Accident Research Competition Papers

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Modification in Strength Requirement towards Evaluation of Rear Underrun Protective Device (RUPD) of Commercial Vehicles as per IS 14812:2005

Saurabh R. Deshpande, Rahul S. Mahajan, N. V. Karanth

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I. INTRODUCTION

Road accidents in India are one of the leading causes of death, disabilities and hospitalization, incurring huge socio-economic costs. As of 2016, road injuries is one of the top four causes of death amongst persons of the working age group (15-49 years). The number of persons killed in road crash has increased by 3.2 percent over previous year i.e. 2015. Rear-end collisions, especially by passenger cars to light or heavy commercial vehicles is the second-most leading cause of accidents, accounting for 16 thousand deaths and 63 thousand injuries in 2016 alone [1].

In order to prevent under-run of passenger cars, commercial vehicles (CVs) are fitted with a rear under-run protective device (RUPD). This device is essentially a horizontal beam with rectangular/circular cross-section which acts as a rear bumper for the CV. The RUPD fitment is mandatory for CVs and is assessed for dimensional and more importantly, strength requirements as per automotive Indian Standard (IS) 14812:2005. The prevalent version of IS 14812 has been harmonized as per the Economic Commission of Europe (ECE) standard number 58 (revision 01) [2].

This paper aims at revising the strength requirements of IS 14812 in line with the latest amendment in ECE 58 (revision 03) based on findings obtained through filtered sampling of collected accident data.

II. METHODS

Filtered Sampling of Collected Data in the Road Accident Database

Accident data for around 206 cases were collected for a small patch of a national highway for two successive years and segregated into separate records (e.g. Accident, Event Sequence, Vehicle, Contributing Factor, Occupant and Injury) based on different accident related parameters. Using pivot table options available in Microsoft Excel (MS Excel), data from Event Sequence, Vehicle and Occupant records were collated using CASEID for unique identification. The cases were filtered for single collision events (EVENTNO = 1) involving rear-end collisions (GADEV = 1) by passenger cars (CLASS = 1 to 21) with CVs (CLASS = 51 to 63).

For these filtered cases, availability of RUPD (RRUNDER) and its effective usage on CV was also assessed, based on the fatalities and injuries of front seat occupants (driver and co-driver). Finally, the relative speed of impact was calculated as the difference between the speeds of the passenger car and CV at the time of collision (VC_1ST). The minimum relative speed of collision causing passenger car under-run and subsequent occupant fatality was considered as an input in the subsequent computer simulation.

Computer Simulation of Passenger Car Full-Frontal Impact on Load-Celled Rigid Wall

Finite element (FE) model of a 2001 Ford Taurus was obtained from the National Highway and Traffic Safety Administration (NHTSA) open-source database as a representative mid-size passenger vehicle [3]. This vehicle was impacted against a rigid wall at the minimum relative speed of collision obtained earlier, thus simulating a full-frontal impact. Load cell elements were modeled across the rigid wall which recorded the impact force corresponding to different loading point locations (P1, P2 and P3 as mentioned in Figure 1) on the RUPD as per IS 14812:2005 [2]. Load v/s time curves were plotted for these elements wherein maximum load values were recorded and compared with load requirements as per IS 14812:2005 to be discussed further.

III. INITIAL FINDINGS

The total number of accident cases in the database were filtered based on the type of impacting vehicle. The classification of vehicles was based on types defined as per Automotive Indian Standard (AIS) 053:2005 including

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passenger cars (M1), buses (M2 & M3) and CVs (N1, N2 & N3) [4]. It was seen that 59% (N = 121) of the reported 206 cases involved passenger cars as the first impacting vehicle, followed by CVs (N = 61) and buses (N = 24). Passenger cars in these 121 cases impacted stationary objects in 50% (N = 60) of the cases, while others impacted CVs (N = 26) and other passenger cars (N = 18). Filtering the 26 cases of passenger car – CV collisions by location of impact, it was seen that 81% (N = 21) of these cases involved rear collision and possible under-run of passenger cars. Other location impact cases involved frontal (N = 2) and side (N = 2) collisions. Of the 21 rear-end collision cases, only 2 cases were multi-event and hence were not considered for further study involving only single event collision cases (N = 19).

The RUPD was missing in 47% (N = 9) of the 19 cases, while in other cases it was either present (N = 7) or not known (N = 3). Also, in these 19 cases, 47% (N = 16) out of the 34 total front seat occupants sustained fatal injuries, while others (N = 18) sustained serious injuries of Maximum Abbreviated Injury Scale (MAIS) value of 3 and above. This indicated that the RUPD was ineffective in preventing passenger car under-run and subsequent occupant fatality and serious injuries, even though it was present.

Out of all the cases where collision speeds of impacting passenger car and CV were recorded, relative speed of passenger car at time of collision was calculated. It was seen that the minimum relative speed of 50 km/hr was sufficient to cause passenger car under-run and subsequent occupant fatality. This speed was used as input for the 2001 Ford Taurus computer simulation (Figure 1). It could be seen from the plotted load cell values (Figure 2), that the maximum load at P1 and P3 locations were around 50 kN, while that for the P2 location were around 100 kN. The current load requirements as per IS 14812:2005 are 25 kN at P1 and P3 locations and 100 kN at P2 location respectively [2].

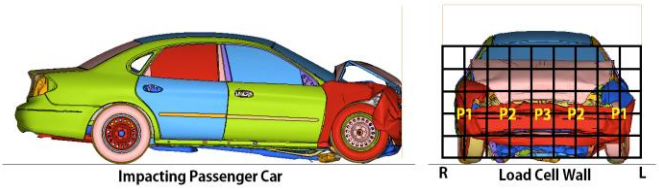

Figure 1 – Simulation of Passenger Car on Load Cell Wall

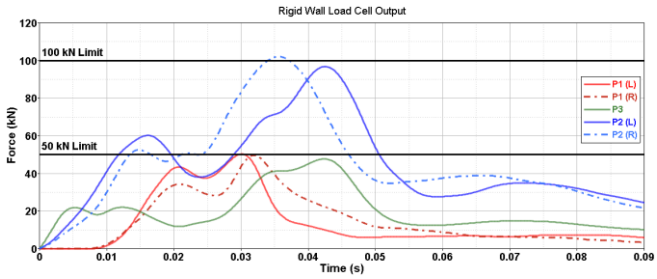

Figure 2 – Loads obtained for P1, P2, P3 locations vs Time

IV. DISCUSSION

From 19 cases, it was seen that frontal occupants in passenger car – CV rear collisions were prone to serious or fatal injuries. Although with a small sample size, it is believed that it may be essential to re-look at the strength requirements associated with fitment of RUPD for CVs. The RUPD was missing in 9 cases, which was in serious violation of the Central Motor Vehicle Rules (CMVR) towards mandatory fitment of RUPD for CVs. This highlights the increased efforts required towards stricter checks of CVs with absent or improper fitted RUPD.

From the results obtained in the passenger car frontal impact computer simulation, it is proposed to modify the current strength requirement of 25 kN and 100 kN at P1/P3 and P2 locations in IS 14812:2005 to 50 kN and 100 kN respectively. This will also justify revising the existing Indian standard and harmonizing it as per the latest ECE standard 58 (revision 03), wherein the load requirements at P1/P3 and P2 locations are 50 kN and 100 kN respectively [5].

V. REFERENCES

[1] Ministry of Road Transport & Highways (MoRTH) Summary Report on Road Accidents in India – 2016 (www.morth.nic.in)

[2] IS 14812:2005 : Automotive Vehicles – Rear Underrun Protective Device – General Requirements (www.bis.org.in)

[3] National Highway and Traffic Safety Administration (NHTSA), USA (www.nhtsa.gov)

[4] AIS 053:2005 : Automotive Vehicles – Types – Terminology (www.araiindia.com)

[5] ECE R58-03:2017 : Uniform Provision concerning the Approval of Rear Underrun Protective Devices (www.unece.org)

Analysis of Crash incidents due to human error and incorporate Low Cost Safety Intelligent Systems for Vehicles Segment

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Analysis of Crash incidents due to human error and incorporate Low Cost Safety Intelligent Systems for Vehicles Segment

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I. INTRODUCTION

In today's fast-moving world, ever increasing vehicles and human population has triggered the necessity of driver and intelligent safety systems. In all the accidents involved roughly about 26.3% are fatal and around 1.5 lakh people died in 2015 alone [1]. Hence there is an increase in effort to incorporate intelligent systems in vehicles which increase the safety and stability and move towards Internet of Things which says about vehicle connectivity, Value added functions which reduce the human intervention. Also, we move towards digitalization where integration of digital technologies is done in everyday life.

Aim of this paper is to show that even though the driving conditions are favorable towards driver, accident rates are more which are mainly caused by human factors and how these accidents could be avoided by addressing human factors highlighted in this paper.

II. METHODS

Accident record were queried for weather condition (WEATHER) and structure of the road (RELINETR). Simultaneously it was analyzed for the severity of an accident (HISADESC). Further highest category in weather condition and structure of the road were queried for vision obstruction (VOBSTRUCT) and distraction to the driver (DISTRACT). The cases were then filtered for clear weather condition, no junction, no driver distraction, and no vision obstruction. On these cases and the vehicles involved during first collision (event number equal one), contributing factors were analyzed. For all these analysis excel sheet and pivot charts were used.

III. INITIAL FINDINGS

In given 206 accidents (76 Fatal; 56 Serious injury; 40 Minor injury; and 34 No injury cases) 64% of accidents were either a fatal or a serious accident. Out of 206 accidents, there were 170 accidents recorded with clear weather condition. Of these 170 accidents, there were 159 accidents happening at no junction involvement. This signifies even though the weather was clear and driver had no junction the accidents rates (77%) were high.

Out of 159 accidents the effect of No driver distraction was found in 70 accidents, 44 accidents were due to sleepy condition and 45 accidents due to other reasons.

Further the effect of No vision obstruction was considered then it resulted in 144 accidents out of 159 accidents. Also 15 accidents occurred due to other reasons. Thus, filtering for clear weather condition, no junction, no driver distraction, and no vision obstruction, resulted in 62 accidents. Only first event of these 62 accidents were filtered and the vehicles involved in those first event were gathered, which gave an insight for the first collision.

By taking this 62 accidents and analyzing the contributing factor, accidents due to human error constitutes to about 51%, Vehicle error about 36% and 13% is Infrastructure error (Figure1).

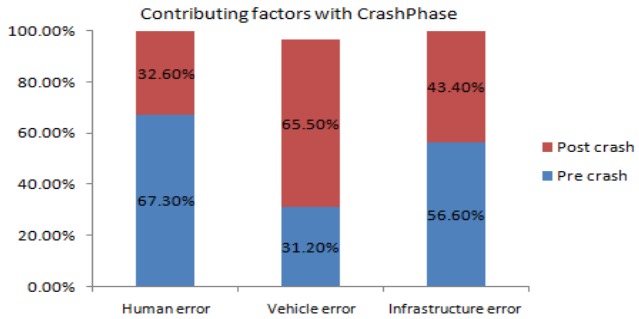

Figure1: Distribution of contributing factors into human, vehicle, and infrastructure.

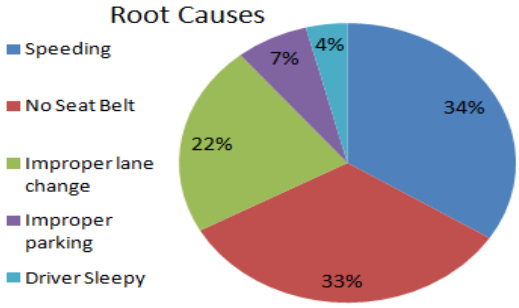

Figure2: Distribution of Root Causes

The root causes for the accidents are in Figure2.

1. Speeding which consists of excessive speed and too low speed for driving.
2. No Seat belt.
3. Improper lane change consists of left overtaking turning suddenly.
4. Improper parking consists of full or partial parking on the road and off road.
5. Driver Sleepy.

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IV. DISCUSSION

We found that, 51.10% of the accidents were caused by human error and 36.10% from the vehicle error. Even though the conditions were clear weather, no intersection, no vision obstruction and no driver distraction which strongly emphasizes to incorporate intelligent systems in vehicles which shall ensures occupants safety. Also, it should be looked for cost efficient solution to target country like India. From Figure 2, it was evident that ≈4% of cases had human error as driver falling asleep. However, 4% was after the filters were applied. It is believed "driver falling asleep" have a higher share for overall accidents. Some key actions are listed in Table 1.

Table 1. Action points and its benefits along with challenges to address the contributing factors-

SL No	Accident Root Cause	Action Points		Benefits	How to incorporate	Target Cost	Challenges
		Non-technical	Technical				
1	Driver Sleepy	1.Avoid long drive	1.Installation of Driver Drowsiness Detection (DDD) systems	1. Reduction for Sleep related accidents. 2. Communication of Drowsiness level. 3. Adaption of Vehicle to Drowsiness level.	1.Available by supplier	Low	Mandatory by legislation is required
2	No Seat belt	1. Do not Drive	1.Seatbelt warning assist for all Passengers	1. Impact of Injury is reduced 2.Passive Safety can become Active Safety 3.Passenger safety is ensured.	1.Available by supplier	Low	Mandatory by legislation is required
3	Over/Under Speeding	1.Speed limit adherence 2.Upgrading the Road infrastructure	1.Speed limit detection based on traffic situation 2.Scope for New Product Development for Driver Warning	1. Reduction of different categories of collision. (Refer to graph 1)	1.Available by supplier 2. Need to be Adapted.	Low	Mandatory by legislation is required
4	Improper lane change	1. Drive with proper indicators during lane change 2. Adding professional driving courses and technical driving courses	1. Installation of ABS systems 2. Lane departure warning system	1.Prevention of locking wheels and preservation of steerability 2.Improvement of vehicle stability on braking of differently frictions and on curve braking 3.Reduction of braking distance compared with locking wheels	1.Available by supplier	Low	Mandatory by legislation is required
5	Improper parking	1.Availability of Lay-by and its display 2.Lane markings	1. GPS enabled information system (NPD) 2. Front warning collisions & ABS	1. Reduction of different categories of collision. (Refer to Figure 1)	1.To be developed	Low	Mandatory by legislation is required

References:

1. Ministry of Road Transport and highways Annual Report 2016-17

Preventing Accidents Using a Road Design Approach

S. Pingale, A. Kothawala

Preventing Accidents Using a Road Design Approach

S. Pingale, A. Kothawala

I. INTRODUCTION

Accidents are not only a cause of careless driving but can also be triggered by lack of meticulous road designing and management. This paper intends to identify the sectors which have been considered as the major reasons for accidents, by adopting a road designing perspective and triangulating it using the data provided by RASSI. The data gives a general idea about the accidents occurred, the contributing factors to accident, injuries happened and vehicles and occupants involved. It is a rich data set which can be used in various fields for improving highway safety and refining or updating the methods by which highway designing is carried out.

II. METHODS

To bring out the inferences, modelling (in Microsoft Excel), analytical and mapping techniques (ArcGIS software) have been used. Detailed approach has been depicted in the diagram.

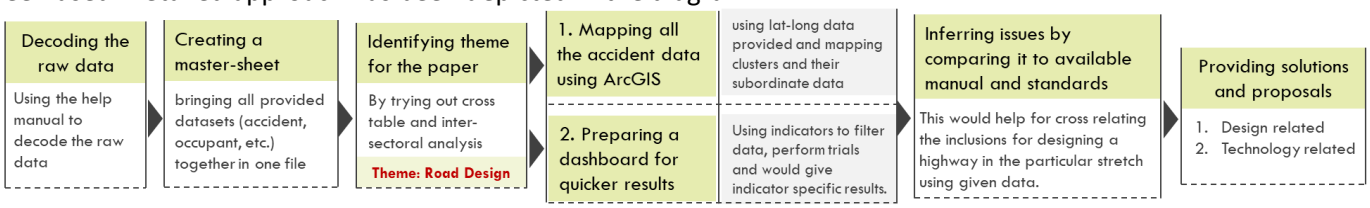

Figure 1 Methodology adopted for the research

III. INITIAL FINDINGS

Road design indicators were identified from the data provided. These were co-related with other general indicators. Initial findings have been mentioned in Figure 2. Another set of findings were obtained, considering all 206 cases, using ArcGIS (mapping technique). These findings were obtained by identifying the cause of accident and contributing factors. The map in Figure 3 depicts a case of only 15 accidents that have happened.

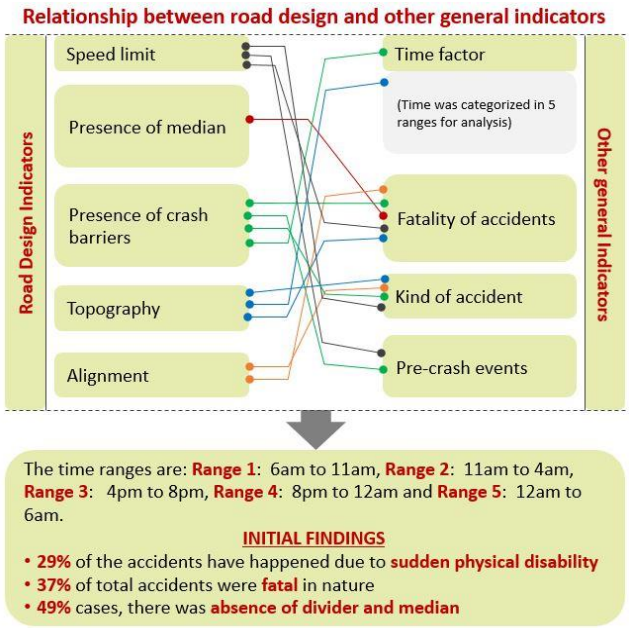

Figure 2 Relationship between road design and general indicators

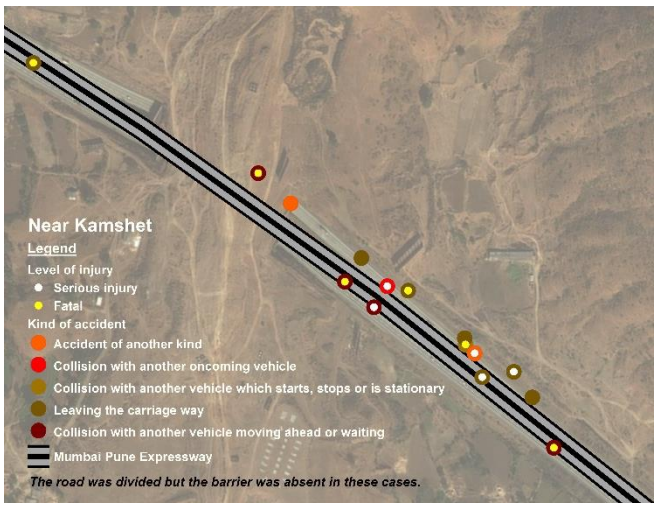

Figure 3 Part of the stretch which has recorded maximum accidents at one location (Sample 15 cases)

For selecting these 15 cases, clusters with maximum number of accidents were identified. One of those clusters is found near Kamshet area and depicted in Figure 3. In this map, level of injury caused is co-related with kind of accident. Here, though the carriageway was divided, crash barriers were absent. Similar co-relations are experimented to obtain spatial findings.

IV. DISCUSSION

Cross tabular and inter-sectoral analysis, for all 206 cases, has been carried out in 3 parts which are as follows:

	Data	Contributing factors and observations	Proposed Solutions
1	64% accidents have occurred in time range 1 (6am and 11 am) and time range 5 (12 am to 6am) Out of these: • 26% accidents occurred between 6am and 11am	Of 64% accidents: • In 17% cases driver's condition (fatigue/ sleep/ drowsiness) was responsible • In 35% cases driver was halting off the road or on the shoulder and got hit by a moving vehicle.	• Adequacy of number of rest points should be checked and augmented as required. • At every 50kms, rest points could be made available. These could be staggered in nature.

	• 38% accidents have occurred between 12am to 6am		• Rumble strips could be used for paved part of the shoulder. • Out of total shoulder area (paved and earthen) paved should be maximum of 1.5m in width.
2	• 48% accidents have occurred on downhill grade • 56% accidents have occurred where crash barrier was not present. (refer figure 3) • Out of total fatal accidents, 38% are Rear end collisions and 29% are object collisions	Of 48% accidents occurring on downhill: • In 15% cases driver's condition (fatigue/ sleep/ drowsiness) was responsible • In 67% cases the crash barrier was not present and vehicle was over-speeding or was driving at an excessive speed for the condition. This might lead to overturning of vehicles on other side of the road.	• The shoulder should be raised by 150mm on hilly as shown in Figure 4. • In case of adequate availability of right of way, the incoming and outgoing traffic lanes should be levelled topographically, i.e. two-lane carriageways on different alignments (contours) on a 4 lane highway.

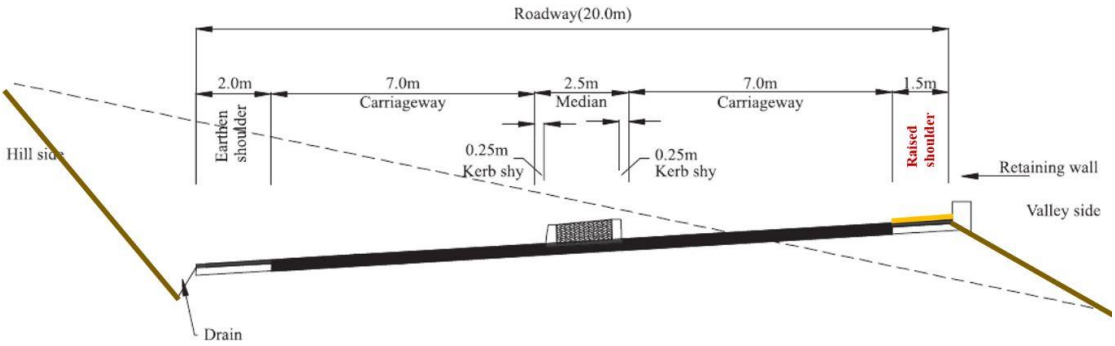

Figure 4 Reference from manual (reference no. 1) as to how shoulder be raised on hilly terrains

In case of hilly terrain, the shoulder should be raised to reduce the impact of accident if it crashes into shoulder.

3	• 56% of total accidents happened where the road was divided but there was absence of raised medians and crash barriers. • 70% out of these faced a fatal or serious accident.	• Absence of raised median or crash barrier • Continuous paved shoulder of 3m acts like an additional lane. Hence, drivers use this to overtake from left and due to less visibility of the vehicles halting on shoulder, they get hit.	• Identifying the kind of crash barrier that should be used on highways. • Reworking on the shoulder measurements. Out of 3m wide shoulder, there should be rumble strips on first 1m of the shoulder. Rest of the 2m should be a paved shoulder. • Rear light of the vehicle should be in a working condition and they should be checked at toll booths. • Additionally, the installation of speed guns would help in controlling over and under-speeding vehicles.

If a vehicle attempts to overtake from left, they would feel a jerk and their speed would also reduce.

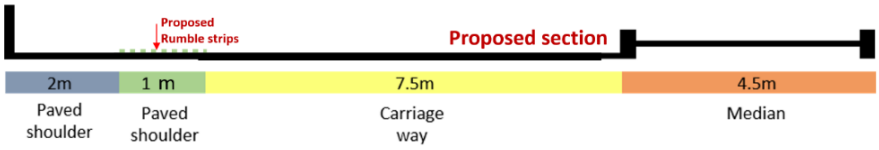

Figure 5 Proposed section on designing of shoulder

While providing the above mentioned solutions (refer figure 4&5) would mitigate accidents approximately by 65%, providing managerial measures would mitigate more accidents. Managerial measures would include setting up of speed guns (to prevent 35% accidents where drivers were over speeding or the speed was excessive for given conditions), checks on highways for light testing, seatbelt checks (preventing 18% accidents) etc. These measures can be generic in nature but would decrease fatalities while driving on the highway.

V. References

1. Planning Commission Government of India. (2010). *Four-laning of highways through public private partnership, Manual of specifications and standards.* New Delhi: Secretariat for Infrastructure.
2. Transportataion Research Board. (2000). *Highway capacity manual.* Washington: National Academy of Science.

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SAFETY AGAINST OBJECT IMPACT ACCIDENTS INVOLVING CARS

Niveditha V

SAFETY AGAINST OBJECT IMPACT ACCIDENTS INVOLVING CARS

Niveditha V

I. INTRODUCTION

Single car accidents predominantly involve a car hitting another object. This object could be trees, poles, wall, and barriers on the road. These accidents involve personal injury and property damage. This paper aims to understand object impact accidents in depth and also suggest solutions to address the cause of object collisions. The problem statement was chosen from analysis of database provided, which showed that significant number of cars hit an object on a straight road.

II. METHODS

For the analysis of 206 accidents the crash configuration information was first studied. Next, structure of road involved in accident was taken. Following this vehicle type information was enumerated. Further, the reason behind object collision on a straight road was noted using pre-crash event and vehicle stability pre-impact. The kind of objects contacted was also recorded. Pivot tables/charts of Microsoft excel were used for this analysis. The columns from database which were of importance are – **Accident Table:** CASE ID, FIRSTCRA, RELINTER, PRECREV; **Vehicle Details Table:** CASE ID, BODYTYPE, PRESTAB, and OBJCONT1. Analysis also involved researching on the solutions to improve safety against object impact accidents.

III. INITIAL FINDINGS

Of 206 cases in the database, about 43.7% of them involved vehicles having contacted objects (Fig 1). This was seen through the element 'FIRSTCRA' of accident table.

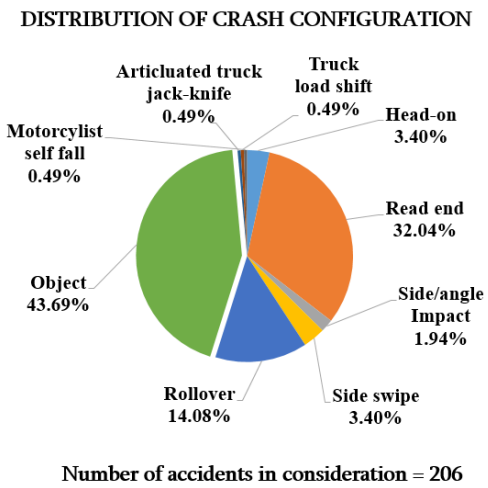

Fig. 1

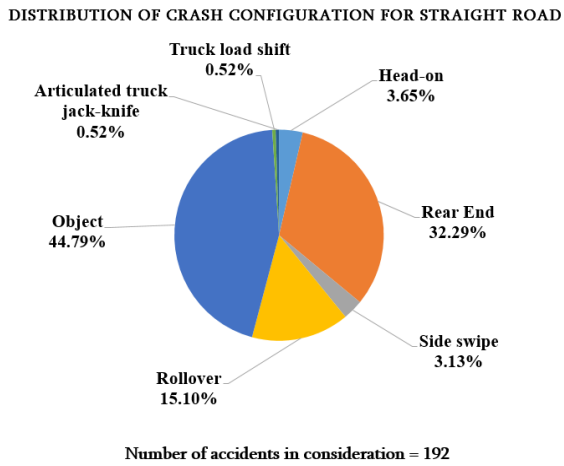

Fig. 2

41.7% of 206 accidents happened on a straight road with no interchange or junction (equivalent to 44.79% of 192 straight road accidents - Fig. 2). This information was seen by using 'RELINTER' element from accident table.

The case IDs of these cases was fed into the vehicle details table. The 'body type' element was studied to find out the most common type of vehicle which had an object impact accident. It was found that in 29.1% of 206 cases a type of car hit an object (equivalent to 69% of 87 vehicles involved in object collisions - Fig. 3).

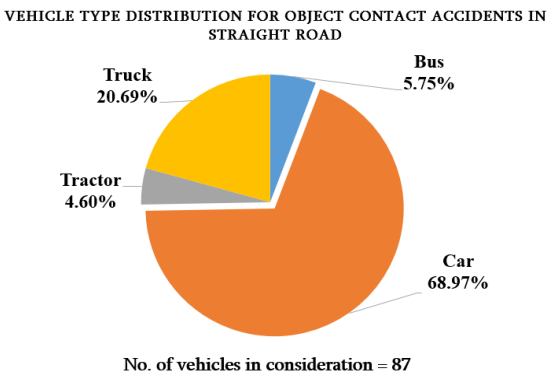

Fig. 3

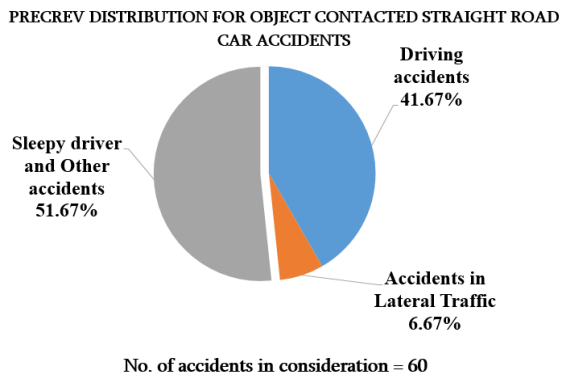

Fig. 4

To understand the reason behind this common occurrence, the 'PRECREV' element of accident table was studied. This showed that "driver falling asleep" was the most common pre-crash event. This is 12.1% of 206 accident cases in the database (PRECREV = 761) (Fig. 4).

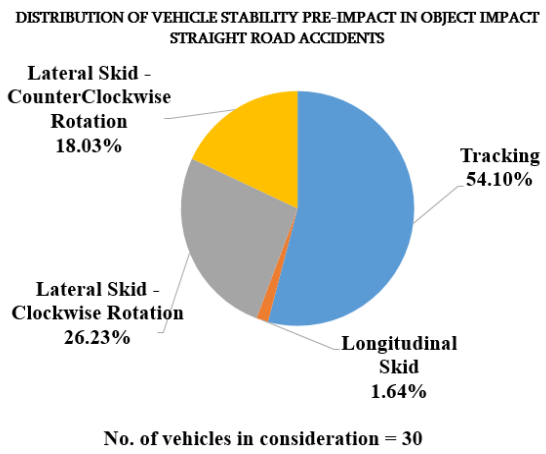

Fig. 5

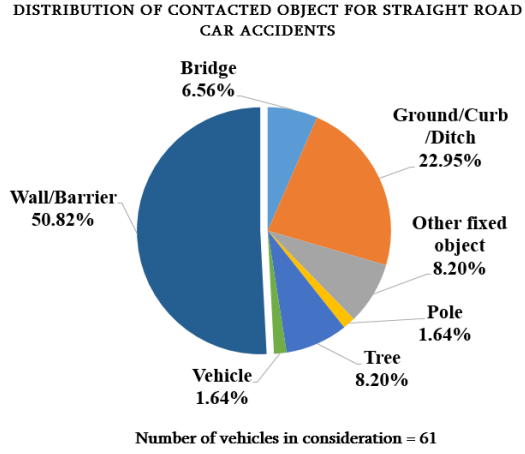

Fig. 6

Further in 29 cases there is 'loss of control' due to PRECREV values = 101,102,141,142,152,153,631,639 and 649. 'PRESTAB' element from vehicle details table was considered and it showed that for 20 vehicle there was a longitudinal or latitudinal skid for the given 'PRECREV' scenario (Fig. 5).

Additionally, in about 35 cases the contacted object was the barriers on either side/median/wall (Fig. 6). This was obtained from the 'OBJCONT1' of the vehicle details table.

IV. DISCUSSION

From the above study, it is evident that the root cause of accident is not a single parameter, but involves multiple parameters like human, vehicle and infrastructure factors. These are therefore the three vital pillars which have to be addressed in order to avoid the accident

The human factors of drowsiness and sleep contributes to 12.1% accidents. These could have been avoided with a system to alert the driver. Such a system could be present internal or external to the car. An internal system could detect driver drowsiness through monitoring the steering wheel movement [1], or standard deviation from the lane position [1], or the eyelid closure of the driver [1]. An external system could be grooved sections in the shoulder of road that loudly announce when tires veer off-course.

Despite having interventions for human factors, the vehicle can also be controlled by installing relevant advanced safety products like ABS, ESP, AEB, Pedestrian protection etc. Nearly 13.1% of the accidents are caused by vehicle skid (for object collision scenario). This could have been easily mitigated through ESC (Electronic Stability Control). For the cases with sleepy driver, it adds a further level of safety.

The last factor which is of utmost importance is the infrastructure as a contributing factor. In India, the scientific design of roads is totally missing. This is not attributed to the quality of the build of the road, but implementation of scientific design of roads. In the present analysis, 17% of the accidents are, where the vehicle hit the road barriers/wall. From the Newton's third law of motion we know that a force will be exerted by the barrier on the car and this cascading effect of forces leads to destruction of property and human life. Even for cases with 'sleepy driver' or 'skid', a better equipped road barrier can act as an extra layer of security/safety.

Certain materials are capable of absorbing the force that is exerted on them and thereby reducing the cascading effect of the opposite force produced. For instance, visco-elastic urethane polymers are used in rockets, or carbon fibers in car's chassis [2] and so on. Silica aerogels [3] could be used to line our concrete barriers. The collapse of the solid network here occurs gradually, thus spreading out the force of impact over a longer time duration. Due to its high porosity, the air contained within the bulk of the aerogel is forced out as the material collapses. Since the pores in the aerogel are very small (20-50nm in diameter) the friction forces on the gas passing through the pores are quite high and the material will absorb a considerable amount of energy. There is little or no recoil (rebound) as encountered with polymers thus mitigating any reverse transfer of energy effects [3].

In effect, changes starting with alerting the driver, equipping vehicle with advanced safety products and also improving the infrastructure could provide 3 levels of safety in object collision car accidents.

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Analysis of Pre-Crash Events of Medium and Heavy Commercial Vehicles Involved in Crashes on Mumbai Pune Expressway

Vinothkumar Kandasamy, Radhika Manikandan

Analysis of Pre-Crash Events of Medium and Heavy Commercial Vehicles Involved in Crashes on Mumbai Pune Expressway

Vinothkumar Kandasamy, Radhika Manikandan

Abstract - This paper focuses on analyzing the Pre-Crash events involving Medium and Heavy Commercial Vehicles (MHCV) and classifying the crashes based on pre-crash event type. The analysis is done based on the sample data of 206 crashes collected on Mumbai Pune Expressway (MPEW). Based on the sample data it was observed that 51% of the crashes involved MHCV, it is critical to ensure that the MHCV crashes are minimized; as the aftermath of the crashes is expensive, focus on the pre-crash events can help avoid the crash.

I. INTRODUCTION

As per Ministry of Road Transport and Highways in 2016 Buses and trucks were involved in 1,38,572 (28.8%) road traffic crashes [1]. This contributes to the country's major disabilities, death and hospitalization, which levies a huge burden in the socio-economic costs. For any crash, pre-crash event is a critical moment. We have analyzed the pre-crash events with an aim to identify the possible root cause of the crashes and provide solution to either mitigate the impact or altogether avoid the crashes

II. METHODS

Crash data collected as part of RASSI (Road Accident Sampling System – India) [2] in MPEW is analyzed in this paper. From the given data 105 MHCV involved crashes are taken for the analysis; of the 300 vehicles, 138 (46%) M3, N2 and N3 category vehicles are considered for the analysis. [N1 and M2 category vehicles are not taken for the analysis.]

- Pre-crash events are grouped based on German Insurance Association Accident Classification System (GDV) modified for Indian conditions and left hand driving.
- Accident type classifies the crashes based on pre-crash event of involved vehicles.
- Data about first crash configuration, availability of reflective tapes, rear under run protection devices and time are also considered for the analysis.
- Primary reason for the crash is derived from the pre-crash event vehicle type coding.

III. INITIAL FINDINGS

Out of 206 crashes, Primary reason for 71(34%) crashes is the MHCV. In the 105 crashes involving MHCV crashes 62% of crashes are primarily due to MHCV.

In 105 MHCV crashes lateral traffic and sudden physical disability crashes contribute to 65.7% of crashes. Other accident type crash distributions are shown in figure 1.

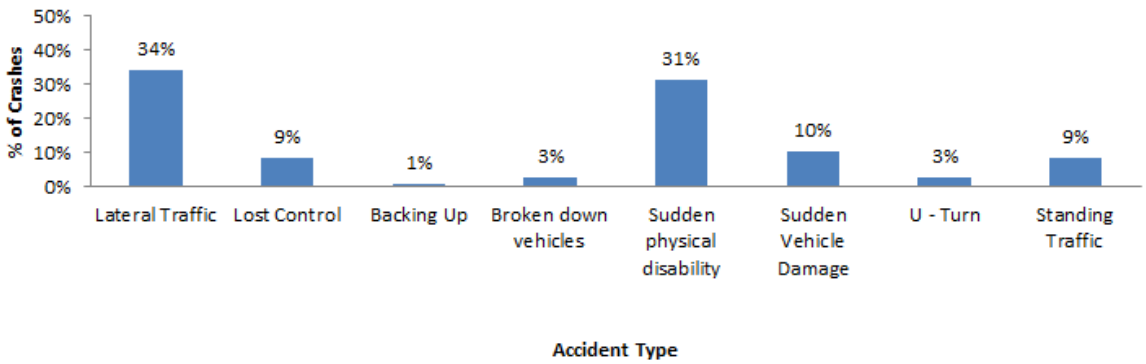

Figure 1. Distribution of 105 MHCV crashes by Accident Type Based on Pre-crash event

Two important pre-crash events observed when analyzing the Lateral traffic crashes, are, conflicts between two vehicles travelling in same direction (Vehicle and Follower) 18 (50%) and conflicts during lane changing 10(28%).

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A conflict between two road users observed in rightmost lane, contribute to (which is a high speed lane) 50% of crashes. Middle lane and left most lane accounts for 33% and 11% of crashes respectively (Figure 2). 29 (81%) of lateral traffic crashes resulted in rear end collision.

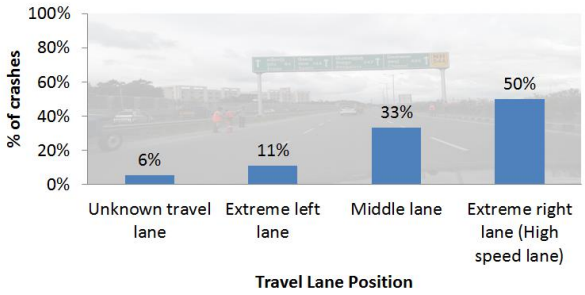

Figure 2. Distribution of 18 Vehicle and follower crashes by travel lane position

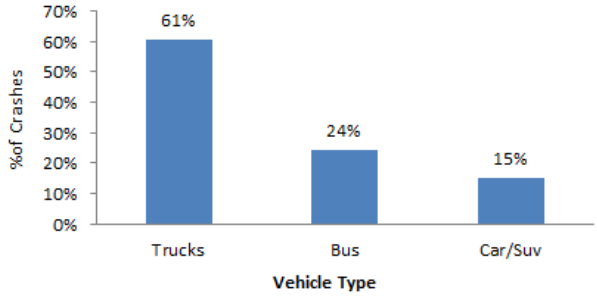

Figure 3. Distribution of 33 Sudden Physical Disability crashes by contributing vehicle Type

Sudden physical disability crashes are the second major accident types which contributes to 33 (31.4%) of all MHCV crashes. 66% of these crashes occur during 03:00HRS to 09:00HRS. In sudden physical disability crashes, 28 (85%) crashes occurred due to MHCV, of which 8 (24%) are passenger carriers (M3 category). Remaining 5 (15%) crashes pertaining to other category vehicles (Figure 3).

The major Pre-crash events observed in sudden physical disability crashes are fatigue 30 (91%) and dizziness 3 (9%). 15 (46%) of sudden physical disability crashes resulted in Object impact and 14 (42%) resulted in rear end Collision.

Based on first crash configuration, 58 (55%) crashes are rear end collision. Based on analysis of all medium and heavy commercial vehicles involved crashes, it is observed that in 86% of crashes the leading vehicles are medium or heavy commercial vehicles. Visibility – is an important factor for MHCV. It was found that in 30% of MHCV's rear reflective tapes are inadequate or not clean or hidden. 9% of the trucks have their rear plane covered with tarpaulin. Of all rear end crash involved trucks, in 23% of trucks Rear Under-run Protection Devices (RUPD) are not available. In 27% of trucks RUPD is damaged. Figure 4 shows few trucks involved in rear end crashes.

Fig. 4A No reflective tapes & Damaged RUPD

Fig. 4B No reflective tapes & No RUPD

Fig. 4C Reflective tapes covered & No RUPD

IV. DISCUSSION

Based on the pre-crash event analysis, it can be observed that MHCV Lateral traffic crashes can be avoided if the MHCV drivers are educated on lane usage, speed management on specific lanes. Also in order to minimize the rear end collision, drivers should be made aware of the importance of safety devices like under-run protection device, reflective strips and tail light. Also 85% sudden physical disability crashes are due to MHCV; this clearly indicates that the work hours should be monitored. As per central motor vehicles act 1989 any national permit vehicles must have two drivers. A single driver should not drive for more than five hours [3]. But in India, currently we do not have any governing body to actively monitor and standardize the Road Safety Regulations. Especially for Commercial vehicle drivers driving hours has to be rigorously monitored and road safety institutions can be created to monitor various aspects of road safety.

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Importance of Drowsiness Detection and Speed Warning Systems on Indian Roads

A N Arjun Bhat

Importance of Drowsiness Detection and Speed Warning Systems on Indian Roads

A N Arjun Bhat

I. INTRODUCTION

Globally, road safety is evaluated by the number of crashes and their consequences in terms of deaths, serious injuries and economic loss to nations. Logically, therefore, to improve safety, the factual causes of crashes should be known. In 2016, nearly 480,652, road accidents occurred in India as per the Ministry of Road Transport and Highway report 2016[1]. Compared to previous year, accidents decreased by 4.1% but fatalities risen about 3.2% [1]. This also gives the hint of increase in severity of the accidents which is 7.9% compared to year 2015[1]. Among the vehicle category 23.6% are cars and, other light motor vehicles stands second in number which involved in the road accidents [1]. Based on the data reported by police, 84% of the road accidents are due to driver's faults [1]. Attempts were made to analyze RASSI (Road Accident Sample System India) data to understand the root cause of accidents and identify the required solution to minimize the road accidents [2]. A correlational analysis was made to identify the interdependency of vehicle speed and the associated contributing factors in the RASSI database.

II. METHODS

The detailed analysis were made from 207 cases involving the 301 vehicles data from the given RASSI database [2]. Close to 59 parameters were analyzed in the vehicle table in utmost details [2]. Firstly driver distraction and vehicle speed during collision was studied from the variables DISTRACT and V0_1ST in detail, through cluster analysis. (Fig 1). Clustering analysis is done using unsupervised learning method. These two parameters were finalized as the cluster indicated some kind of correlation. From the analysis it was found that data can be broadly classified into 3 clusters. Observed three clusters with respect to speed were, 1.Attentive, 2.Looked outside, 3.Sleepy or fell asleep. Fig.1 shows plot of driver distraction and speed (Speed in kilometer per hour and Speed limit status 0: within speed limit, 1: exceeded speed limit and 2: speed unknown). Result shows that 20% accidents were caused during drowsiness (distraction value 3) and 30% were due to exceeding speed limit condition. Further analysis was performed to understand different distraction type.

III. INITIAL FINDINGS

The analysis shows that (Fig.2) 50% road accidents out of 60% known vehicle speed data are due to exceeding the speed limit (Speed Limit not exceeded: 30%, Speed limit exceeded: 30%, Unknown: 40%). This clearly states at least 30 % of the drivers were over speeding beyond the prescribed speed limit. It's also observed that nearly 44% of the drivers that exceeded speed limit, had exceeded by more than 25% than the prescribed speed limit.

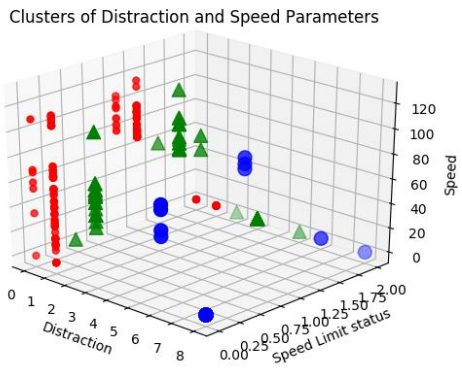

Figure 1 Clustering of Distraction and Speed

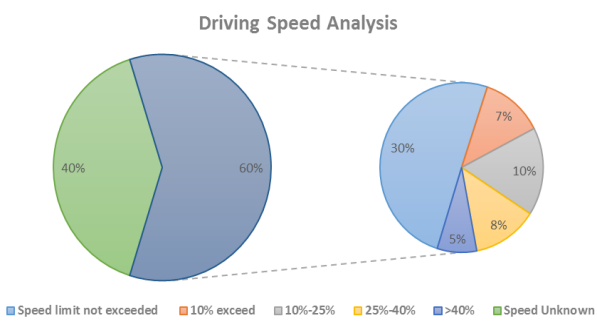

Figure 2: Detailed Driving Speed analysis

As a next level of study driver distraction parameters reveal (Fig.3) that 28.5% of the accidents were due to 20% of the drivers who fell asleep. Observed distraction distribution were, Attentive: 59%, Looked but did not see: 1%, Sleepy or fell asleep: 20%, Distracted by outside person: 0.66%, Eating or Drinking: 0.3%, Distracted/inattentive details unknown: 3.3%, Not applicable: 6%, Unknown: 10%.

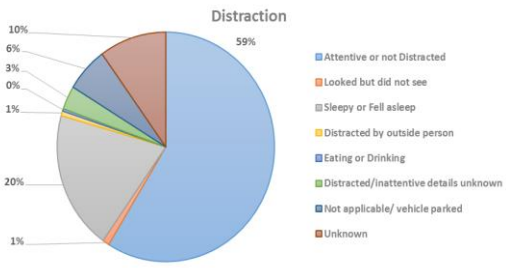

Figure 3 : Detailed Analysis of Different Distraction Type

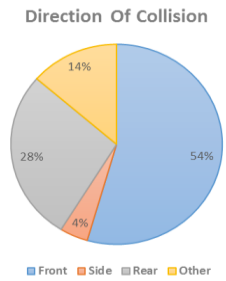

Figure 4: Collision Direction

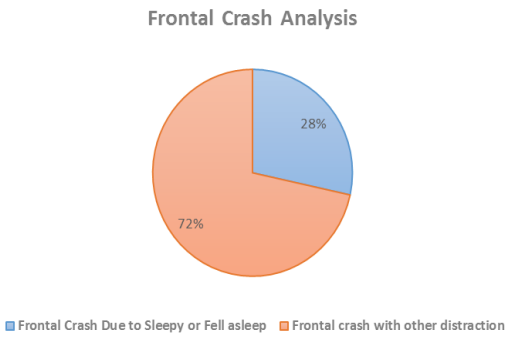

Figure 5: Drowsiness share in Front collision

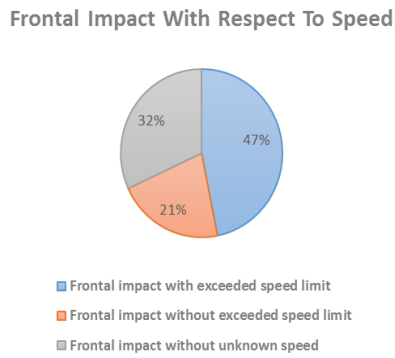

Figure 6: Frontal Collision with different Speed condition

Further investigation with collision type defined in RASSI database DOF1 as additional parameter show (Fig.4) that 54% of the vehicles are involved in frontal collision and 28% out of frontal collision are due to driver sleepy or fell asleep (Fig.5). Vehicle speed analysis on frontal collision show that (Fig.6) 47% vehicles are with exceeded speed limit condition.

IV. DISCUSSION

It is clearly seen that more than 20% of the accidents are due to driver fell asleep. There is immediate need for action to avoid this behavior of the driver by bringing the interventions to have driver monitoring systems, education to driver to have proper rest between his trips and also to add new vehicle safety functions like driver drowsiness detection systems. The driver drowsiness detection systems can have a positive influence in 20% of accident avoidance. It's observed that more than 30% of the drivers exceed the prescribed speed limit. This data is evident to bring region specific products like speed alert warning system, speed cameras and speed monitoring systems from the infrastructure perspective. Also its utmost important to educate the driver to follow the prescribed speed limit and know the stretches of road. Further analysis revealed that out of 54% frontal collision, of which 28% is due to driver drowsiness, combination of frontal airbags and drowsiness detection system can positively influence the 54% of accidents in the sample. These possible solutions can significantly impact on increasing the vehicle safety in a long way.

V. REFERENCES

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2. RASSI (Road Accident Sample System India) data

Crash Investigation of Object Impacted Accidents on Indian Roads

Priyadarshini, Mashhood Raza

Crash Investigation of Object Impacted Accidents on Indian Roads

Priyadarshini, Mashhood Raza

I. INTRODUCTION

A Report on Road Accidents in India 2016, published by Transport Research wing under Ministry of Road Transport & Highways, Government of India, revealed that India witnesses 17 deaths and 55 road accidents every hour in 2016 [1], one of the highest in the world. Out of the estimated 1.4 million serious road accidents occurring annually in India, barely 0.4 million are recorded [2]. Further, only a minimal percentage of these accidents are scientifically investigated due to which the real causes and consequences are never known. Indian roads can be made safer only when we understand the causes and consequences of these collisions so as to work out remedial and preventive measures.

II. METHODS

This study focuses on the crash configuration (rollover, pedestrian, fire, etc.) which took place in the accident and finding the root cause of majority of the collisions. This analysis was performed on the crash dataset of about 206 crashes on Mumbai-Pune Expressway considering parameters such as severe crash configuration, pre-crash event type, moving direction of involved vehicles, weather conditions and injury severity. The tool used for data analysis was Microsoft Excel and Microsoft Access. After analyzing the data, it was found that amongst all the causes, object impact contributes to more than 32% of the accidents. On further investigations as shown in Fig 2, (1) Driver Fatigue and (2) Driver loses control over his vehicle were found to be the two major factors responsible for object impacted accidents.

III. INITIAL FINDINGS

Crash Configuration describes the "intended travel directions" of the colliding vehicles prior to the collision. The plot shown in Fig 1 indicates that rear end collisions, rollovers and vehicle hitting objects were the major scenarios which could have possibly caused highest level of injuries.

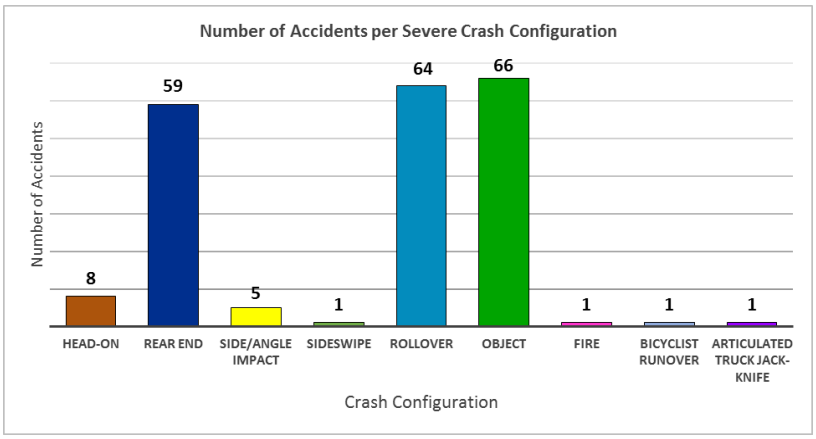

Fig 1 Crash Configuration which could have possibly caused highest level of injuries

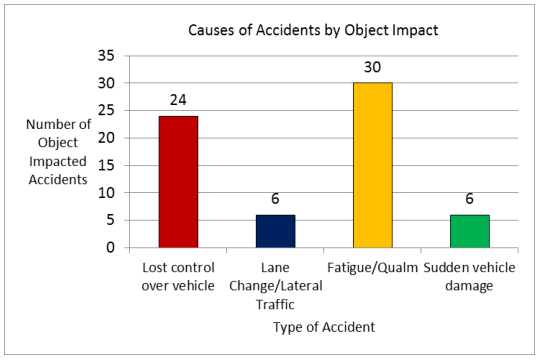

Fig 2 Pre-Crash Event type in Object Impacted Accidents

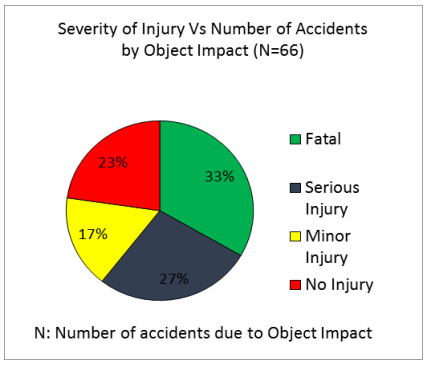

Fig 3 Severity of injuries

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When a vehicle hits an object, it is considered as an object impact. Objects include both fixed objects(trees, lamp posts, etc) and movable objects(construction materials,other vehicles etc). Impacts with animals are also included in object impacts. Investigations on pre crash event types suggests that the number of collisions which occurred due to driver losing control over his vehicle is 24, during lane change is 6, driver fatigue is 30 and due to an unexpected sudden vehicle damage (e.g, sudden technical failure such as tire burst, brake failure etc.) is 6 over total of 66 accidents as shown in Fig 2. Fig 3 illustrates that 60% of the injuries in object impacted accidents were life threatening. It was also found that majority of the crashes occurred in a clear weather and only few in rainy weather.

IV. DISCUSSION

From the above figures and analysis, it is evident that (1) driver fatigue, (2) lost control over vehicle is contributing to more than 69.4% of the road crashes by object impact, the consequences of which can be disastrous. Driver Fatigue affects consciousness, due to which drivers might lapse into a "micro-sleep" without even realizing it. This may only last a few seconds, but if the driver fails to respond to some arbitrary sensory input (e.g. turning the wheel or responding to a stop signal), the risk of crashing is greatly increased. These accidents typically involve a single vehicle that leaves the carriageway to the left/right and collides with another object, such as a tree beside the road or another vehicle.

Fig 4 Crash due to Object Impact [3]

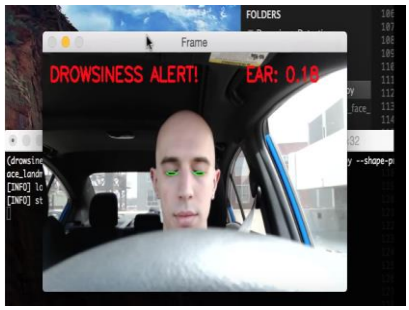

Fig 5 Driver Drowsiness Detection with OpenCV [4]

Fig 6 Extending metal rail guards to reduce the impact of potential collisions [5]

The first proposed solution from driver's perspective is to install Driver Drowsiness Detection Systems in the cars, buses and trucks i.e. an intelligent system which detects the human face and analyses different facial expressions (examples: eye closure, abnormal blink frequency, head jerk, yawning etc.) to predict the driver's attention level. If the attention level falls below a certain threshold, then a warning is raised in the form of acoustic, haptic or photonic signals. The system should be connected to the cloud to receive vehicle and driver attention data for central monitoring.

Another solution from infrastructure's perspective is to launch more initiatives for road-safety like "Zero Fatality Corridor" that identifies risk factors including exposed bridge pillars which have been padded with crash barriers to reduce the impact of a crash, improving road signages, installing guardrails which helps in preventing vehicles from running into hazards near the roadway.

Apart from infrastructure, one of the focus points is to create a quicker emergency response system which might increase the chances of survival of a road accident victim.

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Root Cause Analysis of Belted Occupant Fatalities in Mumbai Pune Expressway during 2015-2016

Sumit Sharma, Shubham Mathur, Virender Singh

Root Cause Analysis of Belted Occupant Fatalities in Mumbai Pune Expressway during 2015-2016

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I. INTRODUCTION

Road safety is a key concern and objective of automobile and safety engineers now days. The United Nations has declared the decade (2011-20) as the Decade of Action on Road Safety. According to a report by Government of India, total number of road accidents per lakh population increased from 39.5 in 2014 to 40.0 in 2015 in India [1]. In order to control this India is also committed to reduce the number of road accidents and fatalities by 50 per cent by 2020.

As the road network in India is growing significantly, several expressways have been constructed since last few years and Mumbai Pune expressway is one of them. Mumbai is assumed to be the administrative capital of India and Pune is one of the Industrial as well as educational hub, around 150 km away from Mumbai. The Mumbai-Pune Expressway is India's first six-lane concrete, high-speed, expressway which connects Mumbai and Pune. According to news published in Hindustan Times on Dec 15, 2016, more than 13000 people dead on Mumbai-Pune Expressway in last 6 years [2]. According to Maharashtra Highway Safety Patrol (HSP) the number of road accidents on the Mumbai-Pune Expressway came down to 281 in 2016 from 313 in 2015, deaths soared by 28% in the corresponding period.

In order to control these fatalities, detailed assessment of the accidents occurred on this highway is required. Subsequently, records and statistics of traffic accidents for two years were carried out by Road Accident Sampling System – India (RASSI) [3]. The main purpose of this research work is to analyse this data, determine road traffic safety issues and suggest solutions to reduce accidents and mitigate injuries on this stretch of highway. A data-driven approach will help quantify the problem and the expected benefits of the suggestions. The suggestions can be related to driver issues, vehicle safety or road engineering and infrastructure safety.

On the basis of various variables available in database, the belted and unbelted occupants were segregated. Seatbelt is a primary restrained system and it is assumed that only seatbelt can save life during accidents. In this research work injury assessment of belted occupants were analysed based on the Abbreviated Injury Scale (AIS) number. Finally the root cause is discussed for belted occupants injuries.

II. METHODS

Microsoft excel statics methodology data was analysed based on the categories specified in the database. First the database of occupant details was used for the analysis. Based in this database, belted occupants with AIS more than 2 were filtered. Vehicle details database was then used to see the type of vehicle associated with these injured occupants. In order to find the root cause, vehicle intrusion was checked from contributing factor code 2602, 2603.

III. INITIAL FINDINGS

Figure 1 shows the total occupants seated in front and rear seats of the vehicles. Out of 810 total passengers, only 149 were restrained by seatbelts. Out of these 149 the injury severity level was known (available) for 79 occupants.

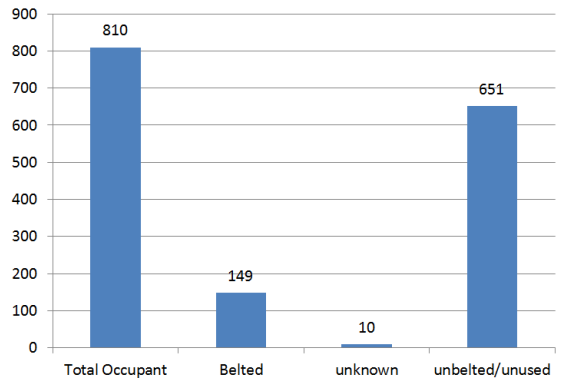

Figure 1: Belted and unbelted occupants

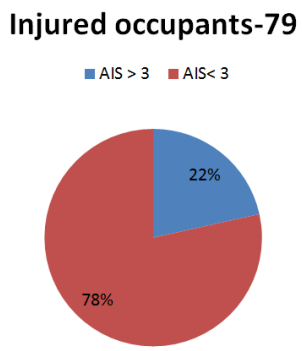

Figure 2: Injury (AIS) level comparison of belted occupants

Filter was applied to find the belted occupant with AIS more than 2 out of 79 belted occupants. As shown in figure 2 that, out of 79, 22% occupants injured severely with AIS more than 2.

Associated vehicle type with these 22% occupants was found to be the passenger vehicles according to the database of Vehicle Details. Figure 3 shows the post accidental condition of the vehicles of these particular cases. The contributing factors for these particular cases are the passenger compartment intrusion with code no 2602, 2603. The main reason behind these fatalities was the intrusion of vehicle compartment for the passengers.

Figure 3: Vehicle condition after accidents

IV. DISCUSSION

It was found that about 22% belted occupants sustained injury levels more than 2. Further analysis was carried out to find the rout cause of these fatalities. It was found that the role of vehicle structure strength is also important to reduce the road accident fatalities. Significant vehicle intrusion was found in all the cases with high injury levels. In order to ensure vehicle body strength, crash testing should be implemented in India. After viewing such scenarios it is also recommended that the automakers should assess the structural strength of the vehicles with proper crash test and improve the vehicle structural strength to provide sufficient safety to the occupants.

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Speed as a contributory factor for the occurrence and severity of collisions on the Mumbai-Pune Expressway

Kevin Gildea

IRCOBI ASIA 2018 – ACCIDENT RESEARCH COMPETITION

Speed as a contributory factor for the occurrence and severity of collisions on the Mumbai-Pune Expressway

Kevin Gildea

INTRODUCTION

An approach used in the analysis of road safety for a particular road type is performing statistical analysis on a relatively small sample of in-depth collision data for a particular roadway segment over a period of time. The data for this study was collected through on-site crash investigations under the initiative of the Road Accident Sampling System India (RASSI), which is a consortium that collects in-depth collision data on certain roadways using trained collision investigators [1]. These collisions are then reconstructed using PC-Crash software, which allows for collision parameters such as pre-collision and post-collision vehicle velocities to be estimated. To be included in this database the collision must involve a motorized vehicle, and occur on a public road. This paper involves the analysis of 206 collisions on the Mumbai-Pune Expressway (MPE) in India. The MPE is a six-lane roadway with a speed limit of 80 km/h along most of it. Two-wheeled vehicles, three-wheeled vehicles and pedestrians are not permitted to use most parts of the expressway and bicycles are not allowed to use any part of it. The most common vehicle types on the MPE are cars, trucks and buses.

The aim of this analysis is to determine road traffic safety issues and suggest solutions to reduce the occurrence of collisions and mitigate the severity of injuries on this expressway. Specifically, in this paper the human factors of speeding, and seatbelt wearing are analyzed. Speeding has been shown to be a significant contributory factor for the occurrence of collisions on the MPE [2], and seatbelts have been shown to have a large effect on the injury severity of vehicle occupants in collisions [3],[4],[7]. An analysis is performed on whether the velocity change experienced by vehicles in collisions can be used as a predictor of injury severity to their occupants, and how occupant seatbelt wearing effects the injury severity.

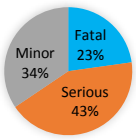
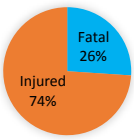
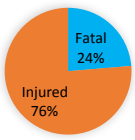
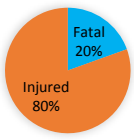
METHODS

RASSI is a relational database with five separate datasets containing information relating to different collision elements ('Vehicle, Occupant', 'Sequence of Events', 'Contributing Factor', 'Accident', and 'Injury Details'). Information relating to specific collision cases can be linked using the common case identification number. Statistical analysis of this database has been performed using IBM SPSS 24 for Windows. A confidence level of 95% is chosen, with statistical significance defined as a p-value of less than 0.05, or an adjusted residual (AR) value greater than 1.96. Very significant difference is defined as a p-value of less than 0.01, or an AR value greater than 2.33. Extremely significant difference is defined as a p-value of less than 0.001, or an AR value greater than 3.1.

INITIAL FINDINGS

In total there were 206 collisions in the RASSI data on the MPE, in which 301 vehicles were involved, containing 810 occupants (131 fatalities, 246 seriously injured, 198 with minor injuries, and 235 with no injury). Comparing the proportions of injury severity with Indian National Data for 2015 [3], shown in Table 1, we can see that the proportion of fatalities to other injuries in RASSI data for the MPE is generally in line with Indian National Data for National Highways (including Expressways), and State Highways.

Table 1: Comparison of RASSI injury and fatality numbers on the Mumbai Pune Expressway with Indian National Data of three road types from 2015.

Injury Severity	**RASSI**	**Indian National Data (2015)** [3]		
	MPE	National Highway	State Highways	Other Roads
Fatal	131	51,204	40,863	54,066
Serious	246	145,341	131,809	223,129
Minor	198			
				

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In the RASSI database, the contributory factors of each incident are listed, and each incident may have multiple contributory factors attributed to it. Of all vehicle occupants in the RASSI database 41% were involved in collisions where speeding is listed as a contributory factor (329 out of 810). Speeding in this case referring to vehicles which exceeded the speed limit, or vehicles which may not have exceeded the speed limit but were travelling at an excessive speed for the weather/road conditions. Shown in Figure 1, the proportion of incidents with speeding listed as a contributory factor is high among both injuries and fatalities (41% of injuries, and 45% of fatalities).

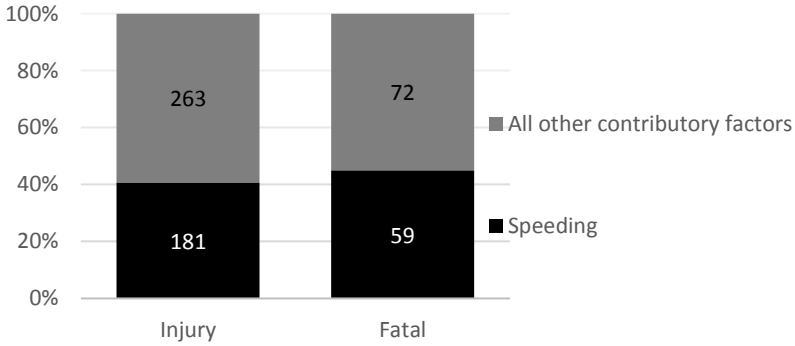
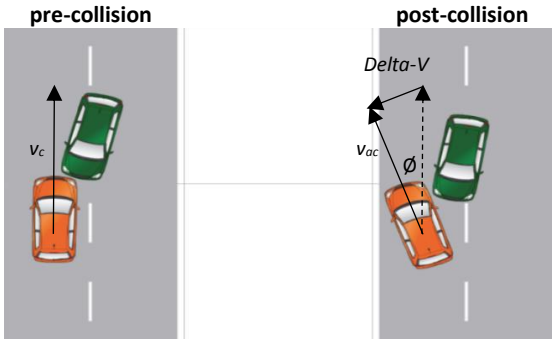


Figure 1: Speeding as a contributory factor for different injury severities (n=810).

In the vehicle database Delta-V gives the vector difference between the immediate post-collision, and pre-collision velocities of the vehicle (Figure 2), where v_c and v_{ac} are the velocities of the vehicle immediately before and after the collision, respectively, and Ø is the change in the angle of the vehicle during the collision..



$$Delta - V = \sqrt{v_c{}^2 + v_{ac}{}^2 - 2\, v_c\, v_{ac} \cos(\emptyset)}$$

Figure 2: Graphic description and equation for Delta-V.

In the data the crash configuration, described as the 'intended travel directions' of the of the colliding vehicles prior to the collision. Of the 206 collisions in the database, 14% are designated as rollovers, 44% collisions with an object (including animals, moveable and fixed objects), 32% rear-end collisions, 3% head-on collisions, 3% sideswipe collisions, and 2% side impacts. Rollover collisions are excluded from Delta-V calculations, and many collisions do not have Delta-V values. At least one value is given for only 99 of the 206 collisions; where it can be determined.

For 394 of the persons involved in the 99 collisions of any configuration there is a value given for Delta-V for the vehicle in which they were an occupant, of which 267 were injured and 127 were uninjured. Splitting Delta-V into ranges (<20km/h, 20-40km/h, 40-60km/h, >60km/h) we see an increasing percentage of injured occupants as Delta-V increases (Figure 3). Pearson Chi-Square testing shows that there is an extremely significant relationship (p-value less than 0.001) between the magnitude of Delta-V and whether an injury occurs to the vehicle occupant.

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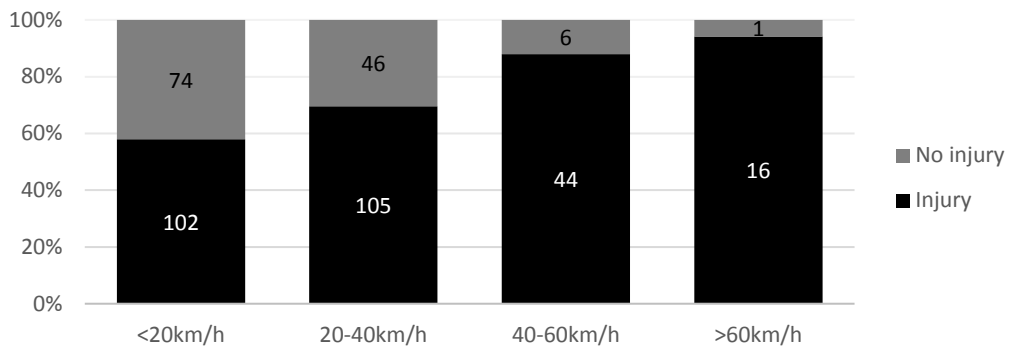
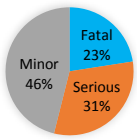
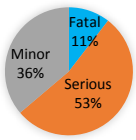
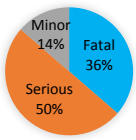
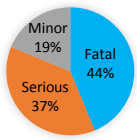
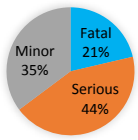


Figure 3: Bar chart of injury outcome for different ranges of Delta-V (n=394).

Post-hoc testing on the percentage of injured and non-injured vehicle occupants within each category of Delta-V, we see that for Delta-V values between 40-60km/h there are a significantly greater percentage of injured vehicle occupants compared to non-injured occupants, with an adjusted residual value (AR) of 3.3 (corresponding to a p-value of 0.00097). for Delta-V values greater than 80km/h there is a significantly greater percentage of injured occupants compared to non-injured occupants, with an AR value of 2.4 (corresponding to a p-value of 0.016). There is a corresponding significantly fewer percentage of injured occupants compared to non-injured occupants for Delta-V less than 20km/h, with an AR value of 3.7 (corresponding to a p-value of 0.0002).

As Delta-V increases the severity of injury and the number of fatalities also increase (Table 2). For lower Delta-V values (less than 20km/h) the proportion of seriously injured vehicle occupants (31%) has been shown to be significantly fewer than the expected proportion (AR=-3.1, p= 0.002), and the proportion of vehicle occupants with minor injuries (46%) has been shown to be significantly greater than the expected proportion (AR=2.9, p= 0.004). For higher Delta-V values between 40-60 km/h there are significantly fewer minor injuries (14%) than the expected proportion (AR=-3.3, p= 0.0001), and a significantly greater proportion of fatalities (36%) than the expected proportion (AR=2.7, p= 0.007).

Table 2: Post-hoc significance testing for the relationship between injury severity and Delta-V (n=267).

Injury Severity	Delta-V				Total
	<20 km/h	20-40 km/h	40-60 km/h	>60 km/h	
Fatal	23 (AR = 0.4)	11 (AR = -3.5)	16 (AR = 2.7)	7 (AR = 2.3)	57
Serious	32 (AR = -3.1)	56 (AR = 2.6)	22 (AR = 1.0)	6 (AR = -0.5)	116
Minor	47 (AR = 2.9)	38 (AR = 0.3)	6 (AR = -3.3)	3 (AR = -1.4)	94
					

Seatbelts are one strategy used to reduce the injury severity in a collision by reducing their movement within the vehicle which is directly caused by Delta-V. Of the total 810 vehicle occupants in the data, 80% were recorded as not using a seatbelt, where either none was available, or one was available but was not used by the occupant. For 394 of the occupants there is a value given for Delta-V for the vehicle in which they were an occupant, of which 267 were injured and 127 were uninjured. Looking at the relationship between seatbelt wearing and the injury outcome for all 394 occupants for all ranges of Delta-V (Table 3) we see that there is no significant relationship.

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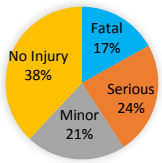
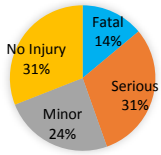
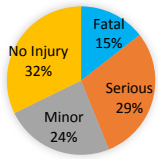
Table 3: Significance testing for the relationship between seatbelt wearing and injury outcome (n=394).

Injury Severity	Seatbelt	No Seatbelt	Total
Fatal	12 (AR = 0.6)	45 (AR = -0.6)	57
Serious	17 (AR = -1.1)	99 (AR = 1.1)	116
Minor	15 (AR = -0.6)	79 (AR = 0.6)	94
No Injury	27 (AR = 1.2)	100 (AR = -1.2)	127







DISCUSSION

The RASSI data on the MPE is generally representative nationally (in terms of the proportion of fatalities to injuries, Table 1) for National Highways (including Expressways), and State Highways. Human factors such as driver fatigue, driver maneuver, and speeding have been shown to contribute to 81.5% of collisions on the MPE [2], of which speeding was shown to be the biggest contributing factor. Speeding is the prevalent contributory factor in this analysis of MPE data, with 41% of all injuries to persons being in collisions where speeding is listed as a contributory factor. The magnitude of Delta-V has been shown to be a significant contributory factor to both the occurrence of injuries (Figure 3), and to the severity of injury sustained to vehicle occupants (Table 2). For Delta-V values under 20km/h, there are a higher proportion of minor injuries and a lower proportion of serious injuries. Consequently, at higher Delta-V values (40-60km/h) there are a lower proportion of minor injuries than expected. For Delta-V values from 20-40 km/h, there is a significantly smaller proportion of fatalities than expected, above 40 km/h there is a significantly greater proportion of fatalities. However, for Delta-V below 20 km/h there are is no significant difference from the expected proportion, which is not in line with the trend of increased injury severity for increased Delta-V values. Further research and analysis is required to determine the effects of collision parameters which directly affect the magnitude of Delta-V and injury severity, such as collision partner type, collision type, and occupant position in the vehicle. In order to perform this analysis, access to a greater number of collisions is required.

No significant relationship has been found between seatbelt wearing and injury outcome for all values of Delta-V. There are not enough cases in the data to perform significance tests for relationship between seatbelt wearing and the injury outcomes for the Delta-V ranges in Table 2. A requirement for Chi-Square testing is that more than 20% of the expected counts are less than 5 [6] , which was not fulfilled by the data, partly due to the low seatbelt wearing rates on the MPE (20%), for this we would need twice the number of cases. However, It is well established that the use of seatbelts has major protective effect in reducing injury severity in collisions [3],[4],[7].

Based on the findings in this analysis, we can conclude that by addressing speeding on the MPE, and other Highways a large reduction in the frequency of collisions could be achieved. A reduction in collision speeds and an increase in seatbelt wearing rates will also reduce the likelihood of injuries occurring, and the severity of injuries on the MPE. Safety improvements on the MPE could be expected from effective speed and seatbelt enforcement, as well as education and media campaigns to highlight these dangers to the public.

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