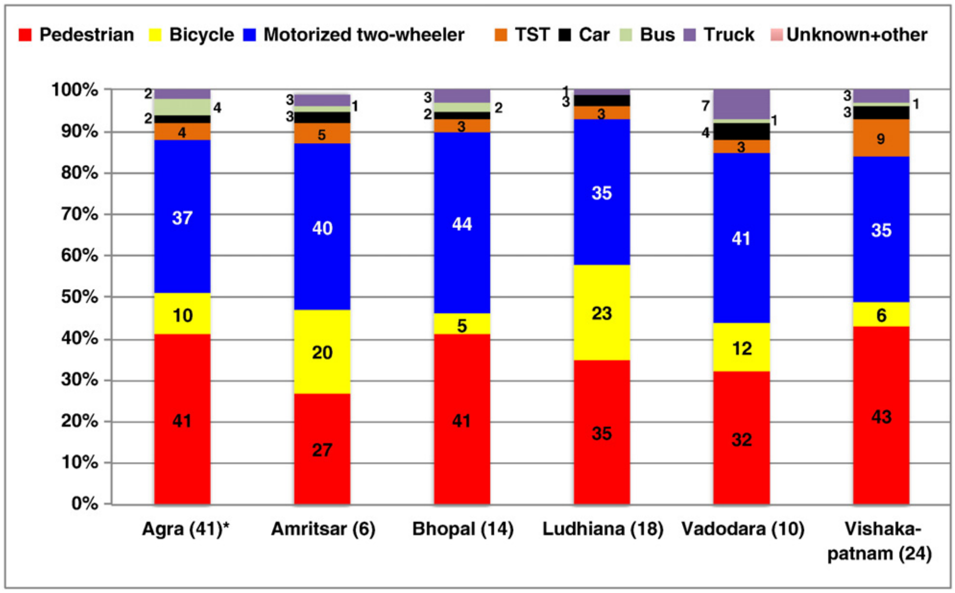

Fig. 2. Proportions of road traffic fatalities by road user type (vehicle occupants, bicyclists, and pedestrians) in Indian cities (*the numbers in parentheses represent the official RTI fatality rate in the city in 2011).

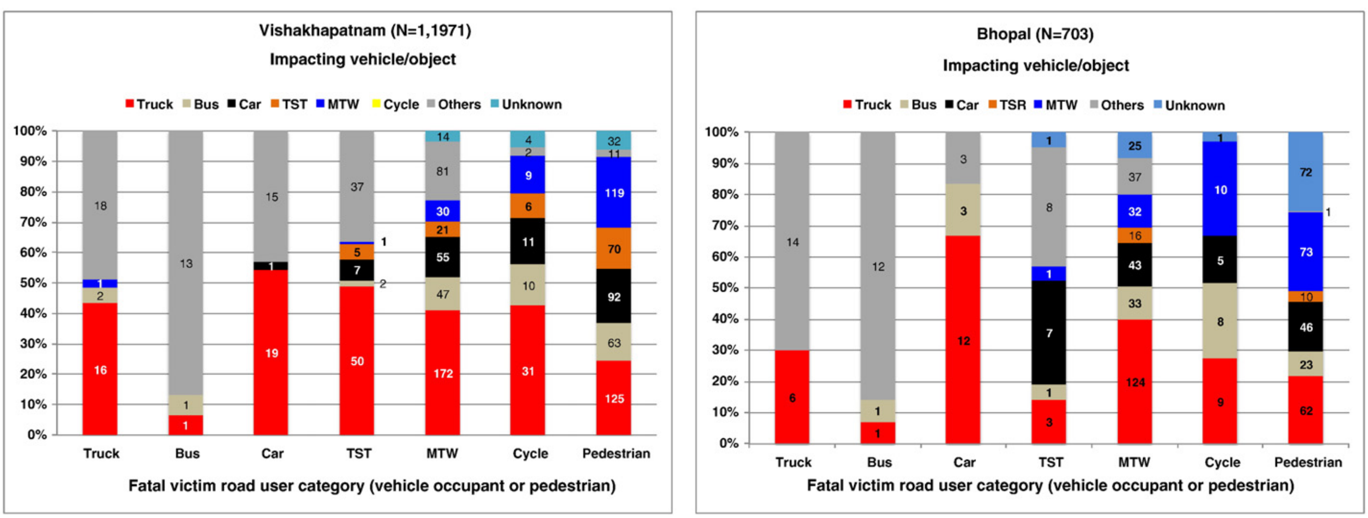

Fig. 3. Fatal RTI victim road user categories and impacting vehicles/objects in Vishakhapatnam and Bhopal (the numbers in the bars represent the corresponding numbers of cases).

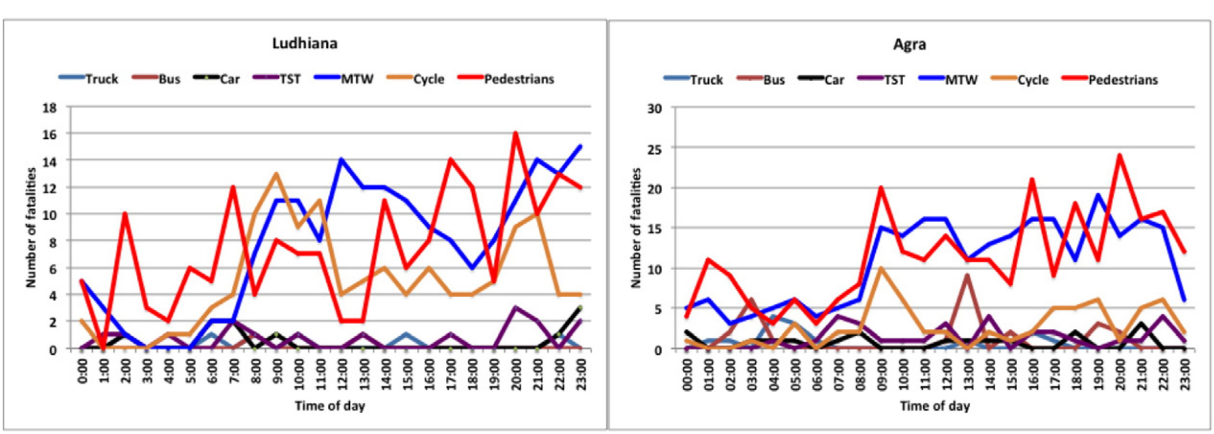

Fig. 4. Road traffic fatalities in Agra and Ludhiana by time of crash and road user type.

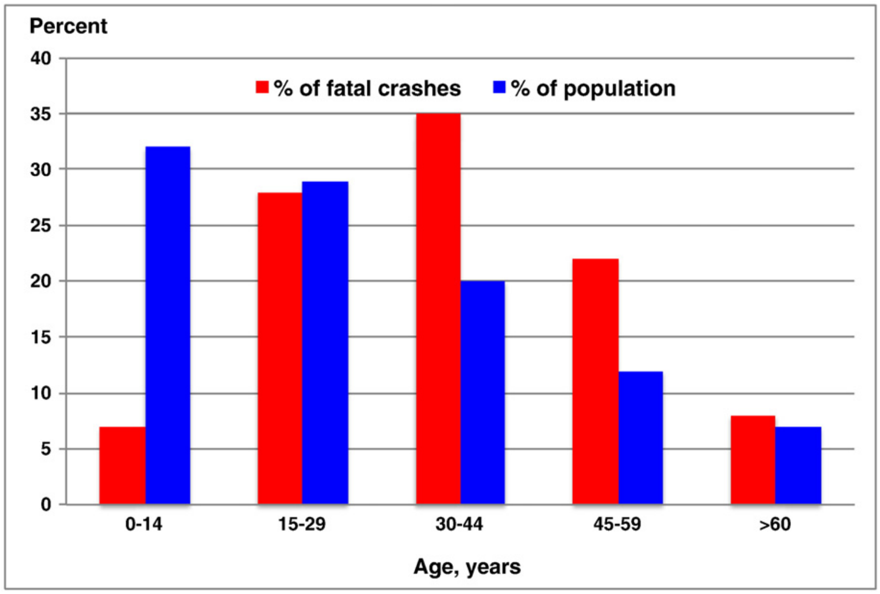

Fig. 5. Age distribution of fatal road traffic crash victims and the age specific population distribution for India in 2011 (Ref 12, 13).

not appear to be enough to account for these very low rates, especially among children on motorcycles. This phenomenon needs further study.

Table 5 provides the distribution of fatalities by gender. The ratio between males and females is roughly 4:1 in all six cities. This difference between males and females can be partly explained by the fact that the labour force participation rate is lower for Indian women than it is for Indian men [16].

3.6. Road user risk analysis

Fatality risk was calculated using different indices to understand the role of different motor vehicles, personal risk per trip by mode, and the risks that different vehicles pose to society.

3.6.1. Occupant risk per 100,000 vehicles

Fig. 6 shows the number of motor vehicle occupant fatalities per 100,000 vehicles for four cities where the vehicle data were relatively reliable. The figures were obtained by dividing the estimated total number of occupant fatalities for each vehicle type in 2011 by the estimated number of vehicles falling into that vehicle category in the corresponding city (corrected for inflated estimates). These data show that occupant fatalities per vehicle are highest for TSTs, followed by MTWs and cars. Occupant fatality rates for MTW and TST occupants are 2–3 and 3–5 times higher, respectively, than that for cars. The high per-vehicle fatality rates for TSTs likely tie into the fact that TSTs carry a much larger number of passengers in the day than MTWs and cars do. The MTW fatality rate never exceeds 5 times the fatality rate for cars in any of the four cities. In Europe and the United States, this ratio is reported to be in the range of 10–20 [21]. We do not have detailed data to explain with certainty why this risk ratio for MTW riders is lower in Indian cities where helmet laws go largely unenforced. Possible reasons could be that the majority of motorcycles on the Indian market are of low power (<150 cm^3), that the majority of riders are not enthusiasts but rather regular commuters, and also the large number effect [26].

Table 5
Distribution of RTI fatalities by gender.

City	% of RTI fatalities	
	Male	Female
Agra	89	11
Amritsar	86	14
Bhopal	87	13
Ludhiana	83	17
Vadodara	83	17
Vishakhapatnam	82	18

3.6.2. Personal fatality risk per 10 million trips

Personal fatality risk was calculated by dividing vehicle-specific occupant fatality rates by estimates of the average daily occupancy of each vehicle. The occupancy rates for MTW, car and TST were estimated to be 4, 7 and 60 persons respectively per day [27–29]. The results of these calculations are shown in Fig. 7. Given the present trip lengths for each vehicle type, MTW riders are 3–6 times more at risk than car occupants are. The MTW fatality rates per trip in Agra and Vishakhapatnam are much higher than those in the other three cities. The reasons for this are not known at present. At an individual level, risk per trip seems to be the lowest for TST occupants in all the cities under the assumed occupancy rates and number of trips per day.

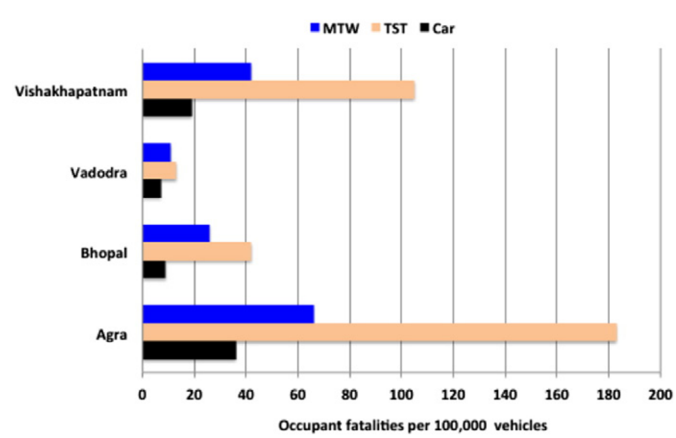

Fig. 6. Motor vehicle occupant fatalities per 100,000 vehicles.

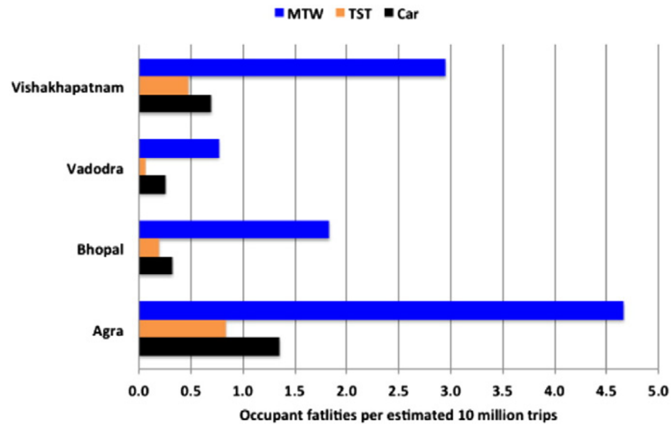

Fig. 7. Personal fatality risk per 10 million trips for occupants of motorised two-wheelers, TSTs, and cars.

3.6.3. Fatalities associated with each vehicle type, accounting for exposure

Fig. 8 shows all the fatalities associated with each vehicle type per 100,000-vehicle km per day. We assumed the following daily travel distance values for the different vehicle types.

- Bus: 150 km
- Car: 50 km
- TST: 150 km
- MTW: 25 km.

The data include fatalities of occupants and road users other than vehicle occupants. For example, if a motorcycle hits a pedestrian and the pedestrian dies, the pedestrian death is also associated with the motorcycle. This index gives a rough idea of the total number of fatalities one might expect for each vehicle type given the present traffic conditions and mode shares. Essentially, the figures indicate that the low rate for TSTs relative to cars is due to the higher exposure of TSTs per day. These indices appear to suggest that, on a travel distance basis, TSTs, MTWs, and cars pose roughly the same level of danger to society under the present conditions. Out of the three vehicle types, MTWs appear to need safety countermeasures implemented urgently (safety helmet use and daytime running lights). Safety is also a pressing concern for TSTs, which are threats to both their occupants and the VRUs that they impact.

4. Conclusions

The total number of vulnerable road user deaths in all the six cities ranges between 84% and 93%, car occupant fatalities between 2% and 4%, and TST occupants less than 5%, except in Vishakhapatnam where the proportion for the latter is 8%. These total proportions are similar to those in the megacities of Mumbai and Delhi. Helmet use by MTW riders is not enforced in any of these cities, though the Motor Vehicles Act 1988 of India mandates helmet use. The high rate of MTW fatalities could be reduced significantly if the existing mandatory helmet laws were enforced in all the cities and laws requiring MTWs to keep their lights on during the day were implemented.

The largest proportion of fatalities for all road user categories (especially vulnerable road users) is associated with collisions with buses and trucks, with cars coming in as the next leading vehicle type. The same holds true for the other four cities, as well. The most interesting finding to emerge from this analysis is that motorised two-wheelers cause a certain percentage of pedestrian fatalities in all six cities. The proportion of pedestrian fatalities associated with MTW collisions ranges from 8% to 25% of the total. The involvement of MTWs as impacting vehicles in VRU fatalities may be due to the fact that pedestrians and bicyclists lack adequate facilities on arterial roads in these cities and have to share road space (the curb-side lane) with MTW riders. The provision of separate and adequate pedestrian and bicycle lanes in all cities is a prerequisite for RTI control.

MTW and pedestrian deaths are relatively high between 8 p.m. and 11 p.m., a time frame when one would expect traffic volumes to be comparatively low. Surveys done in Agra and Ludhiana suggest that, due to the lower traffic volume levels, vehicles drive faster at night. Other factors include insufficient street lighting and limited drunk-driving countermeasures. These findings imply that design- and enforcement-based speed controls, better street lighting, and improved alcohol control would be necessary to limit RTI at night.

The involvement of young children in fatal crashes appears to be low. The underlying reasons for these conditions are unclear, however, and require study. The relative risk of MTW occupants is the highest in India but not as high as the risk levels in high-income countries. Based on total involvement in fatal crashes, however, cars appear to pose a greater risk to society than motorcycles and three-wheeled scooter taxis do. Further research is necessary to determine the veracity of these findings.

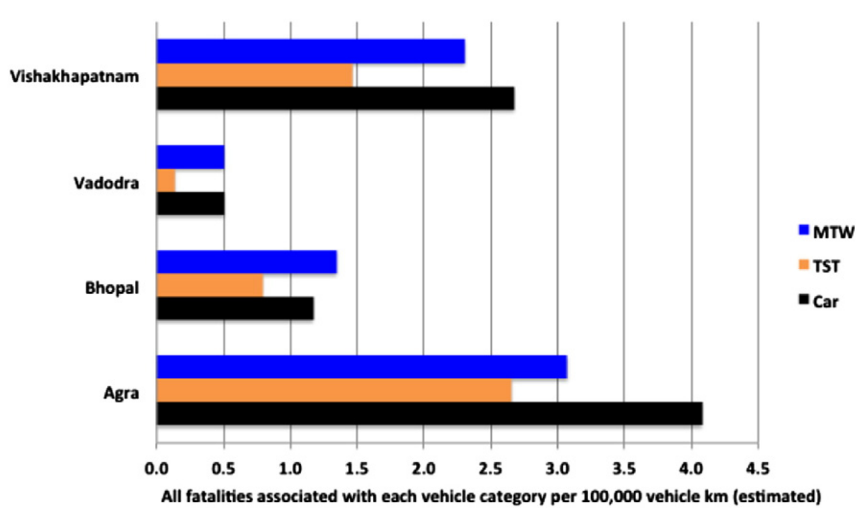

Fig. 8. All fatalities associated with each vehicle category per 100,000 vehicle km (estimated).

Acknowledgements

This project received financial support from IATSS (Project H2429) and Doi Kenji, Takeuchi Kazuhiko, Oguchi Takashi, Kitamura Yuto, Yokoyama Toshio, Omae Hideyuki, Kakinuma Toru, Kajita Tomoyuki, and Sasa Hideko.

Assistance with data analysis was provided by Pankaj Prajapati, Gaurav Pandey, Abhay Jha, and Rahul Goel.

Assistance with obtaining data from various cities was provided by Mahesh Gaur and Sumit Gupta.

Assistance with data transcription and coding was provided by Amrendra Kumar, Arla Sagar, K. Guru Prasad, K. Madhavi, Kamal Preet Singh, Poojari Yugendar, Sunil Sharma, and Vijendra Kumar.

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