Mumbai – Pune Expressway Road Accident Study

Analysis of 110 Road Traffic Accidents examined from January 2018 to December 2018

Submitted to:

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&

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Executive Summary

JPRI has been conducting on-site accident investigation and in-depth accident investigations on the Mumbai-Pune expressway since 2012, with the approval of the Maharashtra State Highway Police and the Maharashtra State Road Development Corporation. Since 2012, JPRI has investigated over 750 accidents on the expressway. As part of its commitment in enabling a data-driven approach to reduce fatalities on the expressway, JPRI has been publishing annual reports on the accidents investigated throughout a given year. These reports highlight the priority areas and low hanging fruits for improving safety of commuters on the expressway. This report is the 5th such report and discusses the findings of accidents investigated in the calendar year 2018.

It is found that the accidents occurring between 00:00 and 09:00 constitute 56% of all accidents and 54% of fatal accidents. Together, collision with another vehicle moving ahead or waiting or stationary (rear-end collisions), leaving the carriageway to the left/right and pedestrian accidents constitute 90% of all accidents and 94% of fatal accidents. Trucks, cars and pedestrians constitute 95% of the road users involved in accidents, and 98% of the road users with at least one fatal victim. 58% of pedestrian accidents involved vehicle occupants outside the vehicle, while the vehicle was parked or was broken-down or being pushed to the roadside.

JPRI employs a Haddon Matrix approach to identify the contributing factors (Human, Vehicle, Infrastructure) influencing the occurrence of each accident and the resulting injuries. Table below lists the top factors under each category.

PHASE	FACTORS		
	HUMAN	**VEHICLE**	**INFRASTRUCTURE**
PRE CRASH	• **Speeding (32%)** • **Driver – Sleep/Fatigue (35%)**	• Absence of reflectors (5%)	• **Inadequate warning about crash/parked vehicle (8%)** • Shoulder – Narrow/None (3%)
CRASH	• **Seatbelts not used (66%)**	• **Passenger Compartment Intrusions (67%)** • **Seatbelts not available (24%)**	• **Object Impacts (12%)**
POST CRASH	• Improper crash/breakdown management (1%)	• **Ejection (16%)** • Entrapment (2%)	--

Enforcement for seatbelt and speeding have a great scope for reducing accidents and fatalities on the expressway. With respect to road infrastructure, ***tactile edge lines*** are recommended to alert sleepy drivers before going off the road and ***advance signage*** **on rest areas** to keep commuters well-informed. ***A single emergency response number*** and ***proper publicity to encourage use of available emergency/breakdown services*** will help reduce accidents due to parked vehicles.

For engineering improvements, the current ***rear underrun protection devices (RUPDs) and guardrails*** need to be scientifically evaluated to be made more effective in reducing fatalities and serious injuries.

Acknowledgements

We express our sincere thanks to the office of the **Additional Director General of Police (Traffic), Maharashtra** and the **Vice Chairman** & **Managing Director** and the **Joint Managing Director (III)** of Maharashtra State Road Development Corporation (MSRDC), for:

a. Giving us the opportunity to continue this study over the years with full support and cooperation.
b. Providing us with all the requisite data as and when requested.
c. Collaborating to reduce road traffic accidents on the Mumbai-Pune Expressway using scientific data analysis and setting a model for others in the nation to follow.

Our sincere appreciation and gratitude to all the **Police officers** of **Maharashtra State Highway Police**, officers of the **Pune Rural**, **Pimpri Chinchwad Commissionerate**, **Raigad** and **Navi Mumbai Police** and the **Traffic Aid Posts** (TAPs) for their support and cooperation. We are also grateful to **IRB personnel** and **Tow truck drivers** who notify us of accidents. The hazardous nature of work performed by the TAPs personnel, the tow truck drivers and the IRB personnel during accidents and road blockages, is still not well understood by most people, and we hope that government soon recognizes their importance and provide them with better protection, equipment, training and facilities to enable them to do their jobs more effectively and, in turn, help in saving more lives.

This study is being conducted under the **Road Accident Sampling System – India (RASSI)** project, which is an initiative financially and technically supported by the following consortium members:

We strongly believe in this pioneering attempt in India towards data-driven road safety strategies, which has been proven to be highly effective in mitigating fatalities, injuries and crashes around the world. We hope that the data collected and analyzed from this study is useful to all the stake holders of the Mumbai – Pune Expressway (including motorists) in helping make all our journeys safer.

We are pleased to note that the accident data, collected through on-site crash investigations conducted by JPRI under the RASSI initiative, is helping set priorities and plan strategies for the Zero Fatality Corridor project initiated by SaveLIFE Foundation, Mahindra Rise and Maharashtra State Road Development Corporation.

This report is dedicated to all those whose lives have been affected, directly or indirectly, by road traffic crashes on the Mumbai – Pune Expressway.

1 INTRODUCTION

The Mumbai – Pune Expressway (MPEW) is a controlled-access highway that connects Mumbai, the commercial capital of India, to the neighboring city of Pune, an educational and information technology hub. This divided 6-lane roadway is an alternative to the old Mumbai – Pune highway and helps in reducing travel time between the two cities. It has a posted speed limit of 80 kmph along most parts of the stretch. Two-wheelers and three-wheelers are not permitted to use most parts of the expressway. Common vehicle types plying the expressway are cars, trucks and buses. The expressway is 94.6 km long and witnesses many traffic crashes, fatalities and serious injuries.

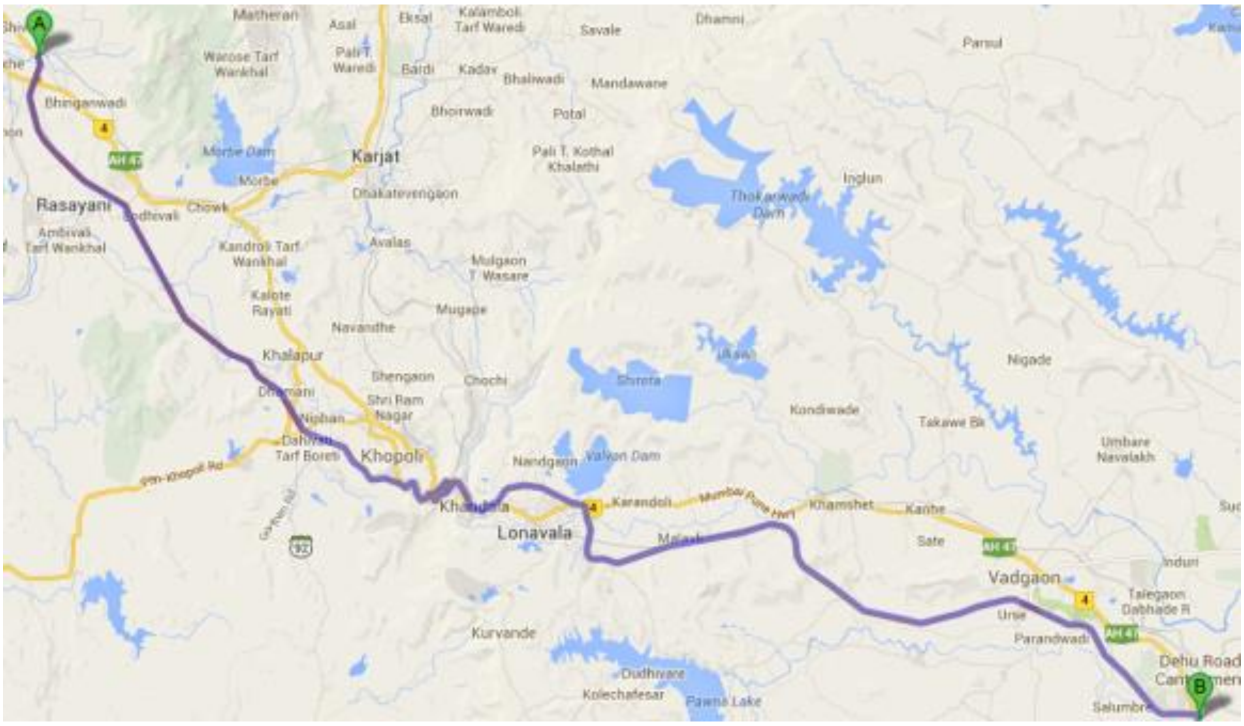


FIGURE 1: MAP SHOWING MUMBAI – PUNE EXPRESSWAY
(COURTESY: GOOGLE MAPS)

This report presents findings of the contributing factor analysis done by JP Research India (JPRI) for crashes that occurred on the MPEW and were examined by JPRI in the year 2018. This report is a follow-up to the earlier four reports on this study.

TABLE 1: LIST OF REPORTS PUBLISHED BY JP RESEARCH ON MUMBAI-PUNE EXPRESSWAY

Report number	*Published*	*Time duration covered*	*Accidents analyzed*
Report 1	Dec 2013	Oct 2012 to Oct 2013	214
Report 2	Dec 2014	Oct 2012 to Oct 2014	372
Report 3	Feb 2017	Jan 2016 to Dec 2016	155
Report 4	Jul 2018	Jan 2017 to Dec 2017	125

1.1 Background

1.1.1 How did this study begin?

In July 2012, JPRI approached the Maharashtra State Highway Police with a proposal to conduct on-site crash investigation and crash data collection on the Mumbai – Pune Expressway. The proposal was accepted, and since 7 October 2012, JPRI researchers have been examining crashes on-site as soon as they are informed of a crash by the police or other stake holders/agencies. JPRI has successfully completed 7 years of scientific crash investigation and in-depth accident data collection on the Mumbai – Pune Expressway.

1.1.2 How can JPRI conduct this study for *FREE* for the government?

This study is being conducted at **NO COST** to the government. JPRI respects, and is grateful, for the cooperation provided by the police and other government agencies for conducting this in-depth crash investigation studies. In return, JPRI provides reports that give scientific, detailed and unbiased insights regarding road safety issues in India.

JPRI accident research teams spend a considerable amount of time examining road traffic accidents. In-depth accident investigations are conducted in a scientific manner involving detailed examination of the accident scene and involved vehicles, and detailed coding of injuries sustained by the crash victims. Whenever possible, victims are also interviewed to better understand the sequence of events. The collected data is stored in a format which allows for detailed analysis of investigated accidents.

Numerous measurements, observations and notes are recorded on accident data forms, which are stored in a relational database called "Road Accident Sampling System – India" (RASSI). This database is shared by a consortium of automotive manufacturers who use it for improving vehicle design and developing India-specific safety technologies. This scientific research consortium provides financial and technical support to JPRI under the RASSI initiative for obtaining this data. *(More details in section 1.3).*

1.1.3 Does this study affect my privacy?

This study is purely scientific, and personal information such as victim names, any contact numbers, vehicle registration numbers, etc. are NOT stored in the database.

JPRI crash investigation processes are designed to make an unbiased scientific examination of each accident to determine the various contributing factors and not to find fault. This helps better understand existing road safety fallacies and thus design effective counter measures. No personal information is used in any analyses and for this purpose, after completing a crash examination, all personal details are anonymized before being entered into RASSI database.

1.1.4 What is the objective of this report?

JPRI examined and analyzed 110 road traffic accidents in detail from 01 January 2018 to 31 December 2018. This report provides a preliminary analysis of these accidents, followed by analyses of various factors influencing accidents and injury occurrences on the Mumbai–Pune Expressway. The report not only identifies these factors but also ranks them based on the number of accidents influenced. This ranking aims to help policy makers, decision makers and road safety stakeholders in planning cost-effective road safety investments using data-driven road safety strategies.

1.2 JP Research India

JP Research India Pvt. Ltd. (JPRI) is a research firm dedicated to the business of automotive crash data collection and analysis. JPRI, a fully owned subsidiary of JP Research, Inc., is a forerunner in road safety research in India and has undertaken pioneering on-scene accident investigation and in-depth data collection projects aimed at scientifically understanding and mitigating road traffic accident fatalities.

In-depth accident investigation and research has proven to be the best way to understand the characteristics of real-world road traffic accidents. Countries such as the USA, UK and Germany have showcased the potential of such studies by significantly reducing the number of road traffic fatalities in their countries. The fact that India has been losing approximately 1,50,000 lives on roads every year makes it imperative that we, too, take such in-depth and data-driven approach to take swift steps in addressing the key factors influencing the high traffic injury and mortality rate in our country.

JPRI is experienced in using accident research methodologies developed in other nations and tailoring these to suit India's unique traffic conditions. JPRI has developed a sustainable and working model of accident data collection through developing India-specific accident data collection forms, a methodology for conducting site and vehicle investigations in the inimitable Indian traffic environment and developing a relational database of in-depth accident data. In addition, the company's experts offer training for those who wish to perform their own data collection and analysis. In other words, at JPRI, our overriding objective is, *"Understand Indian roads, traffic and road users in ways that can be used to save lives: ours and yours."*

FIGURE 2: JPRI ACCIDENT RESEARCH TEAM DURING INVESTIGATIONS

1.3 Road Accident Sampling System – India (RASSI)

The economic and social benefits of implementing a standardized accident reporting and data collection systems to improve road and automotive safety have been demonstrated in Europe and the USA. There has been no comparable system in India. The absence of such systematically collected, nationwide in-depth traffic crash data is significantly impeding scientific research and analysis of road traffic accidents in India.

Only real-world crash data, properly defined, can reliably identify the key factors that contribute to accidents, both in terms of their frequency and severity. Further, since cultural and socio-economic conditions as well as the roads themselves, affect driving conditions and crash outcomes, the data must be specific to a region. An automotive accident data collection system – based on the models used in Europe/US but modified to suit Indian road scenario was thus initiated by a consortium of automobile original equipment manufacturing (OEM) companies and was christened RASSI.

The genesis of the RASSI project began with a study of passenger car accidents undertaken in Chennai, Tamil Nadu. This led to short-term studies on National Highways in the districts of Kanchipuram and Coimbatore, with the cooperation of the Tamil Nadu state police. Based on the experience from these initial studies, a robust methodology was developed to perform in-depth accident data collection and research that applied generically to all Indian roads. A relational database was also developed to record the scientific data obtained from each accident investigated by the researchers. Based on the early success of RASSI, several OEMs came forward to provide financial support for the continuation of the study on a yearly basis. In 2011 in JPRI's Coimbatore Data Centre, the RASSI Consortium officially came into being, and members were granted interactive access to the database.

Accidents are continually being investigated by JPRI in Coimbatore, Pune, Ahmedabad, Kolkata and Jaipur .The program logs a wide array of data and photographs. Evidences such as skid marks, broken glass, impacted objects, and measurements of damage to the vehicle are recorded and assessed in detail to identify interior vehicle locations contacted by occupants during the crash event. On-site investigations are then followed up by linking medical record reviews to document the nature and severity of injury from a crash.

The long-term goal of the RASSI Consortium is to create an integrated network of data centers across India with the support of other automotive and transportation-related companies and of the government. This would result in a common set of traffic accident data for research and analysis of root causes concerning India's high road traffic fatalities.

APPENDIX A: JPRI & RASSI CONTACT INFORMATION.

2 METHODOLOGY

2.1 Accident Data Sample and Data Analysis

A total of **110 accidents** were investigated by JPRI accident research team on the expressway from 01 January 2018 to 31 December 2018. These crashes involved **218 road users (193 vehicles and 25 pedestrians)** and **443 victims (418 vehicle occupants and 25 pedestrians).** Of the 443 victims, **65 were fatal**, **105 were seriously injured** and **129 suffered minor injuries**.

2.1.1 How were these accidents found?

The Operations and Maintenance contractor, IRB, notifies JPRI via phone calls/text messages about any accidents on the expressway that the control room is informed of. In addition, JPRI accident research team calls up Police TAPs to check for any accident notified to them. Also, there have been instances where JPRI accident research team has seen and investigated accidents that were neither reported to the IRB control room nor the Police TAPs. The severity of such non-reported accidents was usually minor or no injury, but occasionally involved serious injuries. Such accidents, although not reported to the police, are still important for in-depth analysis. Hence, the JPRI crash research team goes on regular rounds of the expressway and examines such non-reported crashes, in addition to those informed by the IRB.

TABLE 2: NOTIFICATION SOURCE AND COUNT OF NOTIFICATIONS RECEIVED

NOTIFICATION SOURCE	NOTIFICATIONS RECEIVED
IRB NOTIFIED	129
SELF NOTIFIED	55
POLICE NOTIFIED	4
TOTAL NOTIFICATIONS	**188**

Overall, JPRI has received notifications for 188 accidents from various sources for the year 2018, (Table 2). Of the 188 accidents, **110 accidents were investigated in-depth**. In the remaining accidents, either the involved vehicles were unavailable for inspection or the accident scene was not identifiable with evidence.

2.1.2 Are all accidents reported to the police?

To determine whether an accident has been reported to the police, follow-ups were done with the concerned police station for up to 2 weeks after the data of occurrence and it is seen that one-third of the investigated accidents are not reported to police (Figure 3).

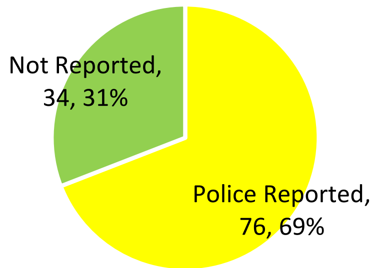


FIGURE 3: PERCENTAGE DISTRIBUTION OF POLICE REPORTED ACCIDENTS IN THE SAMPLE (N=110 ACCIDENTS)

Although JPRI makes meticulous attempts to investigate all the road traffic accidents occurring on the expressway, there are chances that some are still missed.

2.1.3 Why are "not-reported" accidents important?

Having access to all accidents, including those that are not reported to the police, is important because, these:

1. Give a more realistic indication of the total number of accidents on the expressway.
2. Give an indication that not all accidents result in fatalities or serious injuries; even minor or no-injury accidents must be addressed.
3. Allows analysts to determine which safety systems work well, and which does not, in preventing accidents or mitigating injuries.

2.2 Contributing Factors – A Primer

Road traffic accidents are primarily influenced by three main factors:

- Human (drivers, riders, vehicle occupants, pedestrians and cyclists)
- Vehicle (vehicle design/structure, mass, equipment such as seatbelts or tires, etc.)
- Infrastructure/Environment (hereinafter called "infrastructure" and comprising roadway, signage, weather, conditions affecting visibility, etc.)

Conventionally, accidents are analyzed for each of the above factors, and the accident is finalized as a result of a problem with *only one* of these factors. This type of analysis results in an overrepresentation of human failures and tends to identify driver error as the main contributor to road traffic accidents. Thus, the commonly repeated wisdom - "Driver error is the cause of over 90% of accidents".

The problem with this type of analysis is the overemphasis on human factors. Influencing factors which are vehicle-related and infrastructure-related are often not accounted for, even though they are an inseparable part of the sequence of events.

2.3 The JPRI Approach to Studying an accident

When JPRI researchers investigate an accident, they try to determine all the possible contributing factors (human, vehicle and infrastructure) leading to the occurrence of that accident because each of these factors can influence independently or as a combination. This kind of analysis gives a broader perspective and can help identify vehicle and infrastructure related solutions despite human errors.

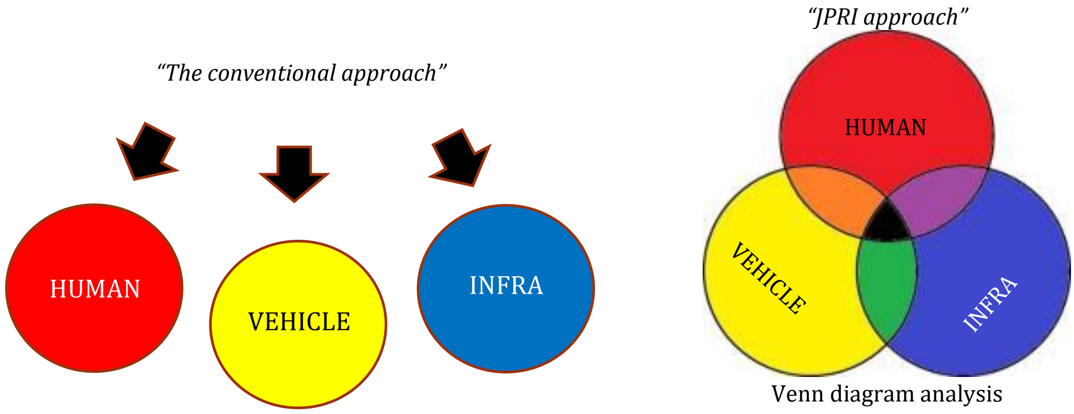


FIGURE 4: APPROACHES FOR ANALYZING ACCIDENT CAUSES

Table 3 is a representation of using the Haddon Matrix to analyze the contributing factors influencing the occurrence of a *road traffic accident* and resultant *injuries*. The Haddon Matrix was developed by Dr. William Haddon in the 1970s and looks at factors related to personal attributes, vector or agent attributes and environmental attributes; before, during and after an accident. By utilizing this framework (the Haddon Matrix), one can think about evaluating the relative importance of different factors and design interventions.

TABLE 3: A REPRESENTATION OF THE CONTRIBUTING FACTORS ANALYSIS, SEPARATING INFLUENCES ON CRASHES AND INJURIES

		FACTORS		
PHASES		HUMAN	VEHICLE	INFRASTRUCTURE
PRE-CRASH	Crash Prevention	• Information • Attitudes • Impairment • Police Enforcement	• Roadworthiness • Working Lights • Good Brakes • Handling • Speed Control	• Road design and layout • Speed Limits • Pedestrian Facilities
CRASH	Injury Prevention during the crash sequence	• Use of Safety Systems	• Occupant restraints • Other Safety devices • Crash Protective design	• Crash protective roadside objects
POST-CRASH	Life Sustaining	• First-aid skills	• Ease of access for rescue • Fire risk	• Access to medics • Rescue facilities

Case Study

The following is a case study of two accidents to demonstrate that accident causation and injury causation differ from each other.

Case 1: A van with 9 occupants was travelling towards Mumbai in the left most lane of the MPEW. The van left the carriageway to the left due to driver fatigue. There was a slope on the left side and no crash barriers were present. On realization of vehicle entering the slope, driver of the van tried to steer right to avoid the slope. However, driver could not control the vehicle and impacted a roadside tree on its front plane and deflected counterclockwise. It then impacted another tree partially on its left and its top plane. After the impact, with the 2nd tree, it rolled over on its right plane. The van completed 1 quarter turn and came to rest partially on the unpaved shoulder and partially off-road. Unit 1 was on its right plane at its final rest position. 2 Occupants of Unit 1 were fatal on spot and 1 Occupant succumbed to his injuries in the hospital. 1 other occupant was seriously injured while 4 others had minor injuries and 1 occupant was not injured

Case 2: A car with 1 occupant was travelling towards Pune on the MPEW. The driver of this vehicle felt asleep causing the vehicle to leave the carriageway to the right. The vehicle impacted the guardrail on the paved shoulder. It travelled for some distance deflecting the guard rail posts in the process and finally came to rest partially on paved shoulder and rightmost lane. Driver of this vehicle sustained minor injuries.

Table 4: Example demonstrating variability of injury outcomes for the same accident contributing factor

	Case 1	Case 2
Scene Photos Taken along the direction of vehicle's travel	   	   
Vehicle Photos Damages sustained by the vehicle		
Injury severity	Fatal	Minor
Contributing factors Pre-crash Phase (accident occurrence)	Driver Sleep	Driver Sleep
Contributing factors Crash Phase (injury occurrence)	Object Impact – Roadside Trees Seatbelts not used, Occupant Ejection, Passenger Compartment Intrusions	Seatbelts not used

Both accidents involved the same pre-crash factor (driver fatigue) causing the vehicle to leave the carriageway, however the injury outcomes were different. In the second accident, the occupant (driver) was able to walk away with minor injuries, while in the first case had fatal and seriously injured victims.

As the Table 4 demonstrates, the event that primarily led to the accident occurrence was similar in both cases: leaving the roadway. In the second case however, the vehicle was obstructed by the metal guardrail from leaving the carriageway. In the first case, the vehicle left the roadway and impacted trees on the roadside, following which it rolled over. In this case, had there been an effective crash barrier to prevent the impacting vehicle from leaving the road, the injury outcome would have been less severe, as can be seen in case 1.

This case study helps us understand:

a. Contributing factor analysis using the Haddon Matrix approach, and
b. Effectiveness of guardrails and their influence on reducing injury outcomes as result of the other contributing factors in a crash.

3 DATA ANALYSIS

The 110 accidents investigated were analyzed to determine the accident characteristics on the expressway.

3.1 Distribution of accidents by Highest Injury Severity

The distribution of the 110 road traffic accidents by injury severity (based on the most severe injury sustained by any human involved in each crash) is shown in Figure 5. Fatal/Serious accidents constitute 74%.

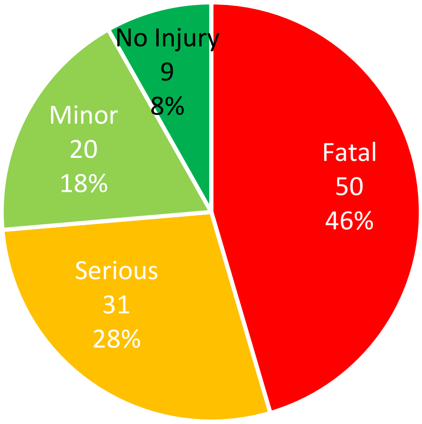


FIGURE 5: DISTRIBUTION OF ACCIDENTS BY HIGHEST INJURY SEVERITY

Injury severity definitions

The following are the definitions used to classify the injury severity outcome of each accident.

Fatal injury: *An accident involving at least one fatal victim.*
Any victim who dies within 30 days of the accident due to the resulting injuries is counted as a fatality.
Serious injury: *An accident with no fatalities, but with at least one or more victims hospitalized for more than 24 hours.*
Minor injury: *An accident with victims suffering minor injuries which are treated at-scene (first aid) or in a hospital as an outpatient.*
No injury: *An accident in which no injuries are reported by any of the involved persons.*

3.2 Distribution of accidents by day of occurrence

Tuesdays have recorded the highest incidence of accidents (25). However, Friday shows the highest risk for fatal accidents at 69% (9 fatal accidents of 13 accidents investigated). This is closely followed by Monday and Sunday with 64% and 62% risk of fatal accident occurrence, respectively.

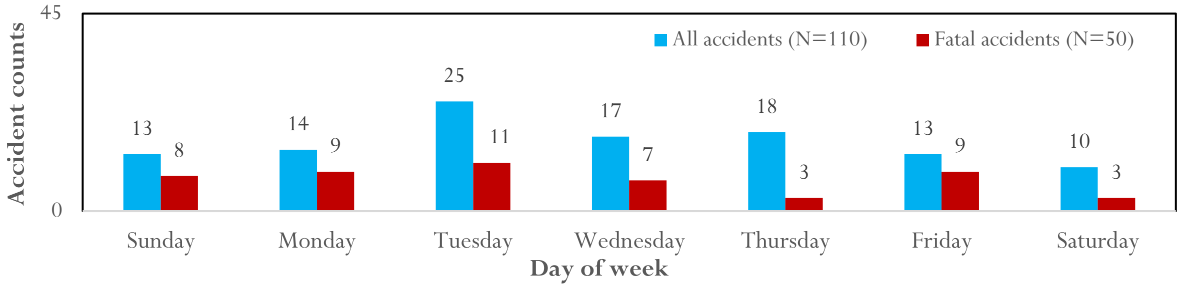


FIGURE 6: DISTRIBUTION OF ACCIDENTS BY DAY OF OCCURRENCE

3.3 Distribution of accidents by Time of Occurrence

The 110 accidents used for the contributing factors study were plotted against time periods of 3 hours (Figure 7). About 37% of all accidents and 42% of fatal accidents between 00:00 to 05:59 hrs. This is followed by accidents occurring between 06:00 to 11:59 hrs during which 31% of all accidents and 34% of the fatal/serious accidents occurred. **Overall, 56% of all accidents and 54% of fatal accidents occurred between 00:00 and 09:00 hrs.**

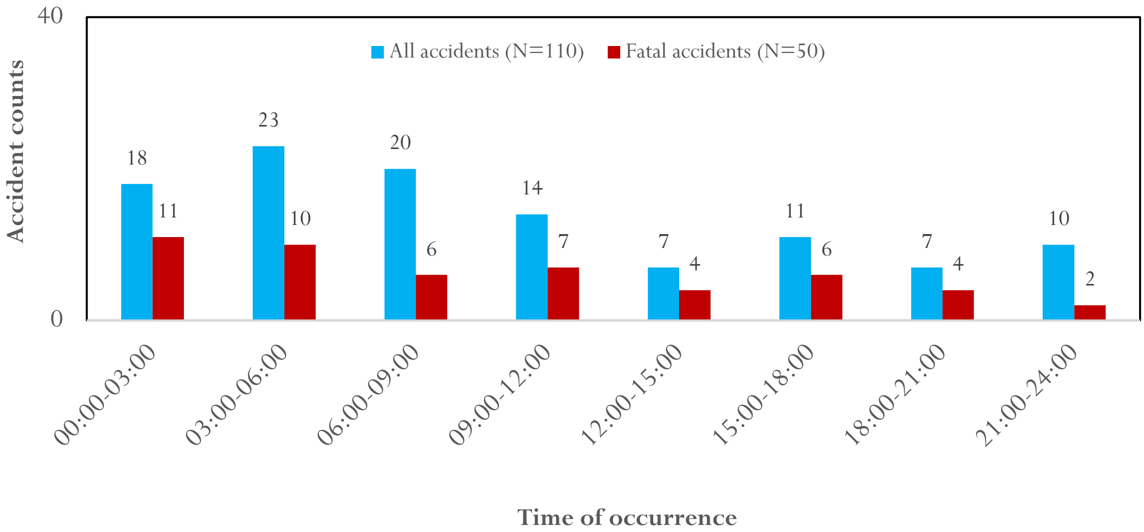


FIGURE 7: DISTRIBUTION OF ACCIDENTS BY TIME OF OCCURRENCE IN 3 HOUR TIME ZONES

3.4 Kind of accident

Figure 8 shows the distribution of the 110 accidents (including the 50 fatal accidents) as categorized by kind of accident. The ten accident types used in categorizing these accidents are listed below and defined in detail in Appendix B.

1. Collision with another vehicle which starts, stops or is stationary.
2. Collision with another vehicle moving ahead or waiting.
3. Collision with another vehicle moving laterally in the same direction.
4. Collision with another oncoming vehicle.
5. Collision with another vehicle which turns into or crosses a road.
6. Collision between vehicle and pedestrian.
7. Collision with an obstacle in the carriageway.
8. Leaving the carriageway to the right.
9. Leaving the carriageway to the left.
10. Accident of another kind (such as truck jack-knifing, fires, and rollovers on the carriageway).

As can be seen from Figure 8, collisions with another vehicle moving ahead or waiting and collisions with another vehicle which starts, stops or is stationary together constitute 54% of all accidents and 58% of fatal accidents. This is followed by "run-off-road" accidents that account for 28% of all accidents and 20% of fatal accidents. Collision between vehicles and pedestrians constitute 7% of all crashes and 14% of fatal crashes.

Together, collision with another vehicle moving ahead or waiting or stationary (rear-end collisions), leaving the carriageway to the left/right and pedestrian accidents constitute 90% of all accidents and 94% of fatal accidents.

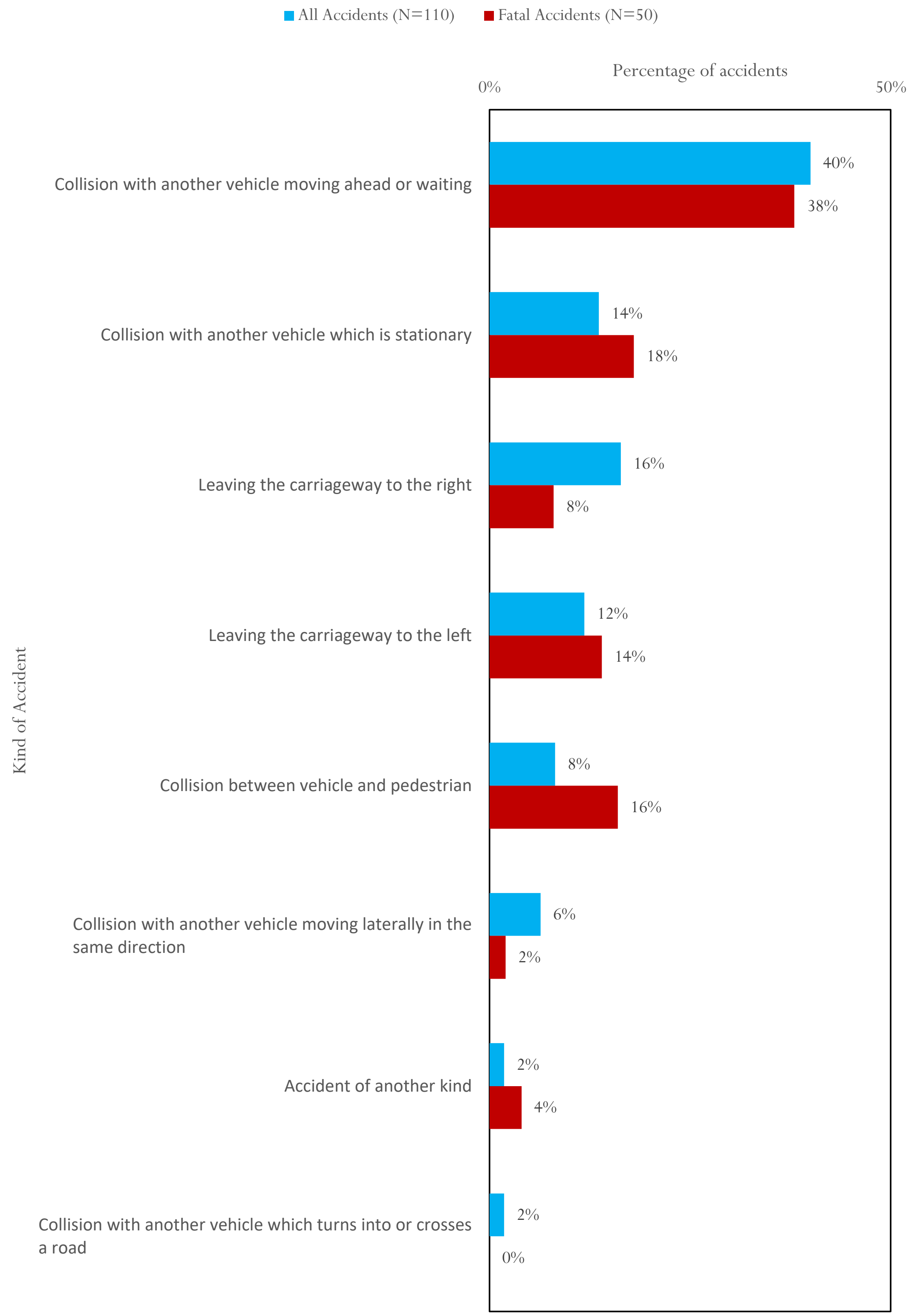


FIGURE 8: PERCENTAGE DISTRIBUTION OF ACCIDENTS BY KIND OF ACCIDENT

3.5 Vehicles/Road Users Involved/Affected

A total of 218 road users (193 vehicles and 25 pedestrians) were involved in the 110 accidents. Figure 9 shows the distribution of road user types involved in all accidents alongside the fatal road users per body type (56 road users).

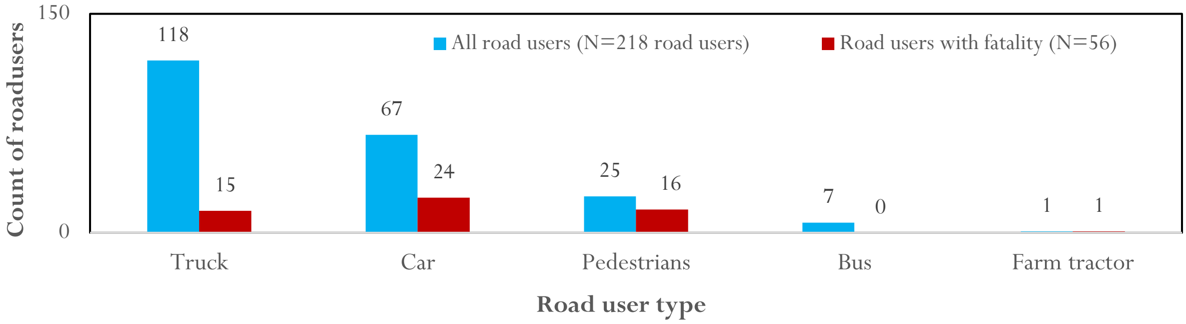


FIGURE 9: DISTRIBUTION OF ROAD USER TYPES INVOLVED/AFFECTED

Please note that the figure is based on a count of the vehicles and pedestrians involved in the accidents analyzed and not the number of occupants or accidents. In the case of pedestrians, each pedestrian is a single count.

Findings show that the road users most often involved in accidents are trucks (54%, 118 out of 218) and cars (30%, 66 out of 218); these are also among the principal road users seen on the expressway. As can be observed, the vehicles with the highest share of fatalities or serious injuries to occupants are cars. Cars constitute 43% (41 cars, by count) of vehicles which had at least one fatal or serious injury occupant.

Trucks, which have the highest involvement in crashes, have second highest share of fatal/serious injuries. Trucks constitute 27% (25 trucks, by count) of vehicles which had at least one fatal or serious injury occupant. Pedestrians account for 11% of the 218 road users involved in the 110 expressway crashes analyzed for this study; however, they account for 23% (or 22 pedestrians by count) of fatal or seriously injured road users.

If pedestrians are prohibited on expressway, how do pedestrian accidents occur?

There were 12 accidents where a pedestrian was impacted by a vehicle. For this study, pedestrians also include any vehicle occupant standing outside the vehicle for any reason; including attending to broken down vehicle or pushing a broken-down vehicle to the roadside. Figure 10 shows a distribution of these pedestrian accidents by situations prior to the accident occurrence.

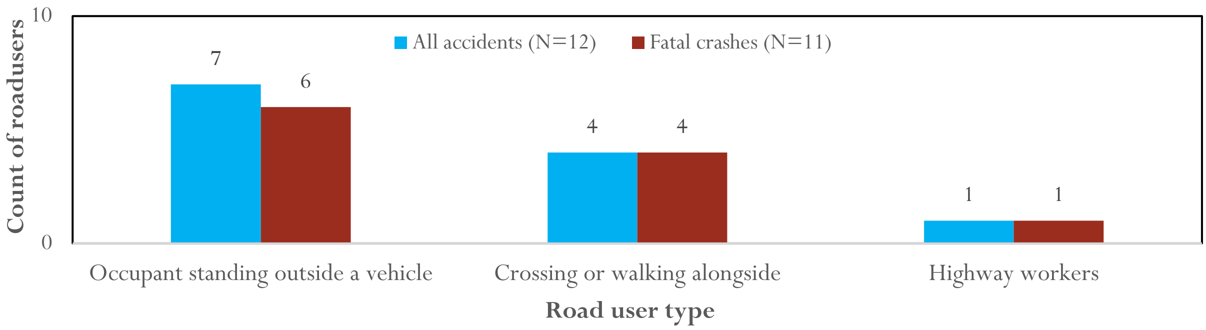


FIGURE 10: PEDESTRIAN BEHAVIOR PRIOR TO VEHICLE IMPACT

Based on the above discussions, the key findings from the 110 accidents resulting in 65 fatalities, 105 seriously injured victims and 129 victims with minor injuries are as follows:

1. Accidents occurring between 00:00 and 09:00 constitute 56% of all accidents and 54% of fatal accidents.
2. Together, collision with another vehicle moving ahead or waiting or stationary (rear-end collisions), leaving the carriageway to the left/right and pedestrian accidents constitute 90% of all accidents and 94% of fatal accidents.
3. Trucks, cars and pedestrians constitute 95% of the road users involved in accidents, and 98% of the road users with at least one fatal victim.
4. 58% of pedestrian accidents involved vehicle occupants outside the vehicle, while the vehicle was parked or was broken-down or being pushed to the roadside.

4 CONTRIBUTING FACTORS ANALYSIS

The contributing factors influencing the occurrence of each of the 110 road traffic accidents and the resulting injuries were analyzed in detail and are presented in the following sections.

4.1 Factors influencing accidents and injuries

A distribution by the attributes of contributing factors (Human/Vehicle/Infrastructure) for the 110 road traffic accidents is shown in the Venn diagram (Figure 11). This diagram shows that combination of human and vehicle factors (56%) had the highest influence on the occurrence of accidents and the resultant injury causation, followed by combination of all factors (24%) and human factors alone (14%).

The influences of each factor in the occurrence of accidents were found to be:

TABLE 5: SUMMARY OF THE SHARE OF CONTRIBUTING FACTORS

Factor	Alone	All Combinations
Human	14%	98%
Vehicle	1%	82%
Infrastructure	0%	29%

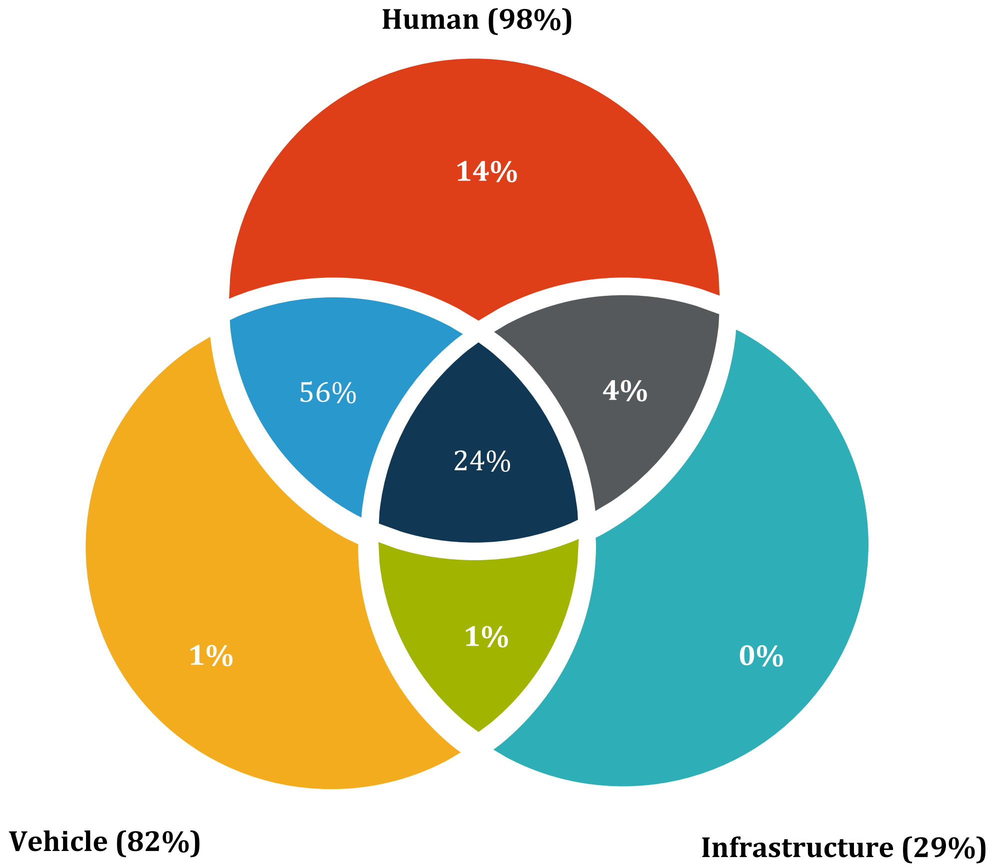


FIGURE 11: VENN DIAGRAM DISTRIBUTION OF 110 ACCIDENTS BY CONTRIBUTING FACTOR TYPE

4.2 Human Factors influencing Accidents and Injuries

Table 6 tabulates all accidents and fatal accidents for each contributing human factor.

Please note that more than one factor can influence an accident/injury causation; hence, the sum of percentage influence will not be equal to sum of human factors influencing crashes (98%). Similarly, the count of fatalities in fatal accidents will not total up to 65 fatalities as more than one factor can influence the occurrence of the same accident or injuries.

TABLE 6: CONTRIBUTING HUMAN FACTORS INFLUENCING THE 110 ACCIDENTS

	HUMAN FACTORS (Influencing accidents and injuries)	**All accidents** (N=110)		**Fatal accidents** (N=50)	
		Counts	%	Counts	%
PRE-CRASH	Driver - Sleep/Fatigue/Drowsiness	38	35%	13	26%
PRE-CRASH	Speeding - Exceeding speed limit	35	32%	19	38%
PRE-CRASH	Overtaking on left side of vehicle	17	15%	12	24%
PRE-CRASH	Improper lane change/lane usage	17	15%	6	12%
PRE-CRASH	Parked - vehicle off the road	11	10%	5	10%
PRE-CRASH	Driving too slow for conditions	11	10%	6	12%
PRE-CRASH	Pedestrian – Dangerous behavior on roadway	11	10%	10	20%
PRE-CRASH	Parked – Vehicle on road (Full or partial)	8	7%	6	12%
PRE-CRASH	Driver Inattention	3	3%	2	4%
PRE-CRASH	Pedestrian Inattention	4	4%	3	6%
PRE-CRASH	Speeding - Excessive speed for conditions	4	4%	2	4%
PRE-CRASH	Following too closely	3	3%	2	4%
PRE-CRASH	Turning suddenly or without indication	3	3%	1	2%
PRE-CRASH	Illegal road usage	2	2%	2	4%
PRE-CRASH	Vehicle slowed down/ stopped suddenly.	2	2%	2	4%
PRE-CRASH	Driver – Alcohol	1	1%	1	2%
CRASH	Seatbelt not used	70	66%	32	64%
CRASH	Occupants in cargo area	1	1%	1	2%
POST-CRASH	Improper crash breakdown/management	1	1%	1	2%

As can be seen from Table 6, **"Speeding – Exceeding speed limit"**, **"Driver Sleep / Fatigue / Drowsiness"**, and **"Seatbelt not used"** emerge as the top factors contributing to accidents and injuries. The following sections will discuss these top factors in further detail and tabulate possible counter measures.

4.2.1 Driver sleep/fatigue

When drivers fall asleep, they lose control over steering and gradually the vehicle tends to drive off the roadway towards the median or the shoulder area, or rear-ends the vehicle travelling in front. On the expressway, trucks (60%) are the most vulnerable to driver sleep/fatigue, followed by cars (37%).

What time do people tend to sleep?

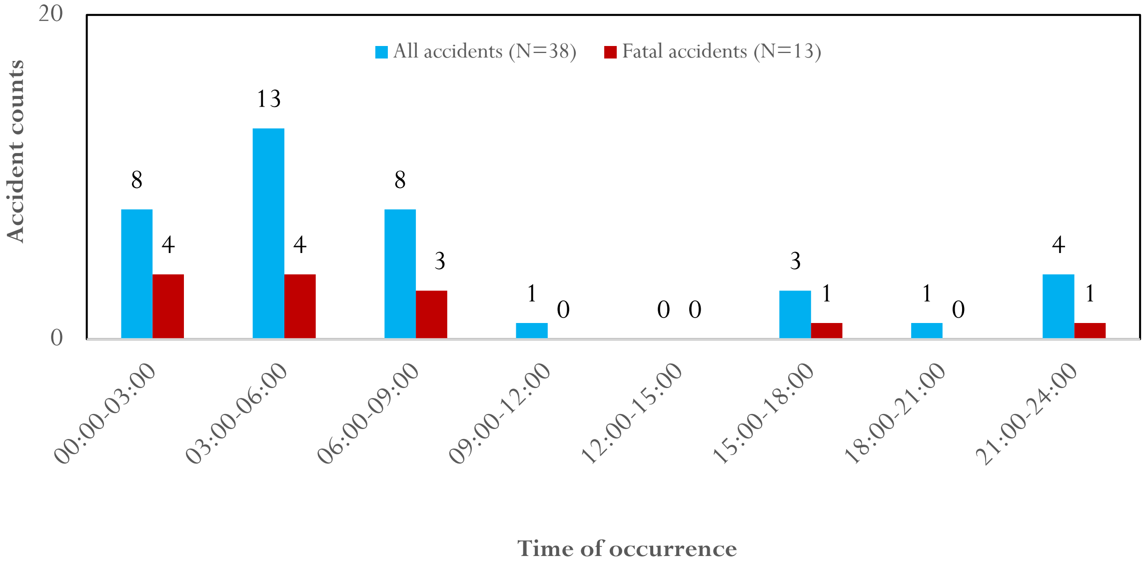


FIGURE 12: DISTRIBUTION OF ACCIDENTS BY TIME OF OCCURRENCE IN 3 HOUR TIME ZONES

87% of all accidents and 92% of fatal accidents involving driver sleep/fatigue have occurred between 21:00 to 09:00 hours.

What happens when drivers fall asleep while driving on the expressway?

Of all accidents involving driver sleep/fatigue, 60% accidents involved vehicles impacting with another vehicle or pedestrian within the carriageway. The remaining 40% of the accidents involved vehicles leaving the carriageway prior to impacting any vehicle or object or pedestrian. In these cases, any solution to alert a sleepy driver about lane departures will be useful. In addition, appropriate signage informing drivers about approaching rest areas will be beneficial.

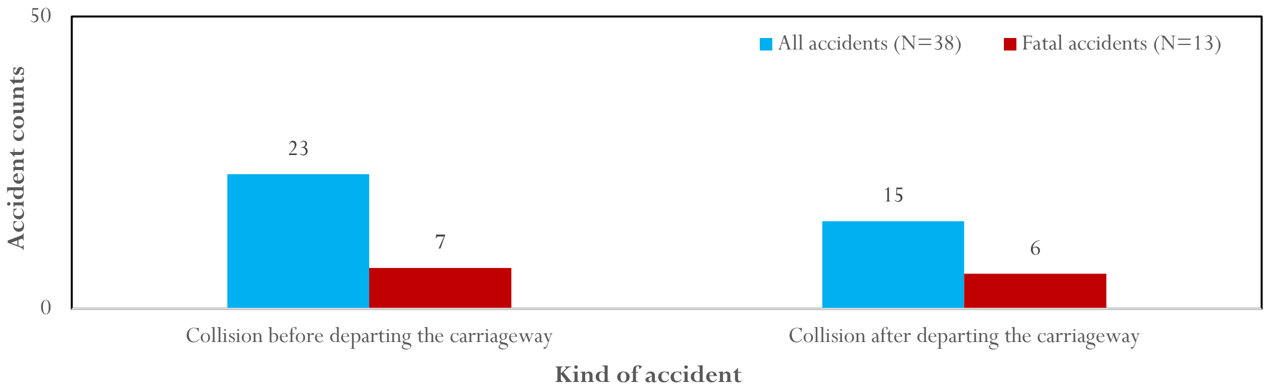


FIGURE 13: DISTRIBUTION OF KIND OF ACCIDENTS INVOLVING SLEEP/FATIGUE

4.2.2 Speeding - Exceeding Speed Limit

When the travel speed of a vehicle involved in an accident is calculated to be over the posted speed limit (80 kmph for the expressway), the contributing factor *"Speeding – Exceeding Speed Limit"* is recorded for that vehicle. Every third crash on the expressway is a result of a vehicle travelling at a speed over the posted speed limit of 80kmph. **Passenger cars (31 involved cars) are the majority road users that speed on the MPEW.**

If this is an expressway, then why is speeding a problem?

While cruising at high speeds on the expressway is enjoyable, it must also be remembered that as the speed of a vehicle increases, the distance required to stop the vehicle (or stopping distance) also increases. The stopping distance of a vehicle is determined by the following 2 parameters:

Reaction time of the driver: The time taken by a driver to identify, realize a hazardous situation, and decide how to avoid it. For a sober and alert driver, this can range from 1 to 2 seconds, but with distracted or drunk drivers it can increase to many seconds or the driver fail to see and react.

> **For the same reaction time, if the vehicle speed is doubled, the distance covered by the vehicle during the reaction time also doubles.**

Braking distance: Once the driver has pressed the brakes, the vehicle will need to cover some distance to come to a complete stop. Braking distance is, however, directly proportional to the square of the vehicle speed.

> **For the same braking deceleration in a vehicle, if the vehicle speed is doubled, the braking distance will increase by four times.**

Figure 14 below shows the stopping distance for a well-maintained passenger car (braking deceleration of 6.87 m/s^2) with an alert and sober driver (reaction time of 1 sec) at various travel speeds. As can be seen, for a speed of 80 kmph, the stopping distance is about 60 metres and for a speed of 120 kmph, the stopping distance is about 120 metres. Hence, a driver travelling at 80 kmph or less, can avoid impacting an object, seen by the driver 60 metres ahead. While a driver travelling at 100 kmph or higher, will impact the same object at speeds of over 60 kmph leading to serious or fatal injuries.

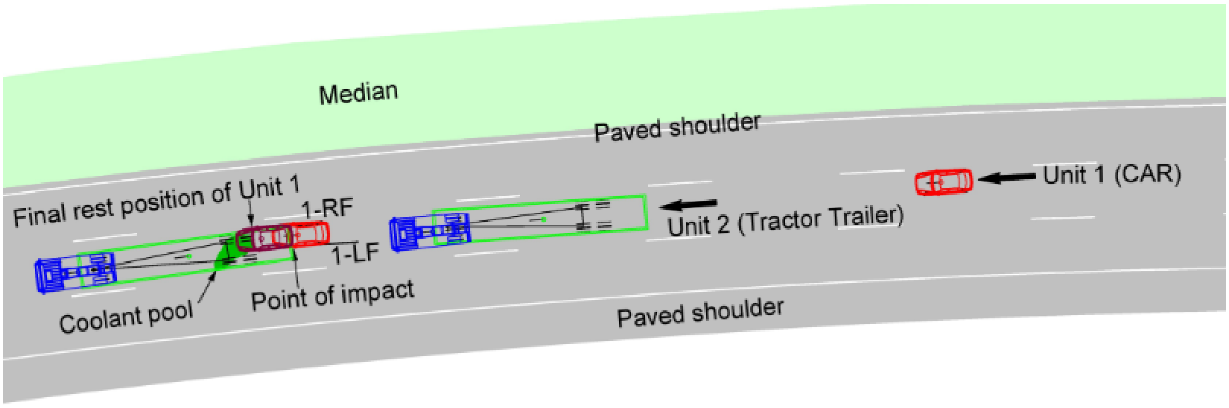
FIGURE 14: STOPPING DISTANCE FOR A PASSENGER CAR AT VARIOUS SPEEDS

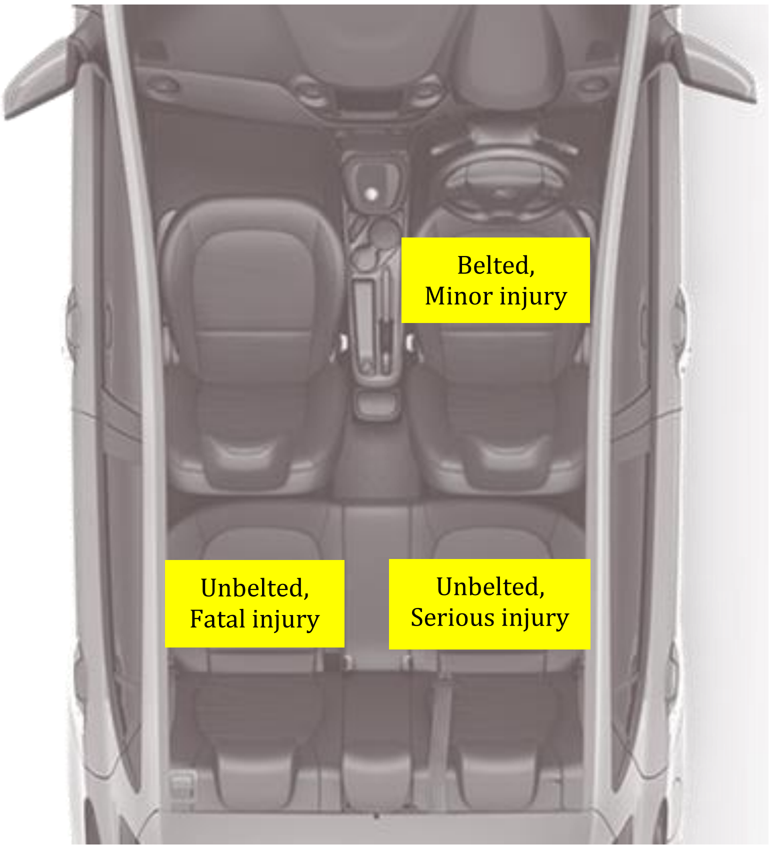
4.2.3 Seatbelt not used

Seatbelts are designed to restrain occupants and their movements within the vehicle in the event of an accident or a sudden stop. Seatbelts reduce injury severity by preventing occupants from being ejected from the vehicle entirely or from the seat and being launched into hard vehicle interiors such as the windshield, steering wheel and instrument panel. Even in airbag equipped cars, occupants need to be belted in order to ensure that the airbag works effectively in mitigating injuries.

Case study

Unit 1 (Car, 3 occupants) was traveling towards Mumbai on the expressway. Unit 2 (Trailer) was travelling ahead of unit 1 at a slower steady speed. Unit 1 braked hard to avoid impact with unit 2 but suffered a rear-end collision. Of the two rear occupants, one was fatal and the other suffered serious injuries. The driver suffered minor injuries.





In this case, the driver had suffered minor injuries despite being belted. This is because of the unbelted rear seated occupant had impacted the driver seat from behind. This had pushed the driver towards the steering wheel.

Similarly, the other unbelted rear seated occupant had impacted the front seat and had been launched further forward, impacting and causing a hole in the windshield. This fatal occupant suffered skull fractures.

This case study emphasizes the importance of the rear occupants wearing seatbelts. Hence, **<u>it is very important that every occupant in a vehicle wears a seatbelt</u>.**

4.2.4 Countermeasures for reducing Human Contributing Factors

Based on the top three Human Factors identified, the following countermeasures are expected to reduce the occurrence of accidents and injuries on the Mumbai-Pune Expressway.

TABLE 7: COUNTER MEASURES FOR REDUCING HUMAN CONTRIBUTING FACTORS

PROPOSED COUNTERMEASURES	*IMPACT*
SPEED ENFORCEMENT 	Conducting random and visible speed checks, to deter speeding over the posted speed limits, can potentially reduce speeding related accidents, which account for 38% of fatal accidents on the expressway.
SEATBELT ENFORCEMENT 	Conducting random and visible seatbelt-usage checks can significantly reduce crash-related injuries as over 60% of the fatal accidents on the expressway had lack of seatbelt use as a contributing factor.
TACTILE EDGE LINES 	Providing profiled tactile edge lines along the length of the road on the shoulder can potentially reduce the occurrence of vehicles leaving the carriageway, by alerting sleepy drivers through tactile vibrations. This has the potential to address 26% of the fatal accidents on the expressway.
REST AREA INFORMATION 	Providing appropriate and advance signage for information on rest areas and truck lay-bys will help drivers plan when and where to take a break. This has the potential to address 26% of the fatal accidents on the expressway.

The intention of the information provided in Table 7 is to list possible directions for developing counter measures and is based on the experience gained by JPRI over the years. Each situation might require a tailor-made solution and hence a thorough assessment by competent authority is warranted before implementation of a counter measure for expected effectiveness.

For further information on the above counter measures and effective implementation, please contact Mr. Bhuvanesh Bharath Alwar on bhuvanesh@jpri.in.

4.3 Vehicle Factors influencing Accidents and Injuries

The following are the contributing vehicle factors determined to have influenced accidents and resulting injuries. The table shows both the number and the percentage of accidents influenced by each factor.

Please note that more than one factor can influence an accident; hence, the sum of percentage influence will not be equal to sum of vehicle factors influencing accidents (77%).

TABLE 8: LIST OF CONTRIBUTING VEHICLE FACTORS

	VEHICLEFACTORS (Influencing accidents and injuries)	**All accidents** (N=110)		**Fatal accidents** (N=50)	
		Counts	%	Counts	%
PRE-CRASH	Absence of Reflectors	5	4%	4	8%
PRE-CRASH	Defective - Brakes	1	1%	1	2%
PRE-CRASH	Vehicle-other	1	1%	1	2%
CRASH	Passenger Compartment Intrusion - Underride/Override & Other	71	67%	36	72%
CRASH	Seatbelts not available/usable	26	24%	10	20%
CRASH	Knock-down of Pedestrian	12	11%	11	22%
CRASH	Runover of Pedestrian	2	2%	2	4%
CRASH	Unsecured Cargo	1	1%	1	2%
POST-CRASH	Ejection	17	16%	13	26%
POST-CRASH	Entrapment	2	2%	2	4%

4.3.1 Passenger compartment intrusion

Passenger compartment intact Passenger compartment intruded

FIGURE 15: AN EXAMPLE OF PASSENGER COMPARTMENT INTRUSION AS A RESULT OF UNDERRIDE

Reduction in the passenger compartment area because of an accident is termed as passenger compartment intrusion. This reduces the occupant survival space and usually occurs at high speeds and impacting rigid bodies/objects. In accidents involving cars and heavy vehicles, it is observed that the frontal crumple zones of cars are not typically engaged, and the impact often begins well above the bumper. The impact forces thus reach the passenger compartment directly. This condition is called underride. Such intrusions may also cause external objects to contact the occupants directly, resulting in severe or fatal injuries. In such accidents, the positive effects of seatbelts and airbags are also significantly reduced.

Who is impacted and what is the severity?

Cars form a significant proportion of crashed vehicles with passenger compartment intrusion and mostly colliding with a truck. Similarly, trucks are almost equally vulnerable to collisions with other trucks.

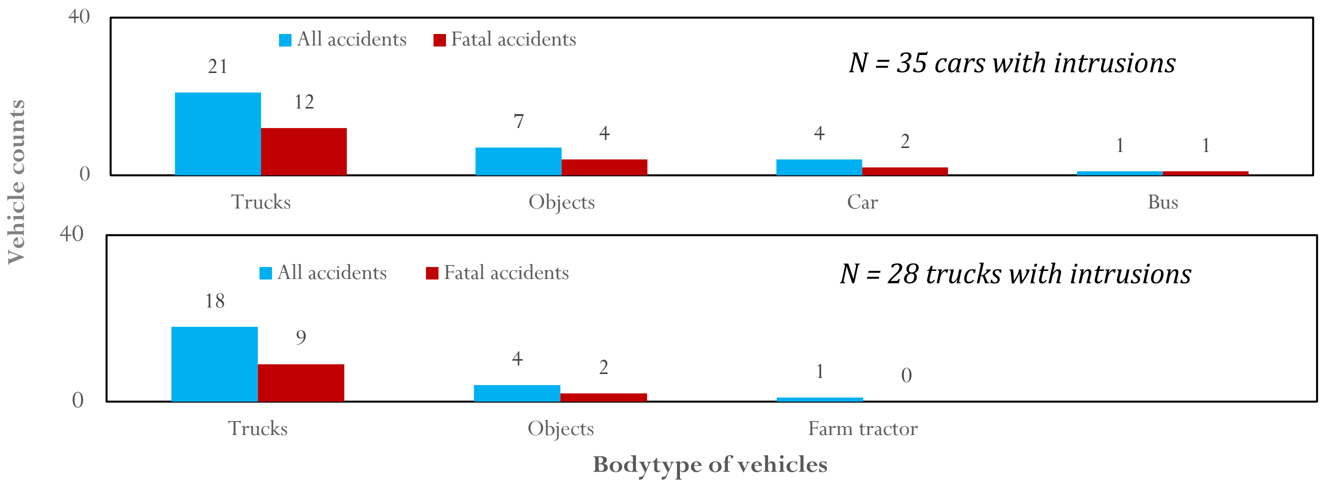


FIGURE 16: INJURY SEVERITY DISTRIBUTION AS A RESULT OF INTRUSIONS

60% of cars and 63% of trucks had suffered passenger compartment intrusions as a result of an impact with the rear of trucks. While many trucks were equipped with rear underrun protection devices (RUPDs), it was observed that such devices are ineffective in preventing passenger compartment intrusion in impacting vehicle, irrespective of being a car or truck.

FIGURE 17: AN ACCIDENT WHERE THE RUPD WAS INEFFECTIVE

4.3.2 Seat belts not available/not usable

This is coded for those vehicles in which seat belts were not available or were rendered inoperative at the time of vehicle inspection. Unavailability of seatbelts were most commonly found in trucks where the driver cabins are mostly custom made and not manufacturer built. In some cases of trucks, seatbelts were provided but were found removed. In case of passenger cars, the seatbelt buckles were found tucked under the rear seat, making the available lap and shoulder belt unusable.

4.3.3 Ejection

'Ejection' is when a vehicle occupant is thrown out of the vehicle, either completely or partially, due to the impact forces acting on them during the crash. There were 21 occupants who were ejected, partially or completely, out of the vehicle. Their seatbelt availability and usage (Figure 18) shows that 71% of these occupants did not use seatbelts and for the 29% of ejected occupants, seatbelts were not available for their seating position.

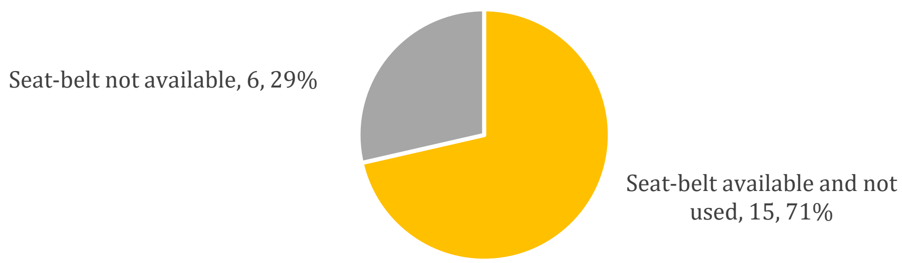


FIGURE 18: DISTRIBUTION OF SEATBELT AVAILABILITY AND USAGE FOR EJECTED OCCUPANTS

Ejection can be avoided by using seatbelts. Increasing seatbelt usage will be effective in reducing the possibility of ejections and ultimately the resulting fatalities. Hence, the enforcements and awareness of seatbelt usage needs more focus and attention.

4.3.4 Counter measures for reducing Vehicle Contributing Factors

Based on the Vehicle Factors identified, the following countermeasures are expected to reduce the occurrence of crashes and injuries on the Mumbai-Pune Expressway.

TABLE 9: COUNTER MEASURES FOR REDUCING VEHICLE CONTRIBUTING FACTORS

PROPOSED COUNTERMEASURES	*IMPACT*
SEATBELT ENFORCEMENT 	Conducting random and visible seatbelt-usage checks can significantly reduce occupant ejection and resulting injuries. Seatbelt usage checks must include all occupants of a vehicle irrespective of their seating position. This will ensure that the available seatbelts, especially for rear seats, are effectively used. This has the potential to address 26% of fatal accidents on the expressway.
TRUCK REAR UNDERRUN PROTECTION 	Providing crash-worthy and effective underrun protection devices on trucks can significantly reduce passenger vehicles under riding them thereby reducing the severity of such rear-end collisions. In addition, the design compatibility of smaller and heavier vehicles must be improved. This engineering challenge has the highest potential to reduce 72% of fatal accidents on the expressway.

The intention of the information provided in Table 9 is to list possible directions for developing counter measures and is based on the experience gained by JPRI over the years. Each situation might require a tailor-made solution and hence a thorough assessment by competent authority is warranted before implementation of a counter measure for expected effectiveness.

For further information on the above counter measures and effective implementation, please contact Mr. Bhuvanesh Bharath Alwar on bhuvanesh@jpri.in.

4.4 Infrastructure Factors influencing Accidents and Injuries

For the 110 accidents examined, the following are the contributing infrastructure factors determined to have influenced the accident. The table shows both the number and the percentage of crashes influenced by each factor.

Please note that more than one factor can influence a crash; hence, the sum of percentage influence will not be equal to sum of infrastructure factors influencing crashes.

TABLE 10: LIST OF CONTRIBUTING INFRASTRUCTURE FACTORS

	INFRASTRUCTURE FACTORS (Influencing Crashes and Injuries on the MPEW)	**All accidents** (N=110)		**Fatal accidents** (N=50)	
		Counts	%	Counts	%
PRE-CRASH	Inadequate warning about accident / parked vehicle	9	8%	6	12%
PRE-CRASH	Shoulder – Narrow	3	3%	1	2%
PRE-CRASH	Sharp Curvature	2	2%	1	2%
PRE-CRASH	Gap-in-Median	2	2%	1	2%
PRE-CRASH	Poor road marking/signage	1	1%	1	2%
PRE-CRASH	Slippery road surface	1	1%	--	--
PRE-CRASH	Animal/Object on roadway	1	1%	--	--
PRE-CRASH	Poor object conspicuity	1	1%	--	--
CRASH	Object impacts - roadside – manmade structures	13	12%	5	10%
CRASH	Object impact – Other	3	3%	1	2%
CRASH	Object impact – Roadside trees/plantation	1	1%	0	0%
CRASH	Work zone	1	1%	1	2%
POST-CRASH	--	--	--	--	--

4.4.1 Inadequate warning about accident/parked vehicle

During the last one year, there were 9 cases where a stopped vehicle (parked or broken down) had influenced an accident. It was found that most of the drivers and occupants were unaware of precautions to be taken in such situations. If a vehicle parked on or near the roadway is not marked properly with advance warning indicators such as warning triangles or safety cones. Particularly in low visibility conditions or after a blind corner, a crash becomes a high probability,

Why are vehicles stopped/broken down?

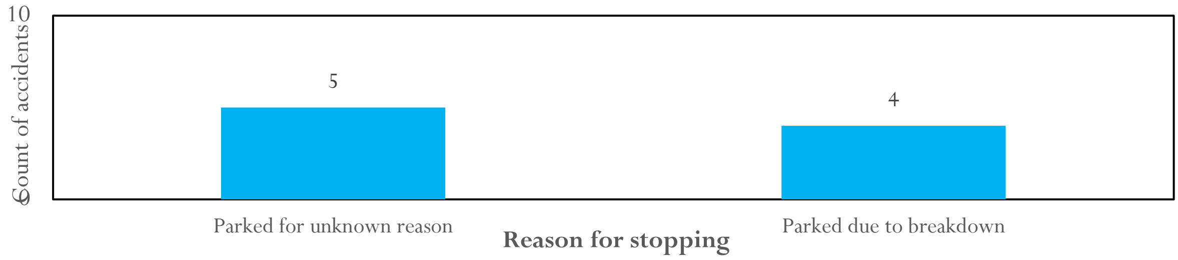


FIGURE 19: REASONS WHY VEHICLES WERE PARKED/STOPPED ON THE EXPRESSWAY

8 out of 9 parked vehicles were trucks. Of which 1 truck was stopped on the right most lane. Of the 9 vehicles involved, almost half of these vehicles were stopped as a result of a mechanical vehicle failure (breakdown). **This emphasizes that any intervention in this regard must focus more on heavy vehicles.**

4.4.2 Object Impact

Object impacts usually occur when a vehicle departs the roadway and enters the roadside or median, following which the vehicle collides with an object.

What kinds of objects are impacted on the expressway?

Figure 20 shows a distribution of the object types impacted in the 17 accidents where object impact has contributed to injury occurrence in the crash phase.

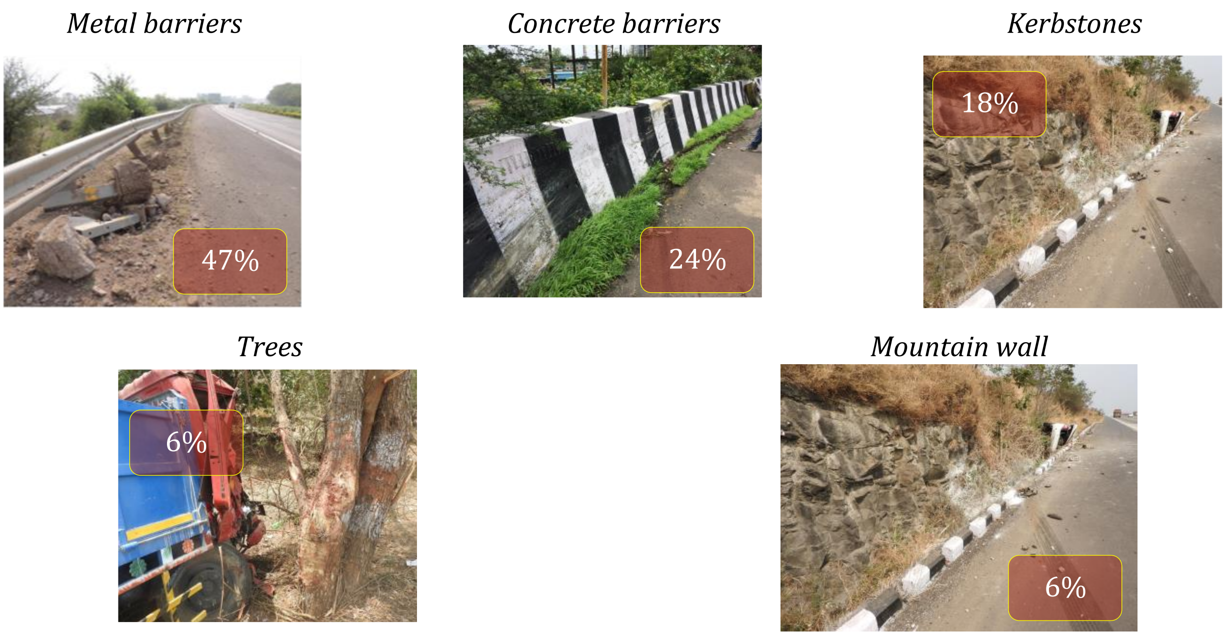


FIGURE 20: DISTRIBUTION OF ACCIDENTS BY TYPE OF OBJECT IMPACTED

Most of the objects encountered along the expressway are manmade structures located on the roadside or median. These objects include concrete barriers, guard rails, signposts, curb stones, roadside trees, etc. Kerb stones may look harmless, but in the event of an impact, these can be quite devastating for vehicles and occupants. Incidentally, vehicle passenger compartment intrusions, which significantly reduce occupant safety, have also been caused by collisions with such objects. Hence, it is important to make these manmade structures more crash-protective and "***forgiving***".

If guardrails are for improving safety, why do they result in fatal accidents?

While the guardrails are a proven measure to prevent run-off the road accidents and impacts with roadside hazards, factors such as impact speeds and angle of departure of impacting vehicles can exceed the design criteria of guardrails rendering the guardrails ineffective.

Most sections of the expressway are now lined by guardrails and they have proven to be effective in reducing fatalities. However, these guardrails have led to 3 fatal accidents resulting in 3 fatalities. The 3 fatal accidents involved 2 cars and 1 truck. All three vehicles had lost control owing to speeding (2 cars over 100kmph, and 1 truck over 50kmph on a downhill grade ghat road). 2 of the 3 vehicles had at least one occupant being ejected (no seatbelt used) resulting in the fatality and the other vehicle involved guardrail piercing through the vehicle.

It is important to consider these accident characteristics to reassess the design of guardrails installed on the expressway. The evolution of crash barriers is still in its nascent stages in India and, using such in-depth crash data, it can be expected that the designs and standards of crash barriers will eventually be improved to make them more effective.

4.4.3 Countermeasures for Infrastructure Contributing Factors

Based on the Infrastructure Factors identified, the following countermeasures are expected to reduce the occurrence of accidents and injuries on the Mumbai-Pune Expressway.

TABLE 11: COUNTER MEASURES FOR REDUCING INFRASTRUCTURE CONTRIBUTING FACTORS

PROPOSED COUNTERMEASURES	*IMPACT*
EMERGENCY & BREAKDOWN ASSISTANCE 	Emergency contact numbers must be prominently displayed at regular intervals and commuters must be made aware of the services they can avail for free/ chargeable in case of emergencies/breakdown. These measures have the potential to address 12% of fatal accidents on the expressway.
HANDLING BREAKDOWNS 	Commuters must be made aware of the dos and don'ts when in an emergency or a breakdown situation. Some basic guidelines for handling emergency/ breakdown on the expressway are provided in page 32. These measures have the potential to address 12% of fatal accidents on the expressway.
CRASH BARRIERS 	Design of crash barriers and standardization based on localized crash data is essential to address the safety concerns with respect to crash barriers. This engineering challenge has the potential to address 12% of fatal accidents on the expressway.

The intention of the information provided in Table 10 is to list possible directions for developing counter measures and is based on the experience gained by JPRI over the years. Each situation might require a tailor-made solution and hence a thorough assessment by competent authority is warranted before implementation of a counter measure for expected effectiveness.

For further information on the counter measure implementations, please contact Mr Bhuvanesh Bharath Alwar on bhuvanesh@jpri.in.

SUGGESTED RULES FOR EMERGENCY STOPPING ON THE EXPRESSWAY

Park vehicle in a safe spot.

Drive the vehicle to the left-hand shoulder of the road, and away from any curves in the road behind you. This helps other vehicles to see you and will aid in re-entering the road.

Let other drivers know your vehicle is stationary.

- Turn on the hazard lights and turn the steering wheel to point the front wheels away from the road. (In case your vehicle is struck, it will be pushed away from traffic rather than into it).
- If it is dark, put the interior light on so that you are more visible. Keep the engine running (if it is operational) so that you don't run the battery down.
- If there is a second vehicle with you, ensure that it is standing well behind the broken-down vehicle (at least 20 meters) so that approaching vehicles will see the first vehicle well in advance.
- Whether it is day or night, the most important thing to do is to place a **warning triangle** well before the car, at least 50 meters before the vehicle if possible. A vehicle travelling at 80 km/h, or about 23 meters per second, needs a few seconds to realize your position and take evasive action.

Get assistance.

- Immediately notify the highway police (**98334 98334**) and the operations and maintenance control room (**98224 98224**) for assistance and inform them your location. Don't think that you do not need them for trivial problems like tire changing. Call them and ask for help, especially at night. They are here to help you and keep you safe.

Kilometer post indicating 94 km from the start of expressway.

Yellow marks indicating 77.698 km from the start of expressway.

- To know your location on the expressway, check for a kilometer post nearby. These blue boards are posted every kilometer. In addition, there are also yellow markings on the shoulder line which can tell you the location as a kilometer.
- While waiting for the police or tow truck to arrive, please ensure that all occupants are standing well away from the vehicle. People standing in front or behind parked vehicles have been killed. Stand away from the vehicle to the side (if there is enough opening) or well in front of the vehicle (in case of barriers).

If you must work on your vehicle, do so safely.

To avoid being hit by a passing vehicle, never work on your vehicle from the side that is exposed to traffic. If you get a flat tire, do not attempt to change it unless you can get to the side of the road and the tire is on the side of the vehicle that is safely away from traffic.

5 CONCLUSIONS

Based on the crash investigation data for the Mumbai – Pune Expressway for the year of 2018, this study concludes the following:

5.1 Accident characteristics

Based on the above discussions, the key findings from the 110 accidents resulting in 65 fatalities, 105 seriously injured victims and 129 victims with minor injuries are as follows:

1. Accidents occurring between 00:00 and 09:00 constitute 56% of all accidents and 54% of fatal accidents.
2. Together, collision with another vehicle moving ahead or waiting or stationary (rear-end collisions), leaving the carriageway to the left/right and pedestrian accidents constitute 90% of all accidents and 94% of fatal accidents.
3. Trucks, cars and pedestrians constitute 95% of the road users involved in accidents, and 98% of the road users with at least one fatal victim.
4. 58% of pedestrian accidents involved vehicle occupants outside the vehicle, while the vehicle was parked or was broken-down or being pushed to the roadside.

5.2 Contributing factors – Haddon Matrix

PHASE	FACTORS		
	HUMAN	**VEHICLE**	**INFRASTRUCTURE**
PRE-CRASH	• Speeding (32%) • Driver – Sleep/Fatigue (35%) • Improper lane change/usage (15%)	• Absence of reflectors (5%)	• Inadequate warning about crash/parked vehicle (8%) • Shoulder – Narrow/None (3%)
CRASH	• Safety system not used (66%)	• Passenger Compartment Intrusions (67%) • Seatbelts not available (24%)	• Object Impacts (16%)
POST-CRASH	• Improper crash/breakdown management (1%)	• Ejection (16%) • Entrapment (2%)	--

(Figures in parentheses is percentage of 110 accidents on the expressway.)

5.3 Counter measures for reducing the contributing factors

PROPOSED COUNTERMEASURES	*DESCRIPTION*
SPEED ENFORCEMENT 	Conducting random and visible speed checks, to deter speeding over the posted speed limits, can potentially reduce speeding related accidents, which account for 38% of fatal accidents on the expressway.
SEATBELT ENFORCEMENT 	Conducting random and visible seatbelt-usage checks can significantly reduce crash-related and occupant ejection related injuries as over 60% of the fatal accidents on the expressway had lack of seatbelt use as a contributing factor. Seatbelt usage checks must include all occupants of a vehicle irrespective of their seating position. This will ensure that the available seatbelts, especially for rear seats, are effectively used.
TACTILE EDGE LINES 	Providing profiled tactile edge lines along the length of the road on the shoulder can potentially reduce the occurrence of vehicles leaving the carriageway, by alerting sleepy drivers through tactile vibrations. . This has the potential to address 26% of the fatal accidents on the expressway.
REST AREA INFORMATION 	Providing appropriate and advance signage for information on rest areas and truck lay-bys will help drivers plan when and where to take a break. This has the potential to address 26% of the fatal accidents on the expressway.

PROPOSED COUNTERMEASURES	*DESCRIPTION*
HANDLING BREAKDOWNS 	Commuters must be made aware of the dos and don’ts when in an emergency or a breakdown situation. Some basic guidelines for handling emergency/ breakdown on the expressway are provided in page 32. These measures have the potential to address 12% of fatal accidents on the expressway.
EMERGENCY & BREAKDOWN ASSISTANCE 	Emergency contact numbers must be prominently displayed at regular intervals and commuters must be made aware of the services they can avail for free/ chargeable in case of emergencies/breakdown. These measures have the potential to address 12% of fatal accidents on the expressway.
TRUCK REAR UNDERRUN PROTECTION 	Providing crash-worthy and effective underrun protection devices on trucks can significantly reduce passenger vehicles under riding them thereby reducing the severity of such rear-end collisions. In addition, the design compatibility of smaller and heavier vehicles must be improved. This engineering challenge has the highest potential to reduce 72% of fatal accidents on the expressway.
CRASH BARRIERS 	Design of crash barriers and standardization based on localized crash data is essential to address the safety concerns with respect to crash barriers. This engineering challenge has the potential to address 12% of fatal accidents on the expressway.

APPENDIX A: JPRI & RASSI CONTACT INFORMATION

For more information on JPRI, RASSI or this report, check out our websites, call or come by one of our offices, or drop us a line by email.

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APPENDIX B: KIND OF ACCIDENT TYPE DEFINITIONS

01. Collision with another vehicle which starts, stops or is stationary.
Starting or stopping as used here refer to a deliberate stopover which is not caused by the traffic situation. Stationary vehicles within the meaning of this kind of crash are vehicles which stop or park at the edge of a carriageway, on shoulders, on marked parking places directly at the edge of a carriageway, on footpaths or parking sites. Traffic to or from parking spaces with a separate driveway belongs to Type No. 5.

02. Collision with another vehicle moving ahead or waiting.
Crashes include rear-end collisions with vehicles which were either still moving or stopping due to the traffic situation. Rear-end collisions with starting or stopping vehicles belong to Type No. 1.

03. Collision with another vehicle moving laterally in the same direction.
Crashes include collisions that occur when vehicles are driving side by side (sideswipe) or changing lanes (cutting in on someone).

04. Collision with another oncoming vehicle.
Crashes include collisions with oncoming traffic, none of the colliding partners having had the intention to turn and cross over the opposite lane.

05. Collision with another vehicle which turns into or crosses a road.
Crashes include collisions with crossing vehicles and with vehicles which are about to enter or leave from/to other roads, paths or premises. A rear-end collision with vehicles waiting to turn belongs to Type No. 2.

06. Collision between vehicle and pedestrian.
Persons who work on the carriageway or still are in close connection with a vehicle, such as road workers, police officers directing the traffic, or vehicle occupants who got out of a broken-down car are also considered to be pedestrians.

07. Collision with an obstacle in the carriageway.
These obstacles include, for instance, fallen trees, stones, lost freight as well as unleashed animals or game. Collisions with leashed animals or riders belong to Type No. 10.

08. Leaving the carriageway to the right.
09. Leaving the carriageway to the left.
These kinds of crashes do not involve a collision with other road users. There may, however, be further parties involved in the crash, e.g., if the vehicle involved in the crash veered off the road trying to avoid another road user and did not hit him.

10. Accident of another kind.
This category covers all crashes which cannot be allocated to one of the kinds of crashes listed under Type Nos. 1 to 9.