Characteristics of Fatal Road Traffic Accidents on Indian Highways

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Abstract

India's increasing trend of fatal road accidents has created a vital and urgent need to understand the factors involved in these crashes. This can only be achieved if good quality in-depth data relating to accident causation and injury causation, correlated with vehicle and infrastructure details are available. A consortium of vehicle manufacturers and researchers, with the support from the police, has developed a methodology to investigate road traffic accidents occurring on highways in South India. This is an ongoing study investigating accidents at the scene.

This paper describes the methodology developed which is unique to India. The methodology also uses established techniques to make it compatible with studies in the other countries (USA, UK, and Germany). A total of 167 accident investigations have been carried out in the Coimbatore District of the state of Tamil Nadu over a period of one year. Data from crash investigations of 71 fatal accidents involving 80 fatalities (66 vehicle occupants and 14 pedestrians) is analyzed in this paper. Findings from the analyses are presented which provides an understanding of the characteristics of fatal accidents on Indian highways.

Fatal accidents account for 43% of all accidents investigated. Motorized two-wheelers (M2Ws) constitute 60% of vehicles with fatal casualties while passenger cars constitute 30%. Majority of the impacts were head-on frontals (35%) followed by pedestrian impacts (18%). M2W collisions with trucks and cars constitute 35% of fatal accidents. Most of the fatal casualties were under 40 years of age. The injury severity (MAIS) ranged from MAIS=3 (21%) to MAIS=6 (10%) while 46% of the casualties suffered fatal injuries at MAIS=4.

Keywords: Road accidents in India, in-depth data, accident investigation, fatal accidents, injury causation

1. Introduction

Reports from the World Health Organization indicate that India has the highest number of traffic accident fatalities in the world [1]. Therefore, there is an urgent need to understand road safety issues and develop immediate measures to mitigate accidents and injuries on Indian roads. This calls for in-depth accident data to be collected in a standardized format which can then be analyzed to identify major problem areas and determine feasible solutions.

Many developed countries have their own ongoing in-depth accident data collection programs. These data sets are used not only to understand the real world accidents and injury causation, but also to develop safety strategies aimed towards improving vehicle safety and road infrastructure. India currently has only one mechanism of collecting road accident data and that is from the police accident investigations. This data is similar to those collected by police in many other countries and is also used for similar purposes. The police data is analyzed by two government organizations to publish two annual reports - The National Crime Record Bureau's "Accidental Deaths and Suicides in India" [2], and the Transport Research Wing, Ministry of Road Transport and Highways' "Road Accidents in India" report [3]. These reports provide an understanding of fatal road traffic accidents at a national level and information such as type of road users (age, sex, vehicle type), incidence rates for states and cities, road type, etc. Data from these reports clearly shows that the number of fatal accidents has been increasing over the last 10 years as shown in Figure 1.

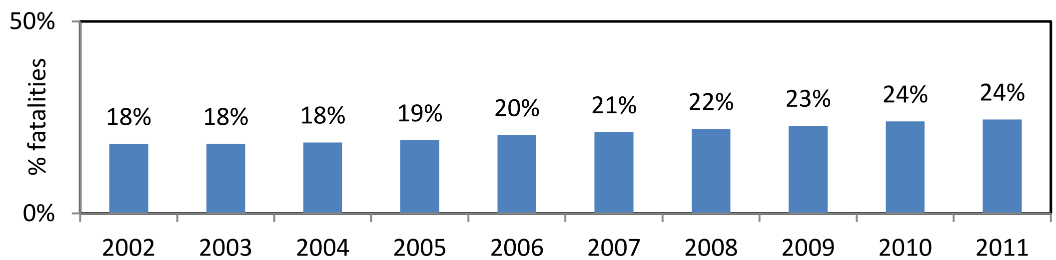


Figure 1. Fatalities in India as a percentage of total accidents for the last 10 years.

Figure 2 shows the percentage distribution of fatalities by road user type for all India. Of the 136,834 fatalities M2W riders constitute 22% followed by heavy truck occupants at 19%. These statistics indicate a stark difference from developed countries where occupants of passenger vehicles (cars and light trucks) are the highest in fatalities.

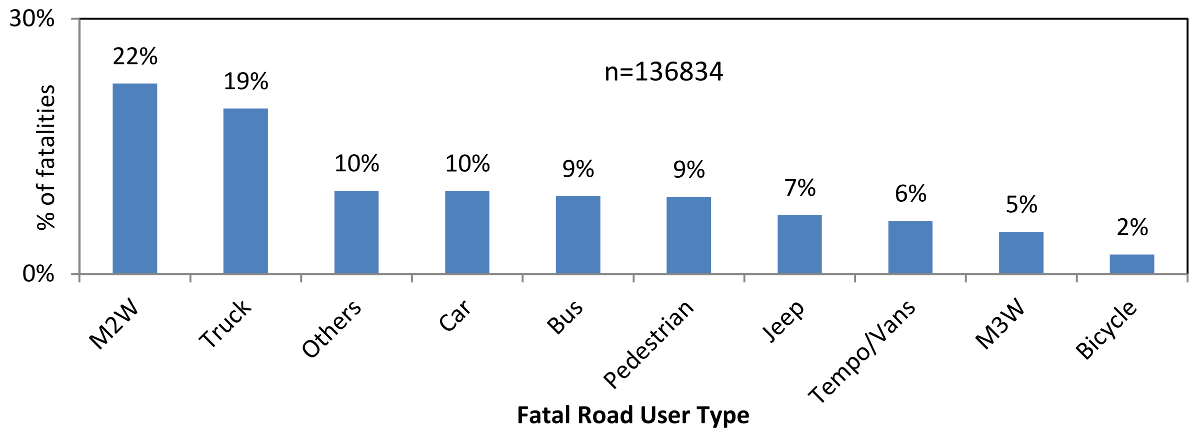


Figure 2. Percentage distribution of fatalities in India by road user type for the year 2011 (Source: NCRB)

The increasing trend of accidents raises concerns and the urgent need to address road safety issues immediately. The accelerating economic growth in India has given rise to an increasing and changing vehicle population mix on Indian roads. Therefore, it becomes important to obtain an in-depth or deeper understanding of fatal road accidents. Currently, in-depth accident investigation data at a national level is not available and therefore it is not possible to obtain a focused understanding of fatal accidents. However, some in-depth investigations of road traffic accidents have been carried out over the last few years on national highways in the State of Tamil Nadu in India. [4][5][6] and [7]. These studies focused on accidents on national highways since 30% of all the total accidents and 36% of total road accident fatalities in India occur on national highway (Figure 3). These studies also helped to develop a methodology for in-depth accident investigation in India.

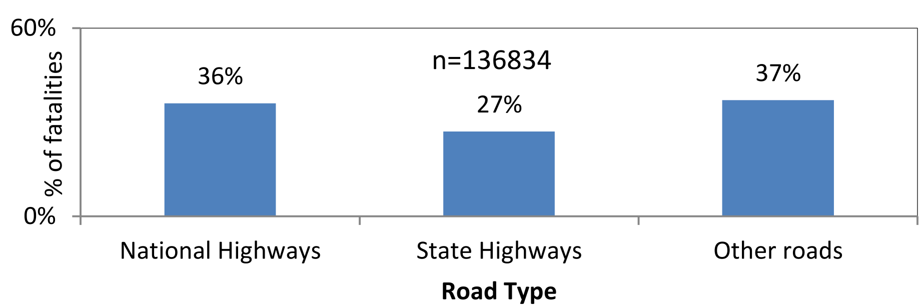


Figure 3. Distribution of fatalities on different road types in India for the year 2011. (Source: MoRTH)

The knowledge gained has helped establish an ongoing in-depth accident investigation and data collection study being carried out by researchers from JP Research India (JPRI) which is supported by a consortium of international vehicle and component manufacturers. The study called Road Accident Sampling System – India (RASSI) was established in mid-2011. A total of 167 accidents which included 71 fatal accidents occurring on national highways and state highways in Coimbatore District of the State of Tamil Nadu in India were investigated during the first year of study. This paper describes the methodology developed for the RASSI study and the analysis of the 71 fatal accidents to provide an understanding of the characteristics of fatal road accidents in Indian highways. This paper also demonstrates that such methodologies can be developed in other newly motorizing countries like India.

2. RASSI Protocol

2.1 Study Area

RASSI is an 'at the scene' in-depth accident investigation and data collection study. The protocol developed for this is based on experience from previous studies and the availability of accident notifications in the study area. A total of 167 accidents were investigated in Coimbatore, in one year. A study area was selected with the cooperation of local police. Police and ambulances were informed about the accident study, and a dedicated phone number was provided to them to notify the accident research team of the location of crash. Trained investigators are housed at location close to study area to provide access to the crash scene as soon as the notification is received. Data was collated from detailed examination of the crash scene, crash vehicle examination. Injury data was obtained at a later date from police stations covered under study area.

The data processing involves deriving other information such as crash severity and injury severity once all the primary data had been assembled. Over 450 variables are coded for each crash. The data is then anonymised and stored in a relational database for analysis. No personal or proprietary information such as details of casualties or vehicles (names, phone numbers, license plate etc.) are stored in the database.

2.2 Crash Investigation

Investigators working at the scene are equally trained in managing the traffic so as to avoid any mishap during crash investigations from moving traffic near the crash scene. The following tasks are performed by the researchers for each accident:

1. Scene examination
2. Vehicle examination

These tasks are explained in detail below.

2.2.1 Scene examination

This involves locating the accident spot, the final rest positions of the vehicles (when vehicles are not available on the spot), recording of GPS co-ordinates, weather conditions, etc. Casualty or eyewitness statements are obtained and verified at the scene for reliability. The scene evidence is marked using chalk or paint. Scene photographs are taken in the direction of travel of involved vehicle(s). The skid marks, debris, point of impact, objects struck, blood marks, fluid spills, etc. are photographed as well. These details and evidences are later converted into a scaled scene diagram using Microsoft Visio software. The scene diagram provides a scaled aerial view of accident scene (Figure 4). The scene diagram is later imported into PC-Crash software for reconstruction of the accident.

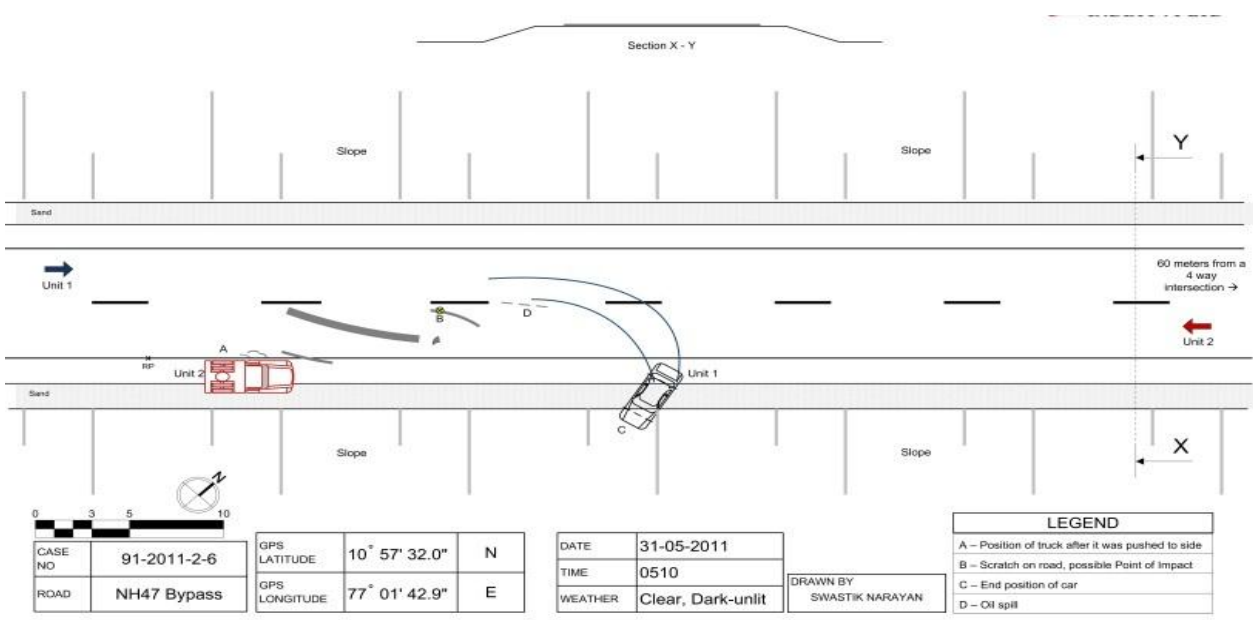


Figure 4. A scene diagram of an accident showing the direction of travel, skid mark and final rest position of accident vehicles

2.2.2 Vehicle Examination

Crash vehicles are examined by the researchers at the crash spot in majority of cases. There are circumstances wherein the crash vehicles are towed to police stations. In that case, vehicle inspection is done at police station. The exterior and interior of the vehicles are examined as described below.

Exterior examination - This involves examining the exterior parts of the vehicle to ascertain the impact and damage profile (direct and indirect). The impact is coded using the well-established Collision Deformation Classification (CDC) code developed by the Society of Automotive Engineers (SAE) [8]. The CDC is a 7 digit alpha-numeric code which states the Principle Direction of Force (PDOF), locates the damage on horizontal and vertical planes of the vehicle, describes the type of impact (e.g., wide, narrow, roll, etc.) and depth of damage at its maximum point. The individual characters of the CDC allow selection of impacts, based on particular criteria, for analysis from a large database. The CDC code is only applicable to cars and light trucks (passenger cars, pick-up trucks, SUVs etc.). A similar code (Truck Deformation Classification (TDC) is also available [9]. However, codes to describe the impact on vehicles such as motorized two wheelers and buses are not available. In such cases, a truncated CDC using only the first 3 digits is used.

The impact damage is also quantitatively measured along the crush profile. The depth of the damage (crush) is measured at several equidistant points (Figure 5). The depth of damage at its maximum point on the impact (maximum crush) is also ascertained. These values are required for determining other properties of impact such as collision severity (delta-V, ETS). The damage profile is further separated into direct and indirect contact damage. Direct damage is caused due to direct physical contact with the collision partner. Direct damage often has indirect damage surrounding it. This is included in the quantitative measurement of the damage profile alongside CDC. Finally, whenever possible, each impact is correlated to the impacts on the collision partner. The impacts are examined for evidence such as paint transfer or deposited debris (e.g., metal, tree bark, graze from contact with a solid object, etc.) which can confirm such correlations.

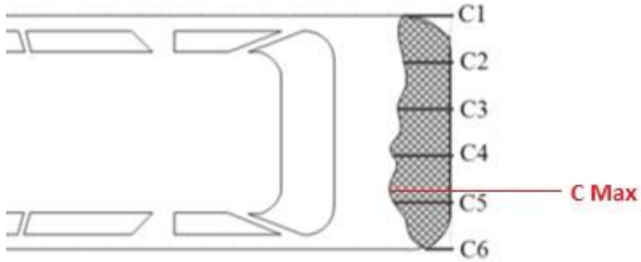


Figure 5. Crush profile measured on a car

Occupant contacts on the exterior surface of the vehicle (e.g. motorcycle riders, pedestrians etc.) are recorded on a vehicle outline sketch. In case of pedestrian impacts, contact points made by the pedestrian on the vehicle are mapped on a pedestrian-vehicle interaction mapping sketch. An imaginary horizontal axis is drawn at the base of the windshield, and another horizontal axis drawn along the longitudinal axis of the vehicle. The contact points are then measured along both axes and are plotted on the sketch along with respective coordinates (Figure 6). The wrap around distance is measured and recorded wherever possible.

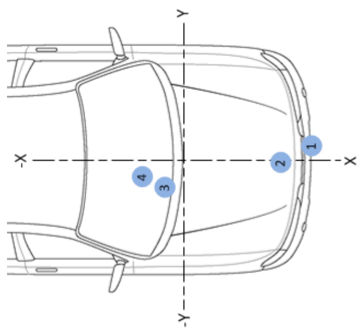


Figure 6.Pedestrian contact mapping on a passenger car.

Tire pressures and tread depth are measured and recorded for all wheels of the accident vehicle and any damage or restriction to the tire or wheel rim is noted. In addition to the above, regulatory compliance is also checked for features such as wipers, tail lamps, head lamps, rear view mirrors, indicators, reflective markings, cargo and overloading, etc.

Interior examination - The interior of the vehicle is then carefully examined to identify any intrusions into the passenger compartment, any occupant contacts with the interior components and structures, use of and deployment of safety systems such as seat belts, pre-tensioners and airbags. Intrusion is the reduction of occupant survival space inside the vehicle created by displacement of vehicle interior structure. The intruding component is identified and reduction in occupant space in any of the 3 axes (longitudinal, lateral or vertical) is determined. The measurements recorded on the crash vehicle are compared with those of an exemplar vehicle or an undamaged side of the crash vehicle, and the amount of intrusion is determined.

The internal structure is scrutinised to identify any occupant contacts. Evidence of human tissue deposits (e.g., blood, hair, cosmetic products, etc.) on the structures is indicative of occupant contact. Deformation of structures due to loading from occupants is also indicative of occupant contact. Analysis of occupant contacts helps in understanding the kinematics of occupants during the time of the crash, and helps in finding the injury sources.

Seat belt components (webbing, pre-tensioners, etc.) are also examined to ascertain whether they have been deployed / used by the occupant. The evidence of seat belt use within the vehicle is usually indicated by residual markings left on the seat belt webbing, the plastic tongue or the plastic D-ring. Deployment of air bag (if available) is also recorded. Any damage to the airbags is recorded and photographed. The use of seat belts, occupant contacts and impact description are some of the factors used in determining the occupant kinematics during a collision. Finally, the vehicle is photographed. All views of the vehicle, the damage locations, occupant contact evidence and any salient points on the vehicles and collision partners are photographed.

2.3 Accident Reconstruction

Reconstruction of an accident is performed based on the accident data collected during the examination of the crash scene and the crash vehicles. Accident reconstruction helps to estimate pre-impact vehicle speeds, heading angle, acceleration/deceleration rate, Delta-V, EES and other variables. The accident data collected combined with the vehicle specification data is used for crash reconstruction using proprietary accident simulation software PC-Crash [10]. In some cases empirical formulas, in combination with laws of physics are used for deducing the necessary values.

Not all accidents are good candidates for reconstruction using PC-Crash. Reliable crash investigation data is very important for reconstructions and information such as impact location and final rest positions are very crucial. Measured scene evidences such as brake marks, skid marks, scratch marks, blood marks, etc. are also required for a reliable reconstruction. Make, model, trim and specifications of the crash vehicles along with passenger and cargo weight should be known and crush profile data should be available wherever applicable.

PC-Crash can prove very challenging while reconstructing accidents involving motorized two-wheelers or pedestrians, heavy trucks involving under-ride/over-ride, sideswipes and rollovers. Due to unavailability of some Indian vehicle models and non-standardized heavy vehicle body work in India, under-ride accidents (for e.g. car & truck) are difficult to reconstruct. In case of sideswipes, the overlap being very small, a large number of collisions are recorded by the PC-Crash software in the simulation. Delta-V is also very small and, hence, it is very difficult to ensure reliable vehicle pre-impact velocities. A trained team of reconstructionists assess each accident case and reconstruct those cases that are a good candidate for PC-Crash simulations. After the reconstruction is completed, the output is stored in two formats:

1. A PC-Crash report summarizing the inputs and outputs.
2. A 3D simulation of the accident.

The report is analyzed and the data such as Delta-V, EES, and velocities before and at the time of impact are coded in the database.

2.4 Injury Coding and Correlation

The injuries sustained by the casualties are obtained from the police or from the hospitals. The police station responsible for dealing with the particular accident will also routinely obtain injury details of the casualty from the hospital and coroner’s office. This eliminates the necessity to separately obtain injury data either from the hospital or the coroner. However on some occasions (i.e. non-police reported accidents) injury details need to be obtained from these sources. The injuries are then coded using the Abbreviated Injury Scale (AIS) version 2005 developed by the Association for the Advancement of Automotive Medicine (AAAM) [11].

AIS coded injuries are then correlated with the occupant contacts having in mind the occupant kinematics and the injury sources are determined. All available information such as vehicle trajectory, restraint use, etc. is taken into account when determining the occupant kinematics. This helps to identify the injury mechanisms and therefore can be used in developing injury mitigating measures. Finally, all the data collected from the accident scene, vehicle examination, occupant injury and any derived information is collated in a systematic manner and inputted in to the RASSI database.

3. Analysis and Results

A total of 167 accidents were investigated on various state and national highways in Coimbatore over nearly 151 km of roads. Out of the 167 accidents, 71 accidents resulted in fatalities. The 71 fatal accidents resulted in 210 casualties out of whom 80 sustained fatal injuries and 31 suffered serious injuries which required hospitalization for more than 24 hours. Of the 71 fatal accident cases, injury reports were obtained for 37 cases which involved 52 fatal and 7 hospitalized casualties.

The distribution of the first crash configuration in the 71 fatal accidents is shown in figure 7. More than one-third (35%) of the fatal accidents were head-on collisions. Most of the roads that these accidents occurred on were undivided carriageways which mean that vehicles were able to encroach into the opposite oncoming vehicle lane while overtaking (refer case study in section 4).

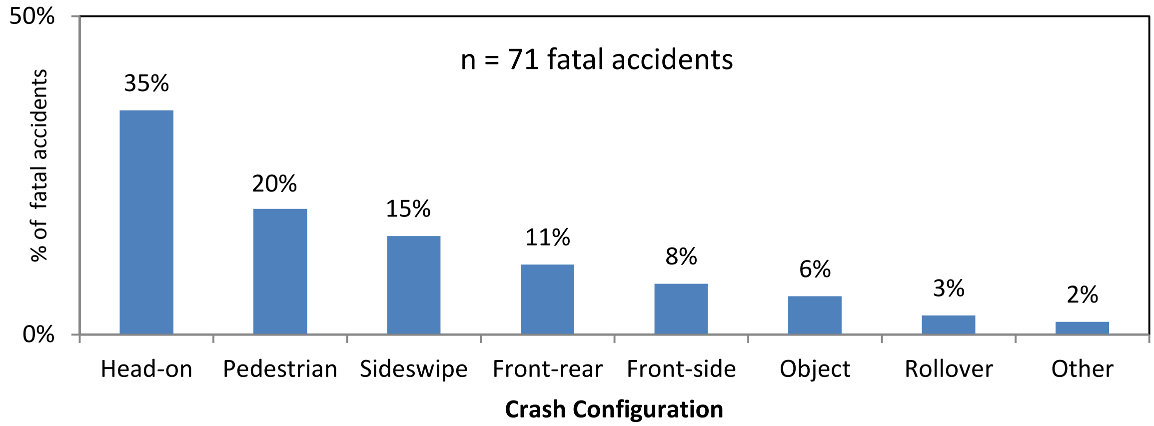


Figure 7. Percentage distribution of crash configuration for 71 fatal accidents

Figure 8 shows the distribution of fatal casualties by road user type. Nearly 64% of the fatalities were M2W riders and pedestrians. This is a common problem in most developing countries where vulnerable road users (pedestrians and M2W riders) share the same road space as heavier and faster vehicles such as trucks and cars.

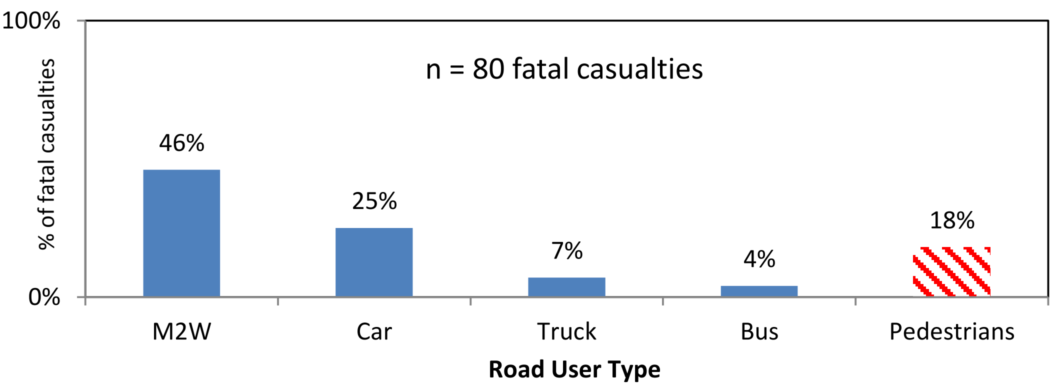


Figure 8. Percentage of fatal casualties by road user type

There were 130 vehicles involved in the 71 fatal accidents. Fatalities occurred in 57 of these vehicles. Majority (60%) of these vehicles were M2Ws and about one-third (30%) were passenger cars as shown in figure 9.

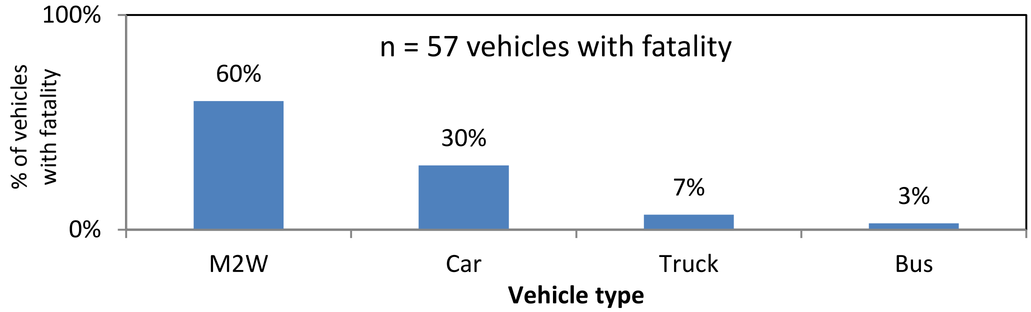


Figure 9.Percentage distribution of vehicle types with at least one occupant fatal

Furthermore, the 57 vehicles with at least one fatality had 49 vehicles as a collision partner (Figure 10). Trucks (45%) and cars (27%) were the most frequent collision partners. This clearly shows that incompatibility issues between smaller and heavier vehicles puts the vulnerable road users such as riders of M2Ws and occupants of cars at high risk.

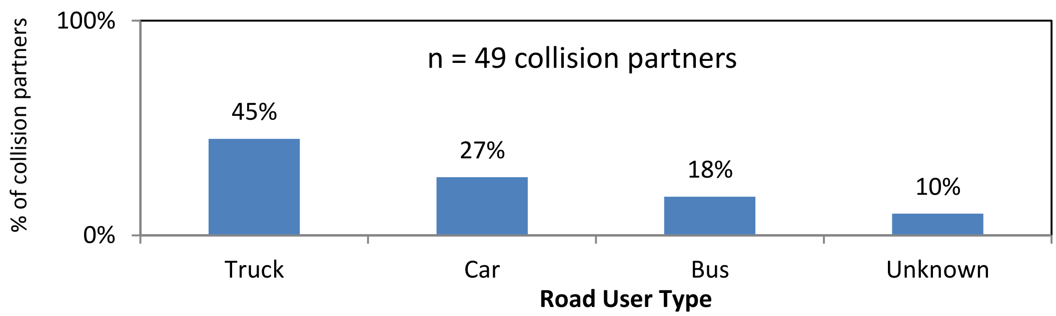


Figure 10. Percentage distribution of collision partner vehicle type.

M2Ws colliding with larger vehicles (cars, trucks and buses) constitute 41% of fatal accidents followed by cars colliding with heavy vehicles (trucks and buses) at 14% (figure 11). Pedestrian collisions are equally distributed amongst all vehicle types while cars are the highest involved in fatal single vehicle accidents not involving pedestrians.

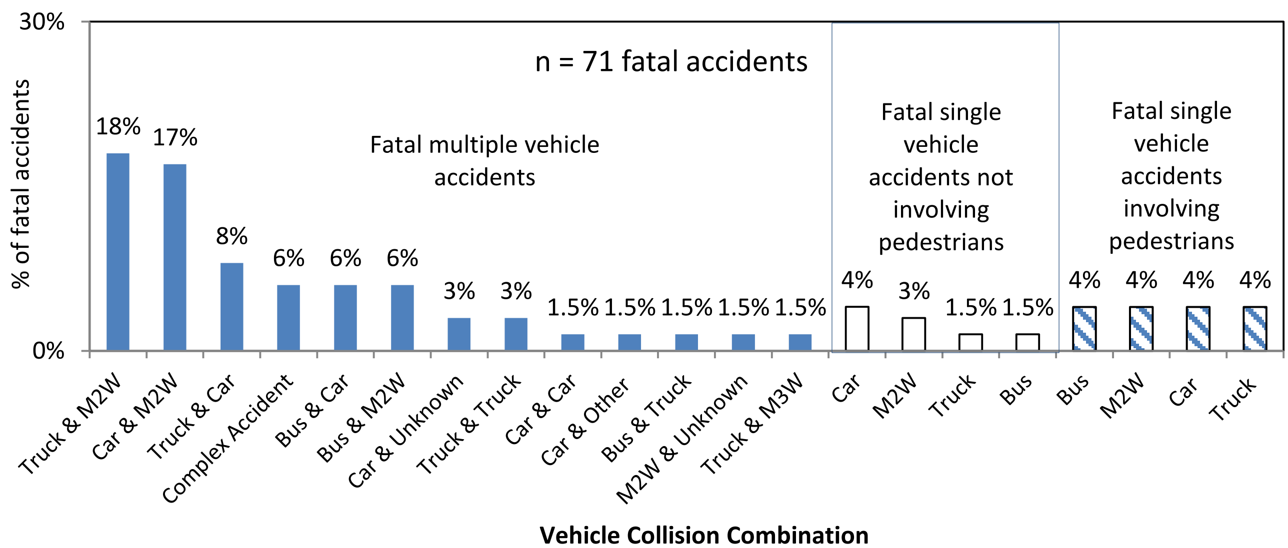


Figure 11. Percentage distribution of fatal accidents by vehicle collision combinations

3.1 Injury Severity

The most severe injury sustained by each fatally injured casualty was assigned the Maximum Abbreviated Injury Score (MAIS). This score was available for 52 of the fatal casualties. The analysis showed that nearly half (46%) of all the fatally injured casualties sustained an injury severity at MAIS 4 level (Figure 12). 21% of the casualties received injury at MAIS 3 level and another 23% received injury at MAIS 5. About 67% of the fatally injured casualties received the most severe injury at MAIS 3 to MAIS 4.

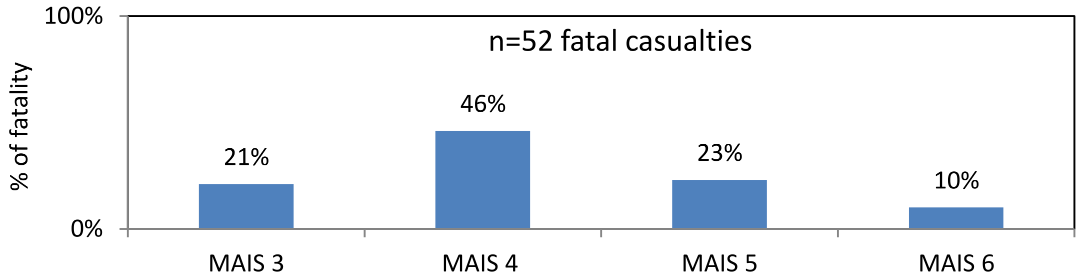


Figure 12. Percentage distribution of 52 fatal casualties by Maximum Abbreviated Injury Score (MAIS)

The distribution of body regions receiving an injury of MAIS ≥ 3 is shown in table 1. Head (56%) and chest (26%) are the most frequent body regions to sustain MAIS 3 injury. Head (88%) was also the most frequent location for MAIS 4 injury. MAIS 5 injuries are mainly located to the spine (54%) and chest (22%).

	MAIS 3		MAIS 4		MAIS 5		MAIS 6		Total (MAIS ≥3)	
Body Region	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Head	15	56	29	88	1	8	0	0	**45**	**58**
Face	0	0	0	0	0	0	0	0	**0**	**0**
Neck	0	0	0	0	0	0	1	20	**1**	**1**
Chest	7	26	2	6	3	22	1	20	**13**	**17**
Abdomen	1	3	2	6	1	8	1	20	**5**	**6**
Spine	0	0	0	0	7	54	2	40	**9**	**12**
Upper Limb	0	0	0	0	0	0	0	0	**0**	**0**
Lower Limb	4	15	0	0	1	8	0	0	**5**	**6**
Total	**27**	**100**	**33**	**100**	**13**	**100**	**5**	**100**	**78**	**100**

Table 1. Distribution of MAIS injuries to body regions

Figure 13 shows the percentage distribution of injury sources by injury seveir

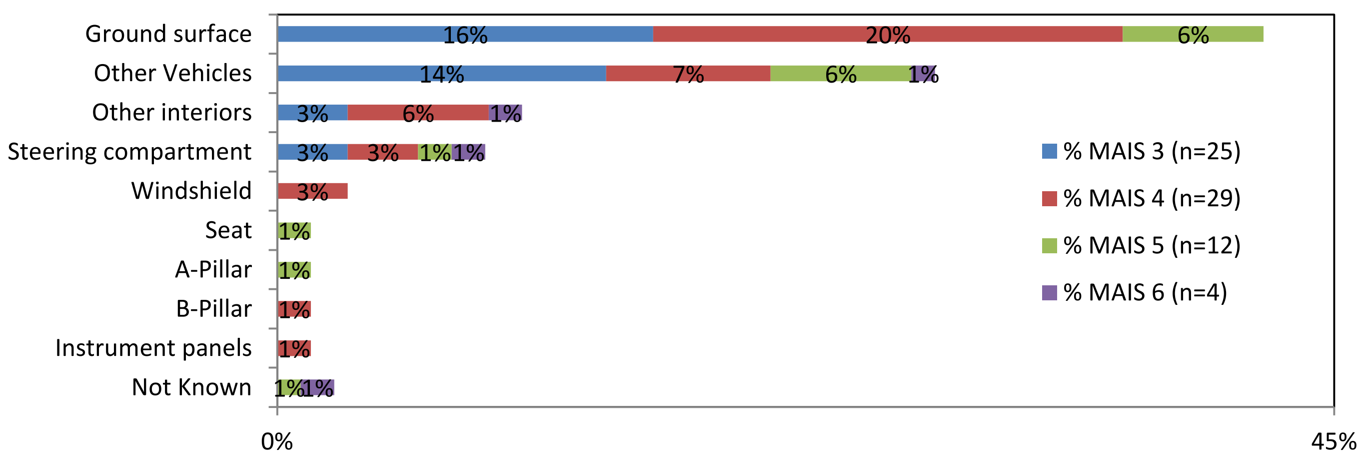


Figure 13. Percentage distribution of injury sources by injury severity

The main source of MAIS ≥ 3 injuries to head was contact with ground surface and other vehicles. Contact with the interior front structures of the vehicle were the main source of injury to vehicle occupants. The head injuries are mostly sustained by M2W riders while spinal injuries are mostly sustained by M2W riders and passenger car occupants. This is to be expected due to the low usage of safety features such as helmets and seat belts.

4. Case Study – Multi Utility Vehicle versus Truck

A Multi Utility Vehicle (MUV) with one male occupant of 24 years, was travelling on undivided highway and was on the on-coming lane while overtaking other vehicles on a curve. The MUV lost control while completing the overtaking manoeuvre. The driver of the vehicle then attempted in vain to steer right to avoid running off the road. The resulting over steering led the MUV into the on-coming lane. The driver braked before colliding head on with the truck, travelling in the opposite direction. Occupant sustained serious injuries and was transferred to hospital, where he later died. Occupants of the truck were uninjured. The scene diagram of this accident is as shown in Figure 14.

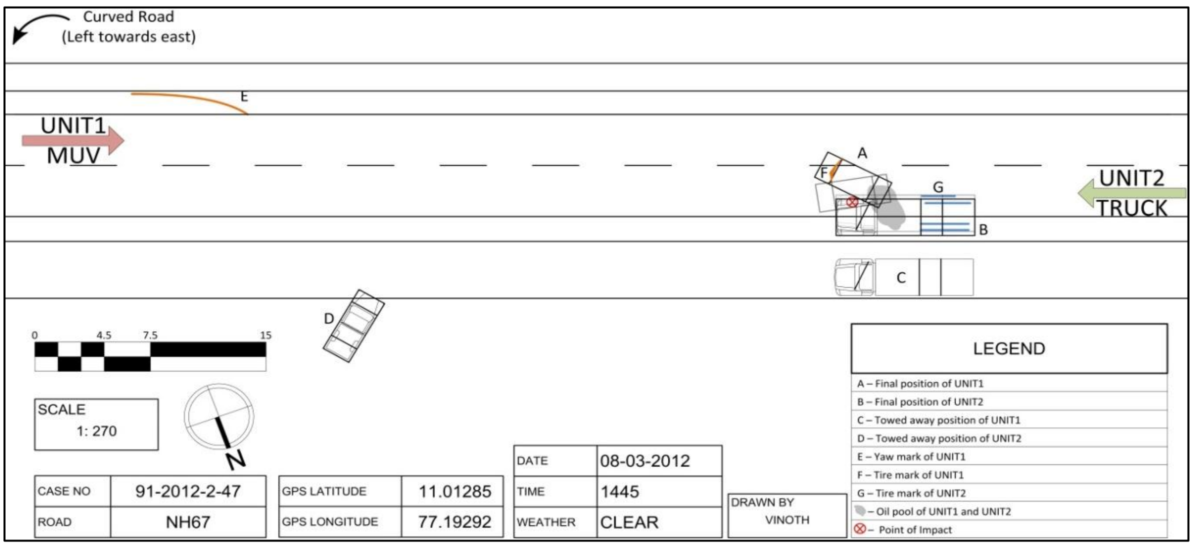


Figure 14. Accident scene diagram

The injuries sustained by the MUV driver were coded and correlated to the contacts as seen in Table 2. Injury report for this fatal occupant was obtained from the police. Out of all the injuries sustained by the victim, 50% is AIS 2+ injuries and 44% of total injuries were head injuries. The main source for the head injuries is windshield, A-pillar, and front header. The occupant died of head injuries.

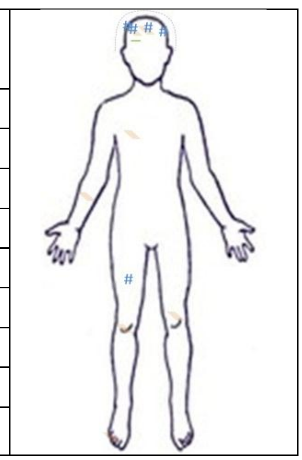
AIS	**AIS Severity**							**Source**	
	1	**2**	**3**	**4**	**5**	**6**	**Total**		
Head	1	4	2	1			8	Windshield,A-pillar,Front header	
Face	3	1					4	Windshield, A-pillar	
Neck									
Thorax	1						1	Steering wheel	
Abdomen									
Spine									
Upper Extremity	1						1	Steering wheel	
Lower Extremity	3		1				4	Toe pan, Steering column	
Total	9	5	3	1	0	0	18		

Table 2. Distribution of injuries to different body region and AIS severity.

5. Conclusions

1. This study shows that the methodology for in-depth accident investigations and data collection programs can be successfully developed for use in new motorizing countries such as those in Asia. The methodologies are comparable to those already established in motorized countries of Europe and USA although some modifications are necessary to meet the local traffic conditions and environment.
2. It is possible to collect all the important data and to use well established systems for data coding and processing whose outcome when analyzed makes it comparable to outcomes from studies from other countries. A sample of 71 fatal accidents was analyzed in this study to demonstrate the type of results that can be obtained.
    a) Most of accidents are head-on collisions.
    b) The casualties were mainly motorised two-wheelers (M2Ws) with cars and trucks.
    c) Head and chest injuries were most received by M2W riders while chest and abdominal injuries were seen to be more common amongst passenger car occupants.
3. The study indicates the possibility of collecting real world accident data in India and similar countries. There for accident mitigation methods can be developed using this more relevant information rather than importing methods from motorized countries whose methods may be less effective.

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