Analysis of Fatal Crashes of Chennai City's Metropolitan Transport Corporation (MTC) Buses

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Abstract – Each year MTC buses in Chennai city are involved in over 130 fatal crashes. Using data for 283 fatal crashes, coded from Detailed Accident Reports (DARs) maintained by MTC, researchers determined that motorized two-wheelers (M2Ws), pedestrians and bus passengers falling off footboards together constitute 89% of fatal road users. Crashes involving these three road user types were examined to understand injury mechanisms, pre-crash conditions and infrastructure issues. It was found that fatalities could be significantly reduced by preventing rear tire run over in buses (30%) using engineering interventions in bus design, using bus doors to prevent passengers from falling off the footboard (22%), helmet use (22%) by M2W riders, pedestrian friendly infrastructure at crossings (64%) and bus stops (30%), and by educating road users on precautionary driving measures. This paper also emphasizes the significance of in-depth data collection for improving the safety performance of MTC buses, and saving lives.

INTRODUCTION

Chennai city and MTC buses

Chennai (formerly Madras) is the fourth largest metropolitan city in India and is the capital city of the state of Tamil Nadu in southern India. Although it has an area of only 178.2 sq. km, Chennai city has a population of around 6 million people creating a population density of 24,682 people per sq. km [1]. With such a high concentration of people, demands on transportation are also high.

Buses are an important mode of public transportation in Chennai. The Metropolitan Transport Corporation Limited of Chennai (MTC), a state-owned organization, owns and operates majority of the public buses in and around the city of Chennai and its suburbs. It is the largest commercial bus operator in the city of Chennai with a fleet strength of 3267 buses at the end of the year 2009. [2]. MTC buses carry an average of 5.5 million passengers every day and earn average daily revenue of INR 20,278,000 (approx. $440,000) [2].

Contribution of MTC buses in Chennai city road accidents

In the year 2008 alone, 982 people were killed in road accidents in Chennai city and its suburbs, and 5554 people were injured [1]. In the same year, MTC buses were involved in 145 fatal crashes resulting in 148 fatalities [3]. Table 1 gives the involvement of MTC buses in crashes from 2006 to 2009. As can be seen, in each year MTC buses have been involved in more number of crashes than the number of buses in its fleet. The fatal crashes per 1000 buses have consistently remained in the forties.

Year	Number of buses	Number of bus crashes	Crashes			Crashes per bus	Fatal Crashes per 1000 buses
			Fatal	Injury	No injury		
2006	2773	2837	129	982	1726	1.02	46.52
2007	2934	3857	142	1213	2502	1.31	48.39
2008	3300	4542	145	1419	2978	1.38	43.93
2009	3267	4284	138	1489	2657	1.31	42.24

Table 1: MTC Bus Crashes Data for Year 2006 to 2009 [3]

This paper is a first effort at studying fatal MTC bus crashes, using the crash data obtained from MTC, to understand the crashes and injury mechanisms in more detail, and to highlight the importance of crash investigation and in-depth accident data collection for improving MTC bus safety and reducing bus crash fatalities.

METHODOLOGY

Acquisition of Detailed Accident Reports (DARs) of MTC Accident Branch

MTC has set up an "Accident Branch" to investigate MTC bus crashes and determine who was at fault for the accident. This department examines, collects and records crash data for all types of crashes involving MTC buses. On receiving notification of an accident involving a MTC bus, investigators at the "Accident Branch" travel to the accident spot and collect information such as, route and direction of the bus, driver details, damages to the bus and other vehicles involved, details of injuries suffered by the victims, hospital admitted to, scene diagram, description of the accident and the severity of injury. The "Accident Branch", with the cooperation of the police, then prepares a Detailed Accident Report (DAR), which is a 2 page form handwritten in Tamil (the state language of Tamil Nadu). The objective of the DAR is to fix the responsibility for the accident.

Researchers requested for the DAR copies for all fatal crashes involving MTC buses for the years 2008 and 2009, through the Right to Information Act (RTI) [4] of India. In two years, MTC buses were involved in a total of 284 fatal crashes (145 in 2008 and 139 in 2009) causing 292 fatalities. Out of the 284 crashes, DAR copies for 283 crashes were obtained by the researchers. After obtaining the DARs, the various parameters and information in the report were translated from Tamil (local language) to English. It was found that one of the crashes involved a truck belonging to MTC and not a bus. Hence, this case was discarded, bringing the total cases to 282.

Creation of analytical database

Researchers then extracted information from the DARs of the 282 fatal crashes to create the analytical database. Personal or proprietary information such as names, driving licence numbers, vehicle registration numbers, etc were not coded in the analytical database. Researchers also created a few variables to collect more data from the information available in the accident description of the DAR. A list of all variables coded by the researchers is provided in Appendix A.

RESULTS

The *282 fatal crashes* were first analyzed on the basis of the fatal road user type involved. As shown in Figure 1, it was found that 42% of the MTC bus crashes involved motorized two-wheelers (M2W) and 25% crashes involved pedestrians. Bus passengers falling of the footboard of the bus while boarding, alighting or simply standing on the footboard accounted for 22% of the crashes.

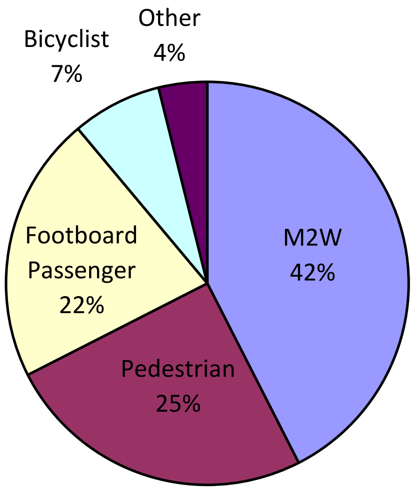


Figure 1. Distribution of MTC Bus Crashes by Road User Type

These bus passengers are denoted as "fell-down passenger" by MTC "Accident Branch", but researchers termed this as "footboard passengers" for the purpose of this paper. 20 cases involved bicyclists and 10 cases involved other vehicles. 1 additional case of pedestrian fatality involved a MTC bus crashing into a motorized three-wheeler which in turn hit a pedestrian. This case was clubbed with the 10 cases involving other road user types and classified as "Other". Researchers noted that apart from passengers falling off footboards of the bus, there were no fatal crashes involving occupants inside the bus.

Figure 1 indicates that M2Ws, pedestrians and footboard passengers constitute 89% of the fatal crashes involving MTC buses. The following sections provide detailed analyses of these fatal crashes to gain a better understanding of the various factors and the injury mechanisms involved in these crashes.

FATAL M2W, PEDESTRIAN AND FOOTBOARD PASSENGERS BY AGE AND GENDER

About 92% of the fatal M2W riders and "footboard passengers" were males, while in case of pedestrian fatalities about 82% were male. Figures 2, 3 and 4 present the distribution of male road users by age group.

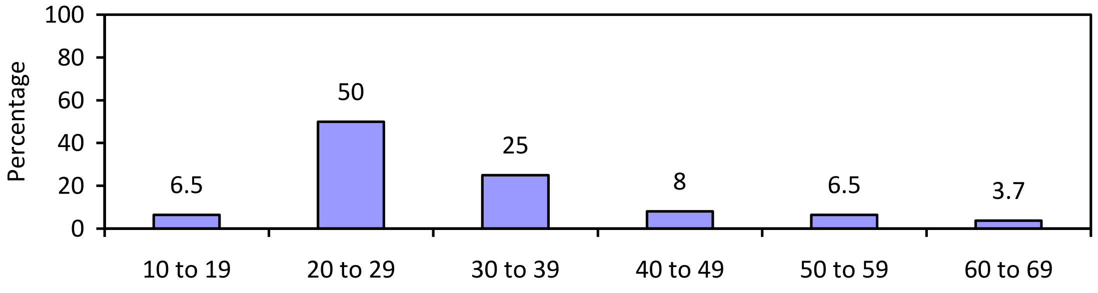


Figure 2. Distribution of Fatal M2W Male Riders by Age.

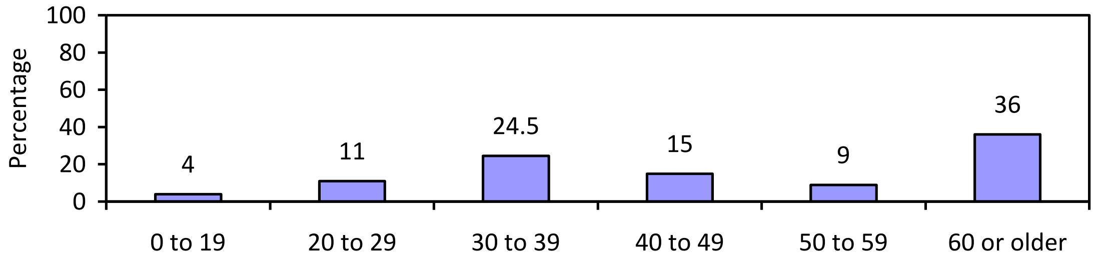


Figure 3. Distribution of Fatal Male Pedestrians by Age.

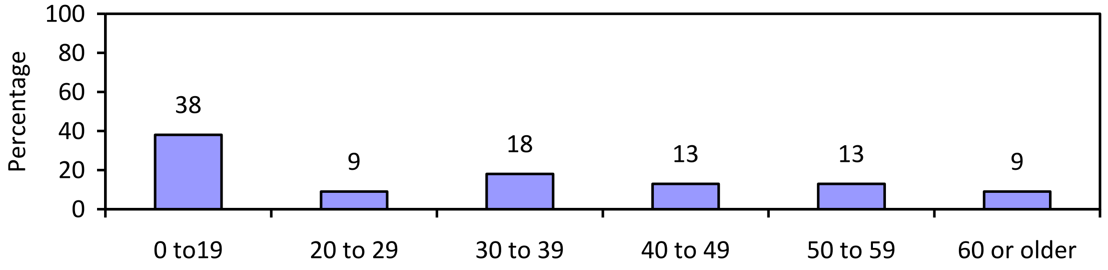


Figure 4. Distribution of Fatal Male Footboard Passengers by Age.

As seen in these figures, there was a significant difference among age groups of different types of road user fatalities. For example, 47% of male M2W fatal riders are young (ages 20-29) (Figure 2), while 64% of male pedestrian fatalities are ages 30 or older (Figure 3), and 38% of footboard passengers (Figure 4) are less than 19 years old, indicating that fatalities involved school/college students.

CRASH INTERACTION – "FALL DOWN" AND "RUN OVER"

During the analysis of the 251 crashes, researchers noted that crashes involved the following sequence of events:

1st event: Road user loses balance on contact with the MTC bus and falls down on the ground. This event was termed as "*fall down*". This event is serious, especially when head injuries are involved due to contact with the bus or the ground. In case of "*fall down*" bus passengers, where there is no impact between the bus and the road user, this event would be falling off the footboard of a bus.

2nd event: In many cases it was found that after falling down, the road user would come under the wheels of the moving bus. This event was termed as "*run over*". These are much more severe due to extreme load applied on body regions of the victim who comes under the tire. In one case, the head of a M2W rider came under the wheels of the bus. As per the report, the rider was wearing a helmet, but the helmet was found cracked and the rider died on way to the hospital.

In 144 crashes it was determined that only the 1st event, "*fall down*", had occurred. In 104 crashes it was determined that the 2nd event "*run over*" had also occurred. For 3 cases, researchers could not determine if a "*run over*" had occurred due to poor/illegible accident description, hence, the 3 cases were considered as "*fall down*".

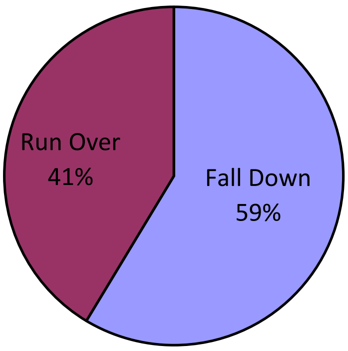


Figure 5. Distribution of Crashes by Type of Crash Interaction.

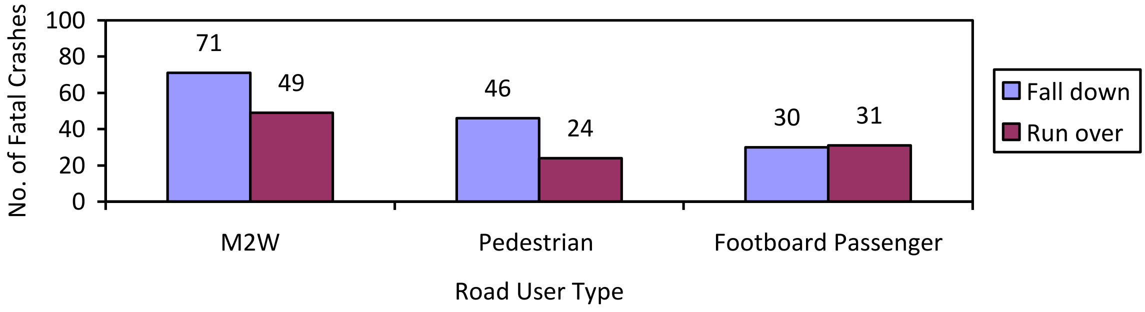


Figure 6. Distribution of Fatal Crashes by "Fall Down" or "Run Over" for Each Road User Type.

Figure 6 shows the number of fatal crashes for "*fall down*" and "*run over*" for M2W, pedestrians and footboard passengers. While "*fall down*" was relatively more for M2Ws and pedestrians, in case of footboard passengers the two events were equally distributed.

Severity

To gain a better understanding of the severity of each of the two events, the variable "Place of Death" was used to determine if the victim died at the accident spot, while in transit to the hospital or while under treatment in a hospital. The distribution of these by each event is shown below.

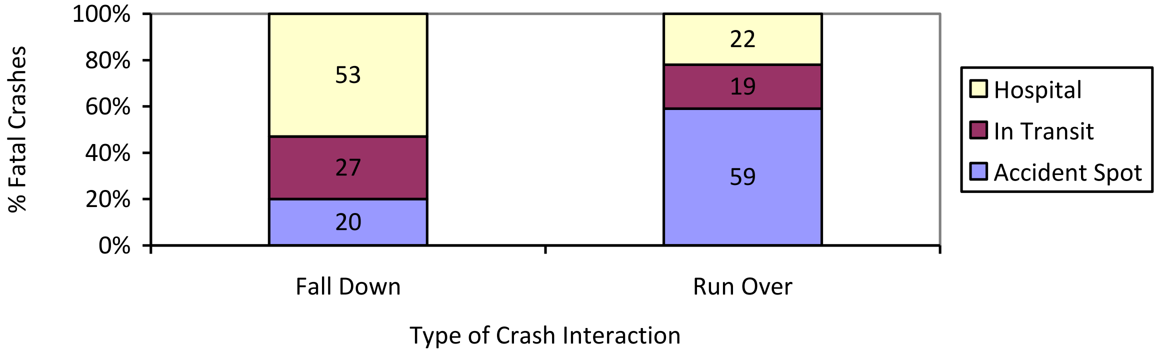


Figure 7. Place of Death by Type of Crash Interaction.

It was seen that in 59% of "*run over*" cases, the victim died on the spot, while only 20% of victims in "*fall down*" cases died on the spot. "*Run over*" and "*fall down*" crashes were further examined as discussed below.

CRASHES INVOLVING "RUN OVER"

Researchers then analyzed the bus tire locations most frequently involved in *"run overs"*. This information was also extracted from the accident description of the DAR. It was found that 65% of "*run over*" cases involved left rear tires (farthest from driver; as India follows Right Hand Drive), while the right front tire (closest to driver) was involved in the least "*run over*" cases. Rear tires alone accounted for 82% of the "*run over*" cases.

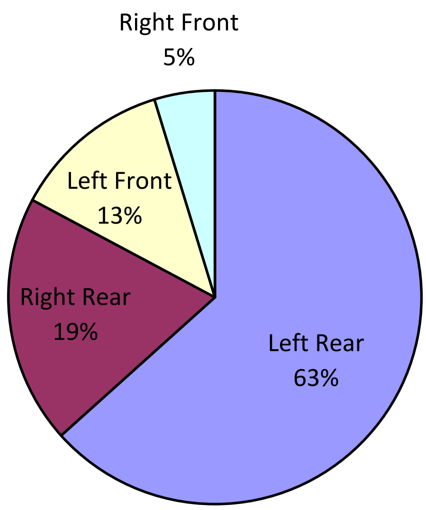


Figure 8. Distribution of "Run Over" Cases by Tire Location.

When analyzing by type of road users, it was seen that all 31 footboard passengers involved in "*run over*" cases, were run over by the left rear tire. Of the 49 "*run over*" cases involving M2W riders, 88% were run over by the rear tires. In case of pedestrians, the "*run over*" cases were equally distributed between front and rear tires.

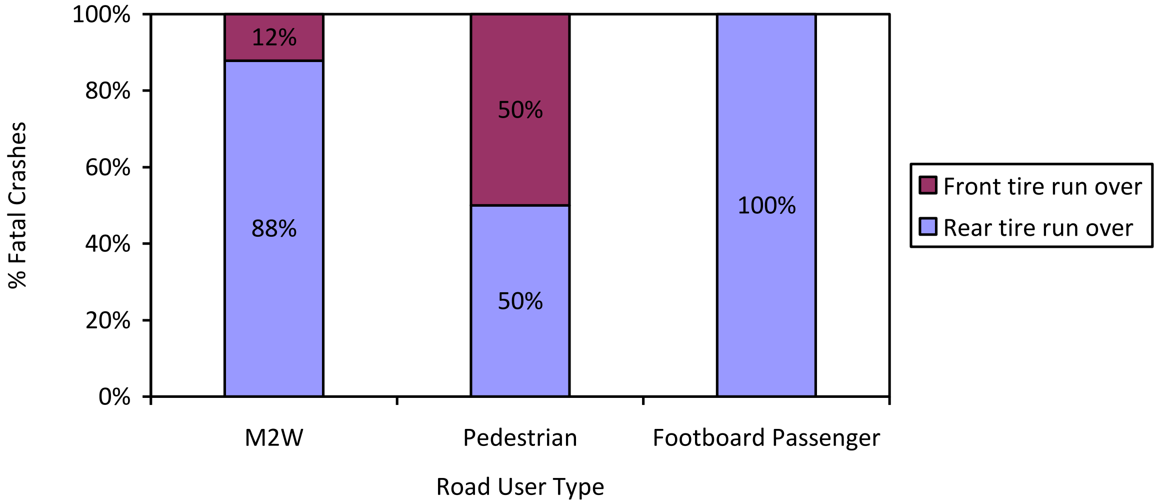


Figure 9. Normalized Distribution of "*Run Overs*" by Tire Location for M2Ws, Pedestrians and Fell-Down Passengers

This indicates that any engineering intervention in bus design that can prevent road users from coming under the rear tires of buses can save many lives. Any such intervention that can prevent rear tire run over could have significantly reduced fatalities.

CRASHES INVOLVING "FALL DOWN" ONLY

Since "*fall down*" cases involve victims contacting the body of the MTC bus and the ground, researchers analyzed these cases for head injuries. The DARs had a parameter called injury details, from which it was determined if head injury was present or not. Figure 10 shows the findings.

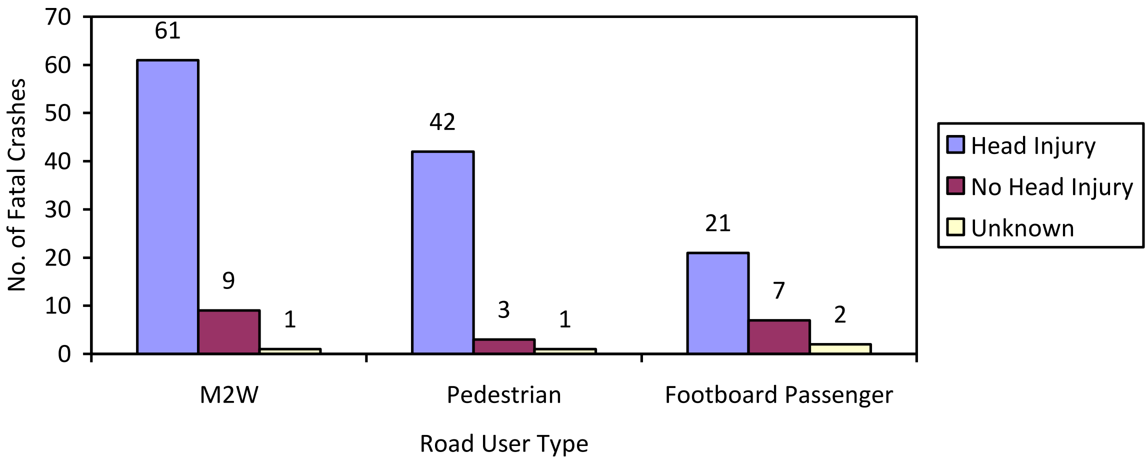


Figure 10. Head Injury Occurrence in "Fall Down" Cases by Road User Type.

It was determined that 84% of "*fall down*" cases involved head injuries. 50% of all crashes involving M2Ws showed head injuries when involved in "*fall down*" cases giving an indication that helmet use is poor. Researchers think that if helmets were worn by all M2W riders, then 22% of MTC bus crashes could have been non-fatal.

Hence, the above analyses suggest that preventing rear tire run over (through bus engineering interventions on the sides) and increasing helmet use would significantly reduce the number of fatalities.

PRE-CRASH CONDITIONS

To understand the conditions leading to a fatal crash with a MTC bus, researchers also analyzed pre-crash factors. The analyses of pre-crash factors have been presented for each of the road user types involved in the 251 fatal crashes, namely, M2W riders, pedestrians and footboard passengers.

Fatal crashes involving M2W riders

Crash Configuration

The 120 crashes involving M2Ws were further analyzed to identify the crash configurations due to which the above interactions occur. Of the 120 crashes, 117 could be classified under four crash configurations, i.e. head-on collisions, front-rear collisions, front-side collisions and sideswipes. The crash configuration in 3 cases could not be determined due to insufficient information. The crash configurations were identified based on the accident descriptions, scene diagrams and the damage areas on the vehicles as mentioned in the DAR. These are explained below.

- Head-On: The front of the bus makes contact with the front of the M2W.
- Front-Rear: The front of the bus makes contact with the rear of the M2W, or vice-versa.
- Front-Side: The front of the bus makes contact with the side of the M2W, or vice-versa.
- Sideswipe: The side of the bus makes contact with the side of the M2W.

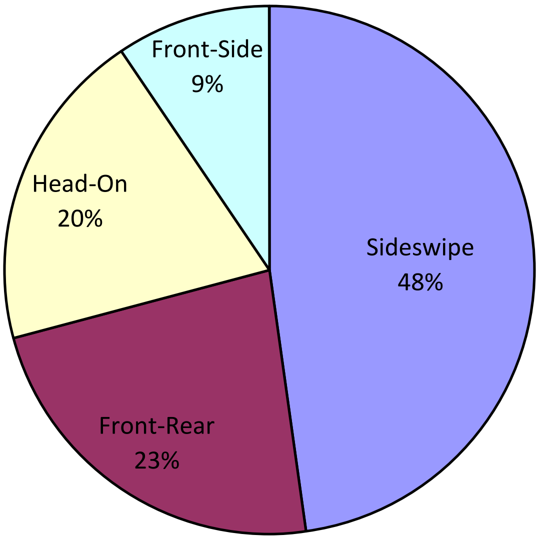


Figure 11. Distribution by Crash Configuration Involving M2Ws.

Sideswipe crashes constitute 48% of M2W crashes followed by front-rear and head-on crashes. In 32 of the 56 sideswipe collisions, the M2W was on the left side of the bus, while in 18 of the 27 front-rear collisions, the M2W was in front of the bus. In 8 of the 11 front-side collisions, the front of the bus struck the side of the M2W.

When these crashes were further analyzed for the type of crash interaction involved, it was found that *sideswipe collisions resulted in 82% of M2W rider "run over" cases. Excepting one, all "run over" cases as a result of sideswipe collisions involved the rear tire of the MTC bus.* "*Fall down*" was predominant in head-on and front-rear collisions.

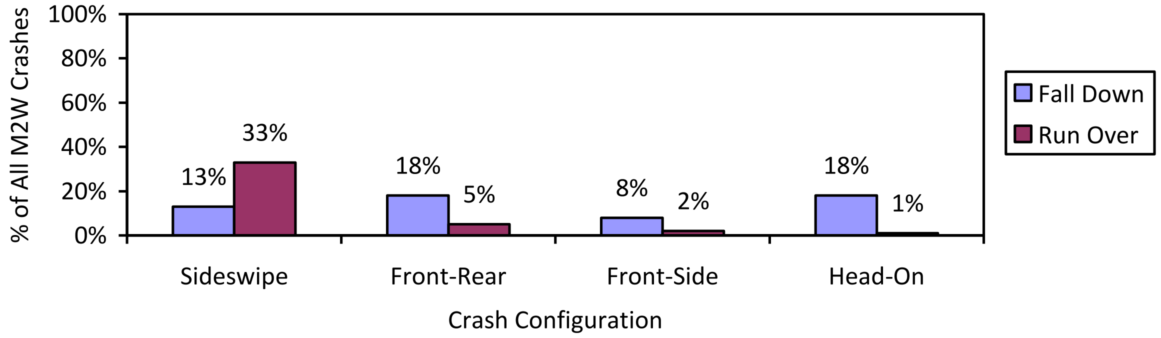


Figure 12. Distribution of "Fall Down" and "Run Over" Accidents by Crash Configuration.

Figure 12 shows that the occurrence of "*run over*" caused as a result of sideswipes account for 33% of all M2W crashes. This indicates that *M2W riders and MTC bus drivers need to be very careful while overtaking or riding alongside each other.*

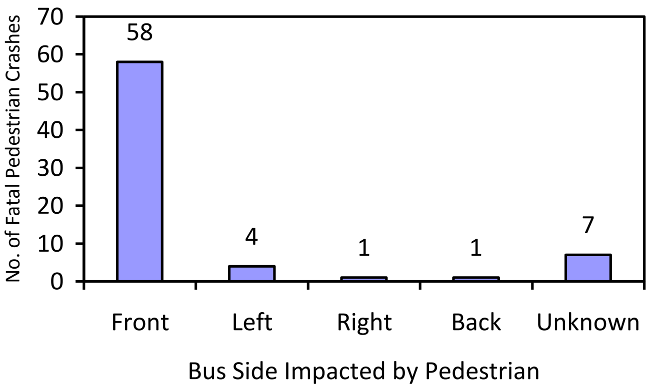
Fatal crashes involving pedestrians

Pedestrian action before impact

64% of the pedestrian crashes involved pedestrians crossing the road. This highlights the need for better infrastructure for pedestrian crossings.

Pedestrian impact location on bus

Researchers determined the approximate impact location of the pedestrian on the bus from the accident description given in the DAR. It was found that 83% of the pedestrian contacts were in the front of the bus. Figure 13 also shows the distribution of pedestrian impacts by zones on the bus front. Detailed examination of these contacts during the investigation can help provide inputs for design of pedestrian-friendly bus front ends.



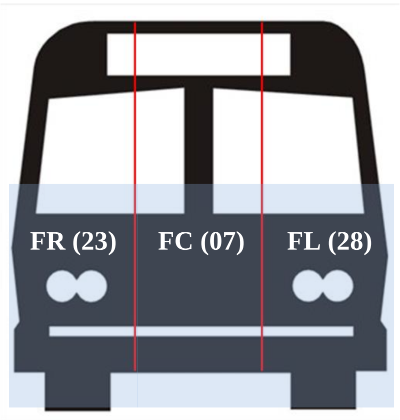


Figure 13. Pedestrian Impact Side with Respect to the Bus; and Distribution of Impacts on the Front of the Bus by Impact Zones (FR - Front Right; FC - Front Centre and FL - Front Left).

Fatal crashes involving footboard passengers

Passenger activity prior to the accident

Using the accident description in the DARs, researchers tried to determine whether the passenger was trying to board (get on), trying to alight (get down) or was travelling on the footboard before the accident occurred. While it was found that 31% of the passengers were travelling on the footboard in a moving bus, boarding/alighting a bus together constituted 59% of passenger activity prior to the fatal accident.

Location of foot board

There are two footboards on the left side of every MTC bus; one in the front and the other at the back. Researchers determined the foot board location of the bus from which the passenger fell down using the accident description in the DAR. 66% of passengers fell from front footboard, while 30% fell from the rear footboard. An important finding was that 94% of footboard passenger "*run over*" cases involved passengers falling from the front footboard.

Availability of doors

MTC has been upgrading their buses, and the new buses being inducted into its fleet have driver-operated doors. When researchers obtained information on bus types, it was found that buses are normally classified by MTC as "Ordinary", "Semi-Low Floor" (SLF) or Volvo. SLF and Volvo buses have recently begun to replace the "Ordinary" buses, and these have pneumatically operated doors which are controlled by the driver. Since the DAR did not mention the type of bus, researchers used the RTI Act [4] to obtain the bus type for each accident. When the bus types involving foot board passenger crashes were analyzed, the results showed that SLF buses were involved in only 3 footboard passenger crashes (shown in Table 2).

Year	**2008**		**2009**	
Bus Type	**Ordinary**	**SLF**	**Ordinary**	**SLF**
Fall Down	13	0	15	2
Run Over	18	0	12	1
No. of Buses	2296	874	1896	1231

Table 2. Distribution of Footboard Passenger Crashes by Crash Interaction Type and Number of MTC Buses in Year 2008 and 2009.

This indicates that doors play a significant role in reducing footboard passenger accidents. Hence, MTC bus drivers, driving the new buses with automatic doors, need to ensure that the doors are used and operated properly to ensure that footboard passenger accidents do not occur.

INFRASTRUCTURE

Researchers were also able to determine infrastructure factors from the DAR. Information such as divided or undivided road, road alignment, structure, the presence of bus stop near the accident spot, etc. were extracted using the accident description, scene diagram and in some cases by visually checking the accident location on Google Earth. This analysis was performed for crashes involving M2Ws and pedestrians only (190 crashes) as it is presumed footboard passengers are not affected by infrastructure.

Divided/Undivided roads

It was found that 57% of the crashes involving M2Ws and pedestrians took place on divided roads. In case of pedestrians, poor infrastructure and lack of pedestrian facilities on both divided and undivided roads are evident on Chennai city roads.

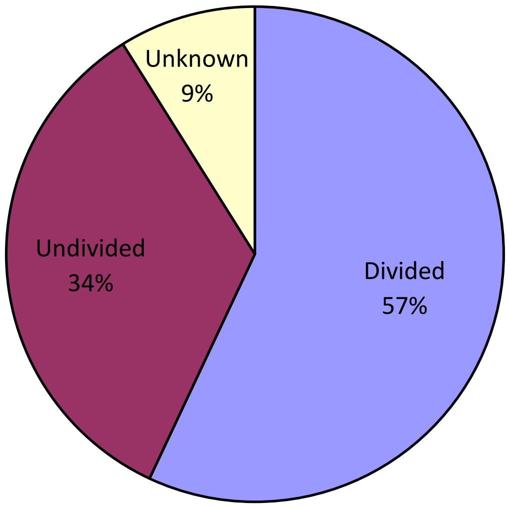


Figure 14. Distribution of M2W and Pedestrian Crashes by Road Type.

When analyzed by crash configuration of M2Ws, it was found that 48% of the crashes occurred on divided roads. Figure 15 shows that sideswipes and front-rear collisions were most common crash configurations on divided roads, while head-on collisions and sideswipes dominated on undivided roads. Researchers also found out that all the front-side collisions had taken place at junctions.

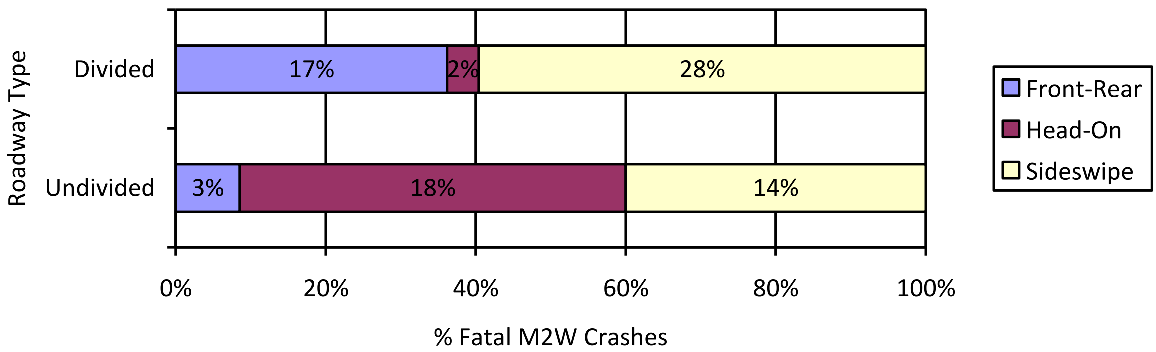


Figure 15. Distribution of M2W Crashes by Crash Configuration on Divided/Undivided Roads.

Pedestrian crashes near bus stops

Researchers also determined that 30% of pedestrian accidents occurred at or near a bus stop, as shown in figure 16. This is a significant finding emphasizing the need for better pedestrian infrastructure as the presence of bus stops compared to the length of the roads is very minimal.

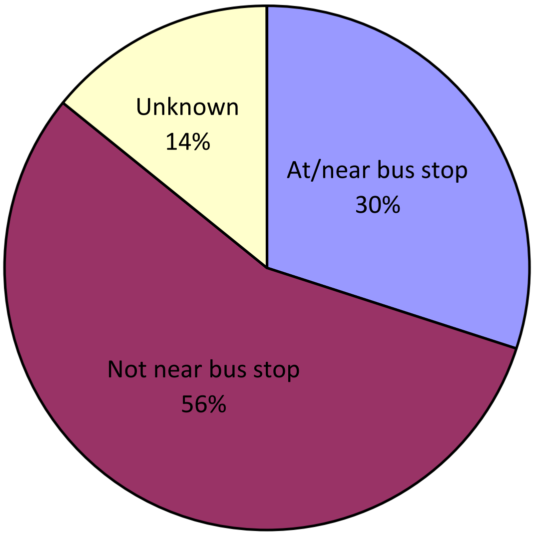


Figure 16. Presence of Bus Stop Near Pedestrian Crash Locations.

CONCLUSIONS

Based on the analysis of 251 fatal crashes of MTC buses with M2Ws, pedestrians and "fell-down passenger", the following conclusions are arrived at:

Bus design

Preventing "run overs"

Bus "*run overs*" result in very high injury severity leading to a greater possibility of the crash victim dying on scene. As per the analysis, 82% of "*run over*" cases could have been prevented by use of an engineering intervention to prevent victims from coming under the rear wheels. Engineering interventions such as side under run protection systems should be looked into. This measure has the potential to prevent fatalities in 30% of the fatal crashes.

Doors

Data shows that buses with doors have far fewer cases of footboard passenger accidents compared with buses without doors. Replacement of old buses (without doors) with new buses (with doors) will significantly lower "footboard passengers" accidents, if they are operated properly by drivers. This measure has the potential to prevent fatalities in 22% of the fatal accidents.

Road user behaviour

Head injuries and helmets

Helmet usage could have prevented fatalities in 50% of M2W crashes. Since M2W riders also constitute the highest road user involved in crashes with MTC buses, helmet usage should be promoted even by MTC, as it will ultimately improve their safety record too. Overall, helmet usage could have prevented fatalities in 22% of the fatal crashes.

Precautionary measures to be taken by M2W riders and MTC bus drivers

Since sideswipes (48%) are the major crash configuration between MTC buses and M2Ws, and the chances of a "*run over*" due to sideswipe collisions is high (82%), M2W riders and MTC bus drivers must be cautious while overtaking or riding alongside each other, and maintain sufficient space between them.

Precautionary measures to be taken by bus drivers and bus passengers

Passengers must avoid travelling on the footboard and should not board or alight from a moving bus. Bus passengers on the front footboard constitute 94% of the footboard passengers involved in "*run over*" cases. Hence, MTC bus drivers must ensure that:

1. Passengers are not standing on the footboard, especially on the front footboard.
2. Automatic doors, if available, should be operated regularly and properly.

Infrastructure improvements

With 30% of pedestrian accidents having occurred at or near bus stops, these areas would be a good place to start an infrastructure intervention. Functional designs for bus stops and pedestrian crossings need to be looked into. In case of MTC bus crashes with M2Ws, front-rear collisions and sideswipes are common on divided roads indicating that infrastructure design, at least for new roads, should incorporate solutions which can separate buses and heavy vehicles from light vehicles.

Importance of in-depth data collection

This pioneering effort of analyzing MTC bus crashes clearly demonstrates that by studying real world crashes through crash investigations and in-depth data collection, it is possible to identify critical safety issues, understand causes and determine cost-effective solutions that when implemented will have a significant impact on road safety. With a more detailed approach to crash data collection and analysis, including detailed injury data, determination of safety system use, bus contact areas, etc., MTC can make better safety decisions and significant improvements in its safety performance resulting in fewer fatalities and providing a safer mode of transportation for the people of Chennai.

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4. Right To Information Act, 2005, Ministry of Law and Justice, India., (http://righttoinformation.gov.in/rti-act.pdf)

APPENDIX A: LIST OF VARIABLES

Variables created by researchers

1. Date of Accident
2. Day of Accident#
3. Month of Accident#
4. Year of Accident#
5. Time of Accident
6. Accident Time Zone#
7. Date of Reporting
8. Time of Reporting
9. Police Station Jurisdiction
10. Place of Accident
11. Message From (Notification of Accident)
12. Accident Description

MTC Bus Details

13. Route No
14. Bus Make
15. Bus Type
16. Bus Depot
17. MTC Driver Age
18. MTC Driver Age Group[#]
19. Damage to MTC Bus
20. MTC Bus Impact Area (for multiple vehicle crashes) [#]
21. Pre-accident condition of MTC bus[#]

Other Vehicle Details

22. Involved with
23. Fatal Road User Type[#]
24. Crash Configuration[#]
25. Number of occupants
26. Other vehicle damage
27. Impact Area on other vehicle[#]
28. Pre-accident condition of other vehicle[#]
29. Pre-accident vehicle position with respect to bus[#]

Victim Details

30. Number of persons injured
31. Number of persons fatal
32. Age of the fatal victim
33. Sex of the fatal victim
34. Details of injury
35. Head Injury? [#]
36. Place of Death
37. Date of Death
38. Time of Death
39. Fatal-Rider/Pillion[#]
40. Fall down/Run over[#] (Crash interaction type)
41. Tire Killed by[#]
42. Pedestrian Activity[#]
43. Pedestrian Impact Area on MTC Bus[#]
44. Pedestrian Contact Zone[#]
45. Fell from-Front or Rear footboard of bus[#]

Infrastructure Details

46. Road type [#]
47. Road alignment[#]
48. Divided/Undivided road[#]
49. Signalized Junction? [#]
50. Accident Spot close to signal? [#]
51. Accident Spot close to bus stop? [#]