Traffic Safety and City Public Transport System: Case Study of Bengaluru, India

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Abstract

Vehicle crashes are a major concern in rapidly growing urban agglomerations. They also have attracted the attention of researchers, academicians, and policy makers. A large body of research literature exists that throws light on the magnitude of this problem and also indicates the interventions required. In a vast majority of Indian cities, buses are the main mode of public transport. An externality of the bus-based public transport system, like any other mode of transport, is the injuries and fatalities arising out of the crashes involving them. Buses are involved in 12-20 percent of fatal crashes in Indian cities. This paper presents an analysis of the fatal crashes that involved public transport buses in Bengaluru, India. The study suggests that low floor buses with mechanical doors and segregated pedestrian and bicycle lanes can have a major impact on reducing fatal crashes of bicycles and pedestrians involving buses.

Introduction

In low and middle income countries, buses are likely to remain the primary mode of mass transit for the foreseeable future (Tiwari 1994). In most transportation scenarios, reliance on buses has a positive impact on air quality because they pollute less per person mile and create less congestion because of their smaller road-use footprint. In addition to these benefits, it is usually assumed that buses are among the safest modes of transport available because they are much larger in size and mass than most other road vehicles. Biomechanics and crash investigation studies have confirmed that occupants of buses are at much lower risk of dying in the event of a crash (Bhalla et al. 2006) However, bus users face risks of road traffic injuries on access trips and buses also are associated with road traffic crashes with other road users (Bhalla et al. 2007, Mohan et al. 2009).

The total motor vehicle population in India has increased from about 300,000 in 1951 to about 73,000,000 in 2004 (see Table 1). The basis of this figure is the number of new vehicles registered each year. The vehicles registered each year are accumulated to arrive at the total figure of vehicles on road, notwithstanding that vehicles do have a specified life. Out-of-use vehicles remain on record. Recent studies have estimated that actual number of vehicles on the road in Delhi is 60-70 percent of the official statistic (Expert Committee 2002; CRRI 2007). The figures in Table 1 reveal that motorcycles are more than five times as numerous as cars and that the total of buses, goods vehicles and other vehicles is similar in magnitude to the number of cars. These proportions of vehicle types are different from those in high-income countries and can influence fatality rate patterns. In the U.S. in 2005, for example, passenger cars constituted 66 percent of vehicles on the road, trucks and vans 30 percent, motorcycles only 3 percent, and buses 1 percent. The number of vehicles in a city with a population of about 6 million (Bengaluru) is indicated in Table 2.

Statistics about road crashes in India are compiled at the national level by the Ministry of Road Transport and National Highways. This is based on the reports received from the state governments. The National Crime Records Bureau (NCRB) of the Government of India also gathers data about fatalities and injuries in road crashes. They source their data from police records. 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). Traffic fatalities increased by about 5 percent per year from 1980 to 2000, and since then have increased by about 8 percent 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 (Mohan et al. 2009). 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

Table 1. Total Number of Registered Motor Vehicles in India, 1951-2004 (in thousands)

Year (as of March 31)		All Vehicles	Two-Wheelers	Cars, Jeeps and Taxis	Buses		Good Vehicles	Others*
1951		306	27	159	34		82	4
1956		426	41	203	47		119	16
1961		665	88	310	57		168	42
1966		1099	226	456	73		259	85
1971		1865	576	682	94		343	170
1976		2700	1,057	779	115		351	398
1981		5391	2,618	1,160	162		554	897
1986		10,577	6,245	1,780	227		863	1,462
1991		21,374	14,200	2,954	331		1,356	2,533
1996		33,786	23,252	4,204	449		2,031	3,850
1997		37,332	25,729	4,672	484		2,343	4,104
1998		41,368	28,642	5,138	538	@	2,536	4,514
1999		44,875	31,328	5,556	540	@	2,554	4,897
2000		48,857	34,118	6,143	562	@	2,715	5,319
2001		54,991	38,556	7,058	634	@	2,948	5,795
2002		58,924	41,581	7,613	635	@	2,974	6,121
2003	(R)	67,007	47,519	8,599	721	@	3,492	6,676
2004	(P)	72,718	51,922	9,451	768	@	3,749	6,828

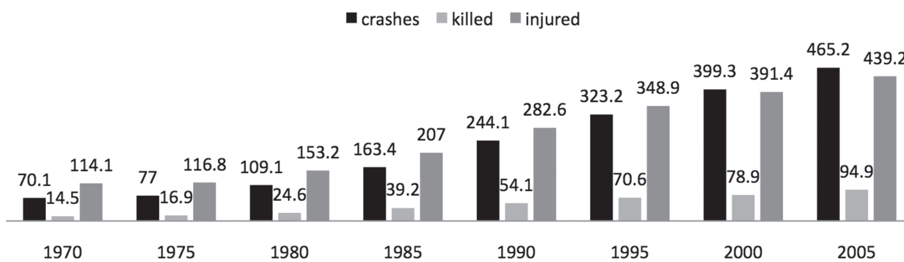
**Others include tractors, trailers, three-wheelers (passenger vehicles), and other miscellaneous vehicles that are not separately classified.*
@Includes omni buses.
Source: Ministry of Road Transport and Highways Web site.

Table 2. Cumulative Number of Vehicles Registered in Bengaluru City

Year	Two-Wheelers	Three-Wheelers	Cars	Jeeps	Taxis	Buses
1991	279,498	31,864	36,602	3,051	1,046	9,706
2000	1,164,204	68,734	230,388	7,986	8,638	6,380
2005	1,876,498	92,722	340,168	9,171	14,250	11,708
2006	2,161,663	94,587	415,645	6,280	19,802	13,032
2007	2,405,727	109,405	486,657	8,775	27,723	14,739

Source: Office of the Transport Commissioner, Government of Karnataka.

2006). According to that study, deaths were underestimated by five percent, and the number injured who needed treatment in hospitals was underestimated by a factor of more than two. In that study, the ratio of injured people reporting to hospitals versus those killed was 18:1. The numbers for crashes and those injured in Figure 1 are, therefore, gross underestimates. The age profile and gender of the crash victims is also available both at the state and the national levels.



Source: morth.nic.in., Ministry of Road Transport and Highways, Goverment of India)

Figure 1. Road Crashes in India (in thousands)

Data for road user types killed are not available at the national or state levels in India (Mohan et al. 2009). Some studies in the past have attempted an analysis of the fatalities in cities due to road crashes. Mohan and Tiwari (2000) concluded that pedestrians, bicyclists, and motorized two-wheeler riders accounted for 60-90 percent of all traffic fatalities. Another study (Mohan et al. 2009) obtained fatalities data from the Delhi police in the form of a consolidated spreadsheet. The data consisted of a list of incidents identified by the time and location at which each incident occurred, the involved road-user type, the number of fatalities and injuries in the crash, a general categorization of the fatality by age and gender, and whether a pedestrian was hit. The dataset provided a reliable view of some characteristics of fatalities that are not available otherwise at the state or national levels. A similar analysis was carried out for the study of Mumbai (Tiwari et al. 1999). Both studies revealed that pedestrians, cyclists, and motorized two-wheeler riders account for 80-90 percent of all the fatalities. The study of Delhi analyzed different categories of road users by the time of day. There were four relevant findings. 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 a high involvement in both daytime and nighttime. Third, buses feature prominently from about 700 hrs to about 2,100 hours. Fourth, the proportion of unknowns is substantial, especially during nighttime.

Figures for fatalities in crashes in all cities having a population exceeding one million were analyzed for the year 2007 (see Table 3). In Bengaluru,[1] the total number of fatal crashes in 2007 was 957, of which 12 percent involved buses of the public transport system (Figure 2). The number of fatal crashes caused by public transport buses in selected Indian cities is shown in Table 4. Fatal crash rates[2] vary from 0.13 in Kolkata to 4.36 in Chennai.

Table 3. Comparison of Road Crash Fatalities in Indian Cities

City	Fatalities in Road Crashes	Population (millions)	Fatalities per Million
Ahmedabad	256	4.5	57
Bengaluru UA	957	5.8	165
Chennai UA	1,146	6.5	176
Delhi	2,141	13.8	155
Hyderabad	391	3.7	106
Kolkata UA	462	13.2	40
Greater Mumbai	651	16.43	40
Pune UA	414	3.76	110

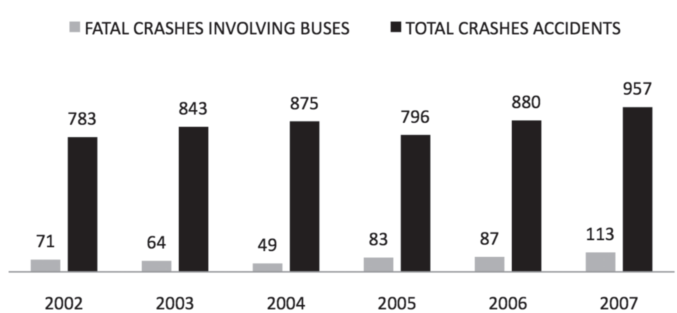


Figure 2. Fatal Crashes in Bengaluru City (Total and Those Involving Buses)

Table 4. Fatal Crashes Caused by City Buses by Ownership

S. No.	STU		Fleet Held	Fatal Crashes per 100 Buses	Vehicle Miles Traveled (million km)	Fatalities per Million Bus km
1	BEST (Mumbai)	35	3,391	1.03	240	0.15
2	AMTS (Ahmedabad)	11	521	2.11	45	0.24
3	BMTC (Bengaluru)	77	3,468	2.22	329	0.23
4	CSTC (Kolkata)	1	741	0.13	26	0.04
5	DTC (Delhi)	63	2,578	2.44	181	0.35
6	PMT (Pune)	15	845	1.77	61	0.25
7	MTC (Chennai)	121	2,773	4.36	219	0.55

Source: Based on figures published by CIRT, Pune.

A comparative analysis of the road crash fatalities in Indian cities was done by Mohan in 2004. He concluded that data show that most of the city rates are higher than the average for India as a whole (80 fatalities per million). Most of the cities have similar rates (100 +/- 20 fatalities/m persons), except a few that are lower than 80/m and higher than 140/m. The same study also confirmed that there were no detailed studies available to come to any firm conclusions regarding the differences in crash rates in different cities. However, low rates in Kolkata and Mumbai may be attributed to lower vehicle speeds on some of their main arteries, as compared to cities like Delhi and Hyderabad where some of the main arterial roads have much more space available for vehicle speeds to be high, especially during non-peak hours. A study on "Transportation Polices and Strategies in Urban Areas" (Wilbur Smith Associates 2008) did a comparative analysis of the crash fatalities in Indian cities. They developed an Accident Fatality Index and a Road Safety index to compare vulnerability of different cities to road crashes. It was concluded that cities with higher slow-moving vehicles in the traffic stream such as Guwahati, Varanasi, Kanpur, Raipur, Amritsar, etc. (populations of less than 3 million) have a worse safety index and are unsafe. It also found that due to the absence of separate lanes for slow-moving vehicles, the right-of-way is shared by all, leading to unsafe roads. It also was brought out in the study that larger cities are safer than smaller and medium cities, as larger cities generally have lower speeds, efficient public transport, and better traffic management.

A major reason why comparisons of fatalities between cities are made difficult is that the geographical jurisdictions of a city are different for different agencies. For example, the city government has well-defined municipal boundaries, but the boundaries of city police are not coterminous with that of the city government. The census that gives the population figures defines a new set of boundaries for itself: the urban agglomeration, the bus transport company plies within limits that are decided by the state government, the urban planning body has a much bigger geographical jurisdiction, the transport department that registers the vehicles and licenses the drivers follows its own territorial jurisdiction which is totally distinct from that of other agencies. Therefore, capture of data by different agencies is from a different base and, hence, comparisons without applying correction factors may give misleading results.

From the above it could be concluded that the data about fatalities are available at the city, state and national levels. However, these data do not capture vital details about crashes, which could throw light on the cause of the crashes. Another limitation of these data at the city level is that the data are reported by the traffic police whose jurisdiction does not coincide with that of other agencies.

Objective

The number of fatal vehicular crashes in cities is on the rise, and a significant number of these fatal crashes involves public transport buses. The objective of this study was to analyze these crashes and identify the major factors responsible for such crashes so that remedial policy measures could be recommended.

Method

All cases involving fatal crashes were studied to capture different parameters of each crash. These parameters were then analyzed to evolve trends and patterns in these crashes. Based on the analysis, measures have been suggested to reduce such crashes.

The records maintained by the bus operating organization in Bengaluru[3] were obtained for five years (2003-2007). The BMTC (Bengaluru Metropolitan Transport Organisation)—the bus operating company—maintains records of all major crashes involving its fleet of buses. Maintenance of such records is used for taking internal corrective measures within the organization and also for deciding on compensation claims. The police also maintain crash records, but these records do not have vehicle and driver details as recorded by the bus company. The analysis was confined to fatal crashes only, as fatal crash records are more reliable and also because injury crashes are under-reported and the record keeping for other crashes is not as meticulous as it is for fatal crashes.

Four hundred cases for the years 2003-2007 were examined, and different parameters for each crash were tabulated. The parameters analyzed for each crash given in Table 5.

Table 5. Parameters Analyzed for Each Fatal Crash

General Details	• Vehicle # • Date of crash • Time of crash • Runover or impact • Straight road or intersection
Vehicle Details	• Bus with or without pneumatic doors • Rear door or middle door • Standard or articulated • Mechanical failure, if any
Driver Details	• Age • Was the driver drunk? • Did inquiry reveal driver's fault?
Victim Details	**If Pedestrian:** • Age • Profession • Gender • Impact from which side of bus? • Run over by which wheel? • Whether crossing or walking alongside • If crossing, left to right or otherwise?
	If Cyclist: • Age • Profession • Gender • Impact from which side of bus? • Run over by which wheel? • Crossing or walking alongside? • If crossing, left to right or otherwise?
	If Motorcyclist: • Age • Profession • Gender • Impact from which side of bus? • Run over by which wheel? • Whether crossing or walking alongside • If crossing, left to right or otherwise?
	If Bus Passenger: • Age • Profession • Gender • What was the victim doing: sitting inside, boarding, alighting? • Run over or impact? • At bus stop or en route?

The results of the analysis and the suggested measures to reduce the number of fatalities are discussed in the following paragraphs.

Results and Analysis

Trend in Road Traffic Crashes

Figure 3 shows the statistics regarding fatal crashes involving buses for the years 2003-2007. The fleet of buses has increased by almost 80 percent during this period (2003-2007), as have the number of crashes. The fatal crash rate per 100 buses, as shown in Figure 4, has not shown any increasing or decreasing trend, thus establishing that the number of crashes is almost directly proportional to the fleet size in the absence of specially-targeted effective countermeasures.

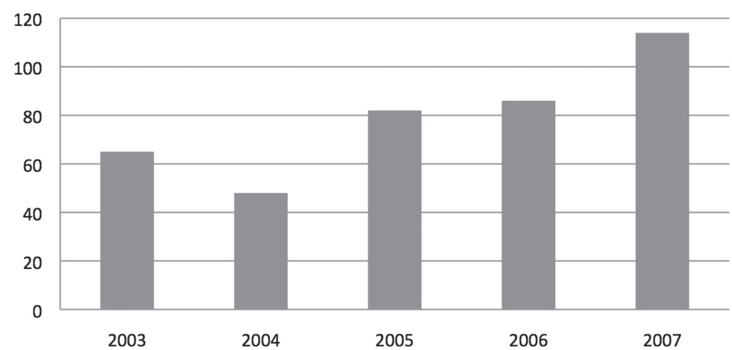


Figure 3. Number of Fatal Crashes Involving Buses

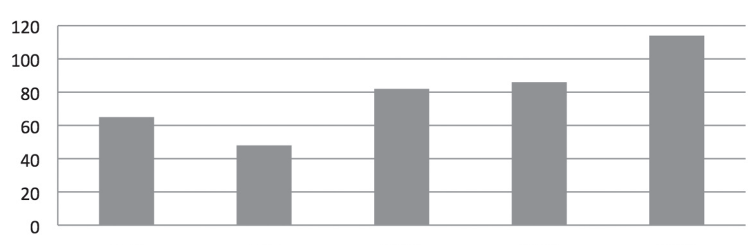


Figure 4. Crashes per 100 Buses Held

Diurnal and Seasonal Variations in the Crashes

To ascertain whether the crashes are dependent on the time of day or are dependent on the seasons during the year, a diurnal and a seasonal analysis was done. Table 6 shows the number of fatal crashes of all vehicles distributed over different months and time of a day. During the day, the variation of traffic on roads is quite pronounced. It is bi-modal, picking up in the morning and then reducing in the noon, then increasing in the evening, and finally tapering off in the night. The traffic pattern on a typical working day is given in Figure 6.[4] Hanowski et al. (2009) found a similar incident to time-of-day relationship.[5]

Table 6. Diurnal and Seasonal Variations of Fatal Crashes

	Month												
Time:Hrs	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
0500-0600							3	1	1				5
0600-0700		2			1	3	1	1		1		2	11
0700-0800		3	1	2	1	1	3	3		1			15
0800-0900	2	5	5	2	1	1	1	3	5	2	4	1	32
0900-1000	4	1	4	1	2	2	3	2		2	3	4	28
1000-1100	3	3	1	1	3		1	2	3	5	2	2	26
1100-1200	2	2		2	1	2		2	1	4	1	2	19
1200-1300		1		1	3	1	1	6		1	3	4	21
1300-1400	1	2		4	1	1	2	2	2	1			16
1400-1500	2		1	3	5		1	3	3	2	1	3	24
1500-1600	3	3	2	1	1	2	2	1	1	4	3	2	25
1600-1700	2	2		1	1	3	4	2	2	3	5		25
1700-1800	2			2	1		4	1	2	5	2		19
1800-1900	4	1	1	3	1	1	5	1	1	1	3	2	24
1900-2000	8	4	2	4	5	3	3	1	5	5	2	2	44
2000-2100	2	2	1	4	1	1	3	1	1	2		4	22
2100-2200	1	1	1	1	5	1	2	4	1		4	3	24
2200-2300						1	3	2	1	1	2		10
2300-2400		2					1		1	2			6
Total	**36**	**34**	**19**	**32**	**33**	**23**	**43**	**38**	**30**	**42**	**35**	**31**	**396**

From Table 6, it is evident that the numbers of fatal crashes is not consistent across the months; thus, there are seasonal variations, but such variations are not significant (mean 33, SD 6.9). Data from Table 6 and Figure 5 show that both the number of crashes and the traffic volume distribution in a day, with respect to time, is bimodal. There are substantial fluctuations in the number of fatal crashes recorded per hour during different times of a day. To compare the vulnerability towards fatal crashes during different time periods of the day, vulnerability factors were calculated by dividing the number of fatal crashes by the average vehicular count during the hour (Figure 6). The factor was set at unity for the time 0600-0700 hours. The vulnerability factor beyond 2100 hours could not be worked out, as the vehicular count was taken up to 2100 hours only. However, the fatality data would indicate that the factor would increase further between 2100 to 2200. The highest (1.3) and lowest (0.52) values were between 1900-2000 and 1300-1400 hours, respectively, with a mean of 0.76 and an SD of 0.22. The relative vulnerability factor was high in the morning between 0600- 0700 hours and again between 0800-0900 hours. This could be due to the relatively low volume of traffic on roads, resulting in higher speeds. However, the values are not significantly different from the mean at 95% confidence levels (Mean +/- 2SD) except for 1900-2000. It is interesting that the two peaks do not coincide. While the crash rate per hour peaks between 0800-0900 hours, the traffic peaks between 0900-1000 hours. Similarly, in the evening, while the crash rate peaks between1900-2100 hours, the traffic peaks between 1700-1800 hours. Also, the crash rate during evening is more than the crash rate in the forenoon. A plausible explanation for this could be that during traffic peak hours, the vehicular speeds are much less and therefore the crash rate also drops. The reason for the more pronounced evening peak crash rate could be the absence of daylight after 1900 hours combined with inadequate street lighting and higher speeds.

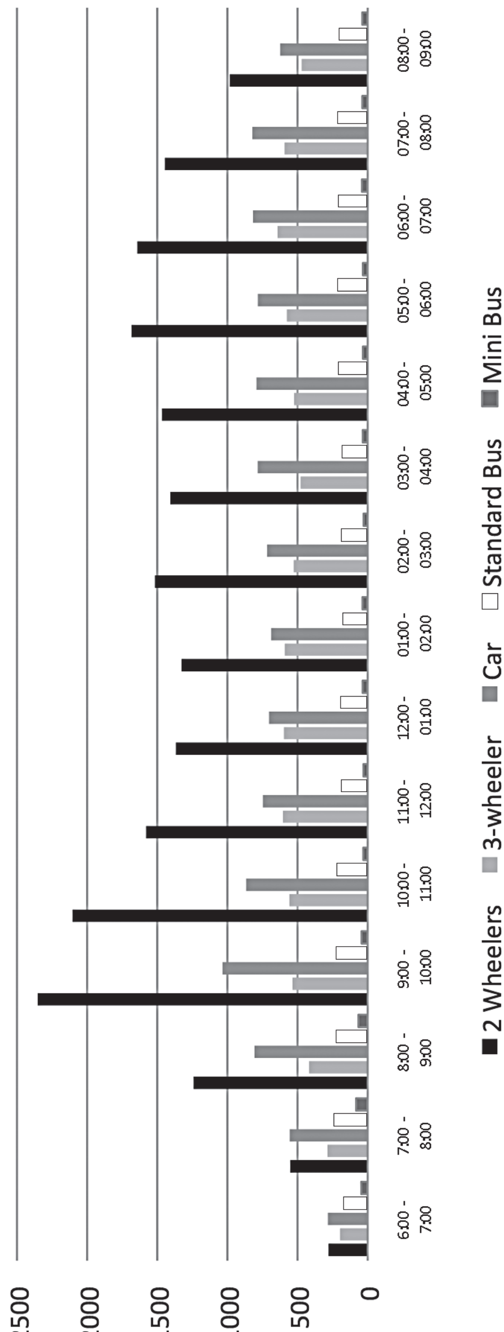


Figure 5. Traffic Distribution During a Day

Analysis of the Mode of Transport of Victims

The risk associated with different modes of transport for being a victim of a fatal crash with buses is different. To analyze this, the modes of travel (of victims) were categorized into six groups: auto rickshaw, cyclist, four-wheeler, two-wheeler, bus passenger, and pedestrian. The mode-wise details of the victims of fatal crashes are given in Table 7. In absolute numbers, motorized two-wheeler riders constitute the largest share of fatalities (40%) and cyclists account for about 10 percent. However, if the probability of a fatal crash is calculated per million km of a particular mode, then the cyclists are about six times more vulnerable compared to motorized two-wheelers. This may be because there are no separate bicycle lanes on arterial roads and bicyclists have to share the left lane with buses.

Table 7. Categorization of Victims

Category of Victim	Impact	Runover	Total	Gross Vehicle km 2003-07 (million km)	Probability of a Fatal Crash per Million km
Auto Rickshaw	5		5	7,606	0.00127
Cyclist	16	16	32	654	0.0949
Four Wheeler	8		8	11,028	0.0014
Passenger	57	26	83	3,075	
Pedestrian	75	32	107		
Grand Total	255	141	396		

**The vehicle kms for the fleet of BMTC buses is readily available (1.17 million km per day). For other modes of transport, it was extrapolated based on the average vehicular count.*

Riders of cars and other four wheelers have a very low risk of being involved in a fatal crash with a public transport bus. These trends can be compared to the trends of fatal crashes in Delhi, Mumbai, and Kota (population 1.5 million), as reported by Mohan et al. (2009) and Tiwari et al. (1998). Buses are associated with nearly 20 percent crashes in Delhi, 12 percent in Mumbai, and 5 percent in Kota. 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 high involvement of buses and trucks has been investigated in a detailed conflict-analysis study (Tiwari et al. 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 analysis further revealed that 36 percent of the victims were crushed under the wheels of the buses; Table 8 gives the distribution of these cases according to the position of the wheel. A total of 85 percent of the cases were reported to be crushed by the rear wheels. This indicates that the victim during the crash went under the bus from the sides. This probably was because the side skirting of the bus has a large ground clearance of 700-800mm, which allows the victim to go under.

Table 8. Wheel by Which Victim was Run Over

	FLW	FRW	RLW	RRW	Total
Cyclist	3		10	3	16
Passenger			25	1	26
Pedestrian	5	1	16	10	32
Two wheeler	4	8	35	20	67
Grand Total	12	9	86	34	141

FLW – Front Left Wheel FRW – Front Right Wheel
RLW – Rear Left Wheel RRW – Rear Right Wheel

Details of Fatal Crashes Involving Bus Passengers: Bus passengers account for about 18 percent of the total fatalities, and 92 percent occurred during boarding or alighting. This is because it is possible to do so while the bus is moving (absence of doors) and, in the case of a fall, the bus floor is high enough (~1200 mm) for the possibility of severe injury in head impact with the road.

Direction of Travel of the Victim: Table 9 gives the breakdown of the direction of travel of the victims. Of the total pedestrians killed during a fatal crash with a bus, 73 percent of them were killed while crossing the road. Similarly, of the total two-wheeler fatalities in crashes with buses, 71 percent of them were killed while they were traveling in the same direction as the bus. This underlines the need for provision of safer pedestrian crossings as well as for better traffic management and speed control.

Table 9. Direction of Victim

Victim	Across	Opposite	Same
Auto	1	4	
Cyclist	3	5	24
Four-Wheeler		7	
Pedestrian	78	3	26
Two-Wheeler	8	39	114
Van Driver		1	
Total	90	59	164

Location of Crash Spot

Table 10 shows the distribution of crashes by type of junction and mid-block locations. A total of 89 percent of the fatal crashes were at mid-block, and only 3 percent and 7 percent were at roundabouts and intersections, respectively. This indicates that much more attention needs to be focused on safety at mid-block sections and also the location of bus stops.

Table 10. Location of Crash Spot

Victims	Bus Stand	Roundabout	Intersection	Midblock	Total
Auto				5	5
Cyclist		1		31	32
Four-Wheeler			1	6	7
Passenger	4		7	72	83
Pedestrian		2	10	95	107
Two-Wheeler		7	11	143	161
Van Driver				1	1
Total	4	10	29	353	396

Driver Age and Involvement in Crashes

To arrive at a conclusion about whether the age profile of drivers of buses is linked to the probability of a fatal crash, the age profile of the drivers involved in the fatal crashes was studied. As the numbers of drivers in different age cohorts were different, the figures were adjusted to 100 drivers per cohort for ease of comparison. The distribution of crashes per 100 drivers by age group is given in Table 11. It is evident that the drivers in the younger age group (under 37 years) are more prone to crashes compared to those who are around 45-50 years of age.

Table 11. Distribution of Crashes per 100 Drivers by Age Group

Age Group	Number of Crashes	Number of Drivers in Cohort	Number of Crashes per 100 Drivers
25-30	84	1,277	6.58
30-36	111	1,564	7.10
36-42	74	1,581	4.68
42-48	52	1,454	3.58
48-54	26	803	3.24
54-60	6	158	3.80

Driver's Fault

Police reports often show "driver fault" in a majority of the crash investigations without conducting an in-depth scientific analysis (Tiwari 2005). The other attributes analyzed in this study were easily quantifiable, but concluding that a crash was the result of driver's error requires a thorough probe into each crash, and even then it remains opinion rather than fact. Under Indian laws, causing death by a rash and negligent act is an offense punishable with an imprisonment of four years. Thus, each death caused by a crash involving a public bus is followed by a police investigation and then a trial in a court.

Apart from investigation by the police, the public transport company carries out an in-house inquiry. The purpose of this inquiry is to arrive at the extent of the driver's responsibility and inflict administrative punishment. The administrative punishments could be in the nature of a warning, a reduction in salary, or removal from service.[6] The standard of proof required in an in-house inquiry is much lower than that required in a criminal court of law. All these case files were analyzed, and it was determined that in 33 percent of cases, the driver of the bus was "solely at fault," in 44 percent of cases the driver of the bus was "also at fault," and in 23 percent of cases the driver was not at fault. It also was revealed that in 23 percent of cases no punishment was imposed, in 1 percent of the cases the driver was removed from service, and in the rest either the salary of the driver was reduced or his training period was extended.

As observed above, in about 44 percent of the cases the driver was "also at fault." This means that there are other external factors that combined with the driver's fault and led to the crash. These factors include contributory negligence of other road users, faulty infrastructure, etc. Several studies have shown that accidents rarely have a single cause (Rumar 1985; Wegman 2001; Mulhrad 2005). Further, Wegman (2001) has stated that "the circumstances in which

a road user carries out his or her traffic task ('definition of the workplace') partly determine the chances of errors and mistakes." Errors in the design and organization of the workplace are called "latent errors or hidden errors": these have been made long before an accident and are triggered by active errors. Finally, there are the political, cultural, historical, and economic environments that determine the demands made on the traffic environment (workplace). "Driver's fault," as reported in the existing database, remains a contentious issue and requires further research for policy interventions.

Policy Implications

Adequate Right-of-Way for All Modes of Transport

The study clearly brings out that about 25 percent of the victims of fatal crashes involving buses are pedestrians. The analysis has adequately established that pedestrians are the most vulnerable groups on Indian roads, closely followed by cyclists and two-wheelers. The fact that almost all fatal crashes take place on straight stretches of roads and also that most occur when the bus and victim are traveling in the same direction is evidence that road design is forcing conflicts between these road users and is a major cause for concern. Of all traffic fatalities in EU countries, the proportion of pedestrian fatalities is about 17 percent, and the proportion of cyclist fatalities is about 6 percent.[7] Separation of buses from non-motorized road users and provision of safe pedestrian and bicycling facilities on arterial urban roads would be expected to go a long way not only in reducing the number of fatal crashes but also improving access to the public transport system. Studies by Elvik and Vaa (2004) revealed that tracks for walking and cycling reduce pedestrian injuries by 35 percent; construction of pavements reduce crashes involving pedestrians by 5 percent; cycle lanes reduce all types of crashes by 4 percent; and grade-separated crossing facilities reduce crashes involving pedestrians by 82 percent. The addition of bicycle lanes in Davis, California, reduced crashes by 31 percent.[8] In Denmark, bicycle lanes reduced the number of bicycle crashes by 35 percent.[9] In the long run, improved road infrastructure with adequate illumination during night can contribute to substantial reductions in fatal crashes. The effectiveness of such designs has been demonstrated on the BRT corridors in

Bogota (Echeverry 2004) and Delhi (DIMTS 2009), where road traffic fatalities have been reduced by more than 90 percent.

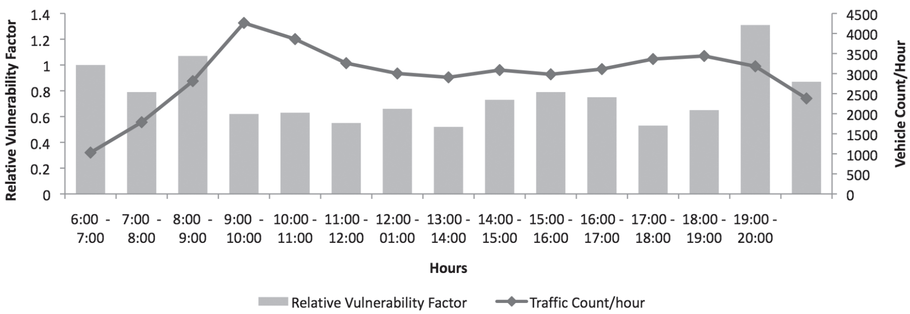


Figure 6. Comparison of Hourly Traffic Count with Relative Vulnerability factor

Installing Automatic Doors

The results of this study show that 92 percent of the bus passengers involved in fatal crashes sustained fatal injuries due to a fall while entering or leaving the bus. Similar results have been reported from a study of DTC[10] operation in Delhi (Mohan 1985). The large number of passenger deaths while boarding and alighting indicates the need for having automatic closing doors and much lower floors in buses. The Motor Vehicles Act 1989 and the Motor Vehicle Rules regulate the manufacture and operation of all transport vehicles. State Governments also are empowered to make rules that all vehicles manufacturers must follow. These rules make various stipulations that are from the point of view of safety of road users as well as others. These rules also lay down some of the critical specifications as well as dimensions of the vehicle. For example, Rule 176 of the Motor Vehicle Rules, 1989 states:

> *176 Width of Doors - (1) Every entrance and exit of a public service vehicle other than a motor cab shall be at least 540 mm in width and of significant height; (2) Every entrance and exit of a stage carriage, not being a stage carriage operating within the limits of a municipal council, municipal corporation or a cantonment board duly constituted or declared under any law for the time being in force, shall be fitted with doors so as to prevent passengers from falling out.*

Most State Governments have similar provisions in their respective Motor Vehicle Rules. These provisions were made in the late 1980s, when the technology of automatic or pneumatic doors was not very popular in India nor were the buses as crowded as they are today. At present, the traffic situation demands that mechanically-operated doors be mandated in city buses. In all high income countries and others such as China, no city buses can operate unless they are equipped with mechanically-operated doors. Several bus transport companies such as the Delhi Transport Corporation (DTC), BMTC, etc. are already fitting buses equipped with pneumatically-operated doors. Therefore, the time has now come to mandate by law (through the Motor Vehicle Rules) that no city bus shall be permitted to operate unless it has mechanically-operated doors. Thus, with this one intervention, fatalities in bus crashes can be brought down by 20 percent and, it would be expected, injuries by a greater number.

Changing the Design of the Bus Body

As shown in Table 7, there is a large number of cases where the victim is run over by the bus. Such crashes could be prevented through better design of buses. At present, most of the buses in Indian cities are fabricated on a chassis that is more suited for trucks. As a result, the bus floor is about 1.0 m above the ground. Such large ground clearances are helpful in negotiating uneven road conditions. Consequently, the side panel of the bus body also is kept at a clearance of about 70 -80 cm from the ground. This leaves a very large opening under the bus, and an inadvertent victim in a crash has a high probability of getting into this opening and getting run over by the wheel. Therefore, there is a strong case for making it compulsory for all buses in cities to have their bodies fabricated in a manner such that the side panels of the bus body are low enough to prevent a person from accidentally or during a crash getting under the bus. Figure 7 show a sketch of an ordinary bus and a modified low-floor bus. This has been made possible by the proposed Automotive Industry Standards Code of Practice for Bus Body Design and Approval (AIS-052), which requires that Automotive Vehicles - Lateral Protection (Side Guards) - Technical Requirements be followed for side under run guards of buses (BIS 1999). This standard mandates that the maximum clearance be limited to 550 mm above road level.

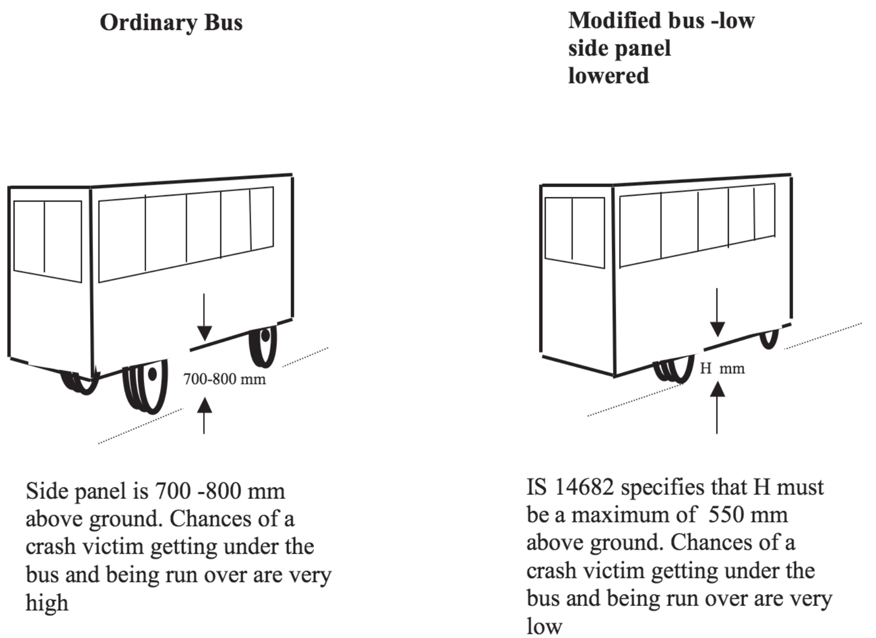


Figure 7. Sketch of ordinary bus and modified low side panel bus model

In a large number of crashes, injuries and fatalities are caused to VRUs (Vulnerable Road Users) in frontal impacts. Research has been done in India and Europe showing that fatalities in such impacts can be reduced significantly by designing safer bus fronts (APROSYS 2004; Chawla et al. 2000; Kajzer et al.1992). It would be appropriate if the recommendations of these reports to set standards for protection of VRUs in impact with buses are put in place as early as possible.

Better Personnel Policies

It has been adequately brought out by the analysis that the risk factor of a driver varies according to his age. As stated earlier, the drivers in the younger age group (under 37 years) are more prone to crashes compared to those who are around 45-50 years of age. This should form an important input in designing the personnel policies of public transport utilities. The public transport organizations in India are government owned, and the general age of recruitment of drivers is 24 years. It also is stipulated in the recruitment rules that to be eligible for consideration as a driver, a candidate should have experience driving a heavy vehicle for at least five years. As the number of drivers in the lower age group are more vulnerable to accidents, efforts should be made to reduce the total number of such drivers. This could be achieved by increasing the minimum age for recruitment or increasing the experience required as a pre-qualification.

The salary structure of the drivers also favors more use of younger drivers. All drivers are on a progressive scale of salary, and their monthly remuneration increases with age. Bus operators have an incentive to use a younger drivers more than relatively senior drivers because the younger drivers cost less per hour. This is especially true when there is a crew shortage and the drivers have to work overtime. This skewed incentive for the bus operators can be corrected by mandating that the overtime rates for all drivers shall be the same.

Another strategy to reduce crashes could be identifying routes that are more prone to crashes. Having done so, only experienced drivers should be deployed on such routes. The study has also brought out that crashes are more probable during certain hours. The reasons for this needs to be investigated further; however, policies for speed control and checking of drivers under the influence of alcohol can be introduced immediately.

Selective but Effective Enforcement of Regulations

The analysis has brought out that, similar to traffic counts, crashes follow a bi-modal pattern in a day. The maximum crashes take place between 0800-0900 hrs and again between 1900-2000 hrs. As shown in Fig 6, traffic peaks and crash peaks in a day do not coincide. This has an important policy implication. At present, all enforcement measures are synchronized with traffic peaks. For example, a maximum number of traffic police are deployed during the traffic peak. As a first step, the traffic regulatory authorities should be sensitized towards the reality that hours during which maximum fatal crashes take place deserve equal, if not more, attention as the peak traffic hours. This should be followed by stricter enforcement of traffic rules during such hours. Bus companies also have their own internal regulatory mechanisms for monitoring the behavior of their crews and their compliance with safety rules. These mechanisms should also be scheduled in a manner such that they are most effective during the hours most vulnerable to crashes.

Incentives for Drivers

At present, there is no system for monitoring the performance of bus drivers. The public transport companies should evolve a system under which the drivers are continuously rated based on their performance on the road. All small mistakes on the part of a driver should be recorded, and this database should be used to impart the requisite training; if the drivers do not respond well, they could be removed from service as well.

Structural Changes for an Integrated Approach

Road safety is rarely a high priority for governments in developing and transitioning countries. Typically, resources are underprovided, and responsibility is dispersed among a number of government agencies.[11] Evidence from some highly-motorized countries shows that an integrated approach to road safety produces a marked decline in road deaths and serious injuries, but that the practical realization of the systems approach remains the most important challenge for road safety policy-makers and professionals. The development of traffic safety policy involves a wide range of participants representing a diverse group of interests, such as governments (police, justice, health, planning and education), citizens, industry, NGOs, professionals, and media.[12]

As has been listed in the preceding paragraphs, to reduce fatalities in crashes, changes are required within the bus transport company, but equally essential are changes by other agencies. More importantly, these measures have to be made in a coordinated manner. Lack of an integrated approach to transport in cities also manifests itself in high rate of crashes. At present, there are multiple agencies in a city each having a specific mandate. This fragmented approach is shown in Table 12. These structures were put in place each for a specific purpose, well before the problem of urban transport began to surface in India and, hence, they do not provide for a coordinated approach for transport safety. As a result, each of these organizations is chasing its own objectives and the overall objective of passenger safety is not getting due attention. A long-term solution to high rates of crashes would require several measures, such as proper planning and provisioning of roads, efficient regulation of traffic, better support infrastructure for pedestrians and other complementary modes of transport, managing the demand for public transport, changing laws governing transport safety, etc. For that purpose, it would be necessary that the right structural arrangements are in place. First, the overall responsibility for managing the overall transport systems should be entrusted to the City Governments. Second, the agencies listed in the Table 12 need to be subsumed into an apex body under the city government.

A good management information system is a prerequisite for proper decision making. The shortcomings of the existing data have been brought out in the study. It would be desirable that bus operators have a specially-trained group of professionals who analyze crashes and report directly to the managing director of the company.

Table 12. Illustration of Multiplicity of Authorities Dealing with Transport in indian Cities

1	Overall responsibility for city transport	No specified agency
2	Traffic regulation	Bengaluru city police
3	Registration of vehicles	Motor Vehicles Department of the State Government
4	City planning	Bangalore Development Authority
5	Construction of roads	Municipal Corporation of Bengaluru,
6	Trauma care and ambulance	Hospitals managed by State Government
7	Fiscal and legal environment	Federal and the State Government
8	Transport safety	No specified agency, but to some extent, city police
9	Pollution control	State Pollution Control Board
10	Rescue	State Fire Force
11	Road safety education	No specified agency
12	Providing bus services	Bengaluru Metropolitan Transport Corporation
13	Suburban rail	Indian Railways (Federal Government)

Lessons for City Administrators

The recommendations that have emerged from this study have been known to the researchers for quite some time, but the fact remains that these have not been translated into action and, therefore, the fatalities in road crashes in Indian cities continues to be high. Therefore, as a first step, a detailed study should be carried out in each city to analyze the factors associated with road crashes.

Lowering the side panels of bus and fixing pneumatic doors is not expensive. Cost figures taken from BMTC indicate that both of these could be achieved at a cost of Rs 50,000 per bus (1 US$ =Rs 45). Assuming a future fleet strength of BMTC at 5,000 buses, this entire exercise could be carried out at Rs 250 million. This has the potential of saving about 50 fatalities per year.

As mentioned earlier, road safety is an interdisciplinary subject and requires a coordinated approach. The existence of a large number of agencies at the city level, each being independent of the other, coupled with weak city governments, does not provide the right structural base for either an efficient transport system no a safe transport system. Making fundamental changes in the structure may require legislation and may be time-consuming, but in the interrim a coordination mechanism may be set up under the leadership of the mayor with the ultimate aim of bringing all the independent agencies under the city government. Such changes would require policy advocacy. One of the most effective ways of bringing about these changes could be to carry out studies like as the present one at frequent intervals, with the results be kept in the public domain. A simple step of keeping details about each fatal road crash would go a long way in generating the right public opinion to bring about the requisite change.

Scope for Further Study

Of the total crash fatalities in Bengaluru city, city buses are involved in 12 percent of the total crashes. Low-floor buses are being introduced in large numbers in Indian cities. A study could focus on comparing the fatalities in these buses vìs-a vìs ordinary buses. Another area of research could be analysis of fatalities in crashes of private buses and comparing these with the fatalities involving buses owned by government companies.

Conclusion

This paper, through a micro-analysis of fatal crashes, has attempted to find patterns in the crashes involving public buses. While some of the findings fortify the existing understanding of the causes of crashes, the study has, nonetheless, provided empirical evidence for it. The analysis has provided a very useful input to policy makers who could take corrective steps and consequently reduce the number of such fatal crashes. The paper establishes that change in bus design with low floors, automatically-closing doors, safer bus fronts, and segregated infrastructure for bicycles and pedestrians would go a long way in reducing the number of fatal crashes on city roads involving public buses.

Endnotes

[1] Bengaluru is a metropolitan city in Karnataka, a Southern Province in India. It has a population of about 6.5 million.

[2] Crash rate is defined as the number of crashes per 100 vehicles per year.

[3] The public transport in Bengaluru city is provided by the Bengaluru Metropolitan Transport Corporation (BMTC).

[4] This is based on a traffic count on 10 arterial roads on a working day. The figure gives average number of vehicles. (Average has been obtained of vehicular counts made at 10 different locations in the city.)

[5] Hanowski, R.J., J. S. Hickman, R. L. Olson, and J. Bocanegra, J. (2009), "Evaluating the 2003 revised hours-of-service regulations for truck drivers: The impact of time-on-task on critical incident risk." Accident Analysis & Prevention 41: 268-275.

[6] The crew in public transport companies are appointed on a permanent basis and their conditions of service are governed by a set of rules

[7] http://ec.europa.eu/transport/road_safety/specialist/knowledge/pedestrians/index.htm, retrieved on 1-5-10.

[8] Federal Highway Administration, Bicycle Safety-Related Research Synthesis, 1995. Referenced in http://www.cambridgema.gov/~cdd/et/bike/bike_safety.html#7.

[9] Danish Road Directorate, Safety of Cyclists in Urban Areas, 1994.

[10] DTC-Delhi Transport Corporation.

[11] P. Elsenaar and S. Abouraad (2005), "Road safety best practices: Examples and recommendations," Global Road Safety Partnership.

[12] http://grsproadsafety.org/knowledge-why_do_road_crashes_happen-2.html, retrieved on 1-5-2010.

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