

# Mumbai – Pune Expressway Road Accident Study

Analysis of 214 accidents examined between October 2012 and October 2013

Submitted by:

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# Mumbai – Pune Expressway Road Accident Study

<b>ACKNOWLEDGEMENTS</b> .....	2
<b>1 INTRODUCTION</b> .....	3
BACKGROUND.....	3
HOW DID THIS STUDY BEGIN?.....	3
HOW IS JPRI CONDUCTING THIS STUDY FOR FREE FOR THE GOVERNMENT? .....	3
DOES THIS STUDY AFFECT MY PRIVACY? .....	5
OBJECTIVE OF THIS REPORT.....	5
ABOUT JP RESEARCH INDIA.....	6
ABOUT ROAD ACCIDENT SAMPLING SYSTEM – INDIA (RASSI).....	7
<b>2 METHODOLOGY</b> .....	8
ACCIDENT DATA SAMPLE AND DATA ANALYSIS .....	8
HOW WERE THESE ACCIDENTS FOUND? .....	8
WHY ARE SUCH “NON-REPORTED” ACCIDENTS IMPORTANT?.....	8
CONTRIBUTING FACTORS – A PRIMER.....	9
THE JPRI APPROACH TO STUDYING AN ACCIDENT .....	9
<b>3 DATA ANALYSIS</b> .....	12
DISTRIBUTION OF ACCIDENTS BY HIGHEST INJURY SEVERITY .....	12
INJURY SEVERITY DEFINITIONS .....	12
DISTRIBUTION OF ACCIDENTS BY TIME OF OCCURRENCE.....	13
DISTRIBUTION OF ACCIDENTS BY DAY OF WEEK.....	13
VEHICLES/ROAD USERS INVOLVED .....	14
VEHICLES/ROAD USERS AFFECTED IN CRASHES WITH FATAL OR SERIOUS INJURY .....	15
ACCIDENT TYPES .....	15
<b>4 CONTRIBUTING FACTORS ANALYSIS</b> .....	17
ANALYZING ACCIDENT AND INJURY CAUSATION.....	17
FACTORS INFLUENCING OCCURRENCE OF ACCIDENTS (214 ACCIDENTS) .....	17
FACTORS INFLUENCING OCCURRENCE OF INJURIES (68 FATAL/SERIOUS ACCIDENTS).....	18
HUMAN FACTORS INFLUENCING ACCIDENT OCCURRENCE .....	19
COUNTERING HUMAN FACTORS THAT CONTRIBUTE TO ACCIDENTS .....	19
VEHICLE FACTORS INFLUENCING ACCIDENT OCCURRENCE.....	23
COUNTERING VEHICLE FACTORS THAT CONTRIBUTE TO ACCIDENTS.....	23
INFRASTRUCTURE FACTORS INFLUENCING ACCIDENT OCCURRENCE .....	25
COUNTERING INFRASTRUCTURE FACTORS THAT CONTRIBUTE TO ACCIDENTS .....	25
HUMAN FACTORS INFLUENCING INJURY OCCURRENCE.....	32
COUNTERING HUMAN FACTORS THAT CONTRIBUTE TO INJURY .....	32
VEHICLE FACTORS INFLUENCING INJURY OCCURRENCE.....	34
COUNTERING VEHICLE FACTORS THAT CONTRIBUTE TO INJURY .....	34
INFRASTRUCTURE FACTORS INFLUENCING INJURY OCCURRENCE.....	37
COUNTERING INFRASTRUCTURE FACTORS THAT CONTRIBUTE TO INJURY .....	37
<b>5 CONCLUSIONS</b> .....	41
<b>APPENDIX A: ACCIDENT TYPE DEFINITION</b> .....	44
<b>APPENDIX B: ACCIDENT-PRONE SECTIONS</b> .....	45

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Our sincere appreciation and gratitude to all the officers of Maharashtra State Highway Police and the Traffic Aid Posts (TAPs) for their support and cooperation. We are also grateful to the tow truck drivers who called us for some of the accidents. The hazardous nature of work performed by the TAPs personnel and the tow truck drivers is still not well understood by most people, and we hope that governments soon realize their importance during accidents and road blockages and provide them with better protection, equipment, training and facilities so that they can do their jobs more effectively and, in turn, help in saving more lives.

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



We thank the RASSI consortium members not only for their financial support but for their belief in safer road travel for India, which ultimately has made this project possible.

*This report is dedicated to all the people  
whose lives have been affected, directly or indirectly,  
by road accidents on the Mumbai - Pune Expressway.*

We think this is a pioneering attempt in India towards data-driven road safety strategies that have proven to be highly effective in mitigating fatalities, injuries and accidents around the world. We hope that the data collected and analyzed from this study is useful to all the stakeholders of the Mumbai – Pune Expressway (including motorists) in helping make all of our journeys safer on the expressway.

## 1 INTRODUCTION

The Mumbai – Pune Expressway 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 speed limit of 80 km/h 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 km long and is witnessing a large number of traffic crashes, fatalities and serious injuries.

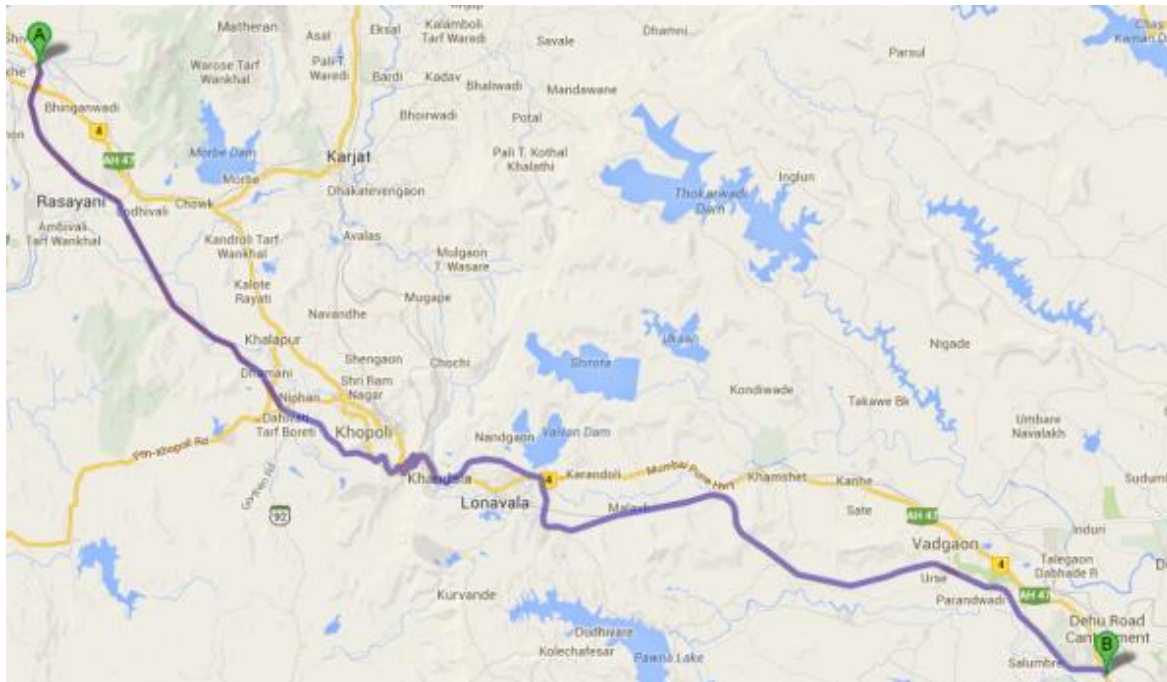


FIGURE 1: MAP SHOWING MUMBAI–PUNE EXPRESSWAY (COURTESY GOOGLE MAPS)

## BACKGROUND

### How did this study begin?

In July 2012, JP Research India (JPRI) approached the Maharashtra State Highway Police with a proposal to conduct on-site crash investigation and accident data collection on the Mumbai – Pune Expressway. The proposal was accepted, and from 7<sup>th</sup> October 2012, JPRI researchers have been examining accidents on-site as soon as they are informed of a crash by the police.

### How is JPRI conducting 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 these 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 crashes. In-depth crash investigations are conducted in a scientific manner involving detailed examination of the crash scene, crash vehicles and the injuries sustained by the victims of the accident. Whenever possible, researchers also interview the accident victims to understand the accident



sequences better. The data collected is stored in a database in a format which allows for detailed analysis of accidents. Numerous measurements, observations and notes are taken on scientific accident data forms, which are used to build a scientific database called “Road Accident Sampling System – India”, or “RASSI” in short. This scientific 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 scientific data. (More details in the following sections).



FIGURE 2: CRASH INVESTIGATIONS BEING CARRIED OUT BY JPRI ACCIDENT RESEARCH TEAM

### **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 analytical database.***

JPRI crash investigation processes are designed keeping in mind that the entire purpose is not to investigate accidents to find fault, but to make an unbiased scientific examination of each accident to determine the various contributing factors in order to better understand what could be done to prevent reoccurrences of such accidents. Since personal information is not needed for analysis, JPRI researchers, after completing an accident examination, de-identify all the details that go into the analytical database.

### **Objective of this report**

Over the first year of this study, 214 accidents were examined and analyzed in detail. This report provides an in-depth analysis of these accidents and offers an analysis of the various factors influencing accidents and injuries on the Mumbai – Pune Expressway.

The report not only identifies these “contributing factors” but also ranks them based on the number of accidents these factors have influenced. This ranking is to help policy makers, decision makers and road safety stakeholders in planning cost effective road safety investments using data-driven road safety strategies.

## **ABOUT JP RESEARCH INDIA**

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

Accident research has proven to be the best way to understand the characteristics of real-world road traffic crashes. Countries such as the USA, UK, Germany and Japan routinely use the results of such research to significantly reduce the number of road traffic fatalities in their countries. The fact that India has been losing approximately 150,000 lives on its roads every year makes it imperative that we, too, conduct this kind of research to identify and then take swift steps to address the key factors influencing the high traffic injury and mortality rate in our country.

JP Research India is experienced in using accident research methodologies developed in other nations and customizing these to suit India's unique traffic conditions. After conducting numerous studies and on-site crash research projects on Indian roads, JP Research India has developed its own India-specific crash data collection forms, a methodology for conducting site and vehicle crash investigations in the inimitable Indian traffic environment, and a searchable database of in-depth accident data. In addition, the company's experts offer training in all of these areas, for those who would prefer to perform their own data collection and analysis.

In other words, at JP Research India, our overriding objective is to understand Indian roads, traffic and road users in ways that can be used to save lives: ours and yours.

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## **ABOUT ROAD ACCIDENT SAMPLING SYSTEM – INDIA (RASSI)**

India is currently ranked highest in the world for traffic fatalities; thus, there is a critical need to reduce the number of road traffic-related fatalities across the country. While the economic and social benefits of implementing standardized accident reporting and crash data collection systems to improve road and automotive safety and reduce fatalities have been demonstrated in Europe and the USA for some time, there has been no comparable system in India.

The absence of systematically collected, nationwide in-depth traffic crash data is seriously impeding scientific research and analysis of road traffic accidents in India. To address root causes of real crashes and injuries across India, it is necessary to fully understand the traffic accidents taking place throughout the country. Only real world accident data, properly defined, can reliably identify the key factors that contribute to traffic crashes, 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 particular region. Recently, an automotive accident data system—based on US/European design, but modified for Indian conditions—has been successfully demonstrated in the state of Tamil Nadu by a consortium of private companies. This initiative is called **RASSI**.

The genesis of the RASSI project began with a passenger car crash analysis study undertaken in Chennai. This led to short-term accident 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, a number of 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.

Crashes are continually being investigated in detail by JPRI teams in Coimbatore and Pune, and the program logs a wide array of data, as well as vehicle and crash site photographs. The teams collect and assess detailed evidence—such as skid marks, broken glass, impacted objects, measurements of crash damage to the vehicle—and identify interior vehicle locations contacted by occupants during the crash event. They then follow up on-site investigations 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 extend RASSI to create an integrated network of data centres across India with the support of other automotive and transportation-related companies and of the government. This would result in a common set of automotive crash data for research and analysis of root causes of India's road traffic issues.

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## 2 METHODOLOGY

### ACCIDENT DATA SAMPLE AND DATA ANALYSIS

JPRI researchers examined a total of 214 expressway accidents between 7<sup>th</sup> October 2012 and 31<sup>st</sup> October 2013. These accidents involved 328 road users (317 vehicles and 11 pedestrians<sup>1</sup>) and resulted in 72 fatal victims and more than 140 serious injury victims.

#### How were these accidents found?

JPRI researchers are informed by the police of any accidents that occur on the expressway that the police come to know of. During the first year of this study, the JPRI accident research team also came upon many accidents on the expressway that had not been reported. These accidents were usually minor or no injury, but occasionally involved serious injuries. The crashes were not reported to the police as the vehicle owners preferred not to register a complaint. Such accidents, although not reported to the police, are still important for in-depth accident analysis. Hence, the JPRI accident research team goes on regular rounds of the expressway and examines many such non-reported accidents, in addition to those they are informed of by the police. To determine whether an accident has been reported to the police, JPRI researchers follow up with the police station up to 2 weeks after the accident.

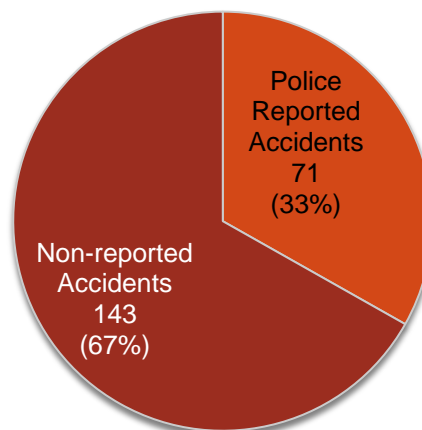


FIGURE 3: DISTRIBUTION OF POLICE REPORTED ACCIDENTS AND NON-REPORTED ACCIDENTS IN THE DATA SAMPLE.

*Although JPRI researchers have examined more accidents than have been reported to the police, there may still be other serious/minor accidents which may have been missed.*

#### Why are such “non-reported” accidents important?

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

1. Gives a more realistic indication of the number of accidents actually happening on the expressway.
2. Gives an indication that not all accidents result in fatalities or serious injuries; even minor or non-injury accidents should be addressed.
3. Allows analysts to determine which safety systems work well, and which ones do not work as desired, in preventing an accident or mitigating injuries.

<sup>1</sup> Pedestrians also include occupants standing outside their vehicles.

## CONTRIBUTING FACTORS – A PRIMER

Road traffic accidents are primarily influenced by three main factors:

- Human (usually drivers and vehicle occupants, but also pedestrians and cyclists)
- Vehicle
- Infrastructure (roadway and the environment)

Typically, 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 errors as the main contributors 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 assumption that the driver initiated the accident and hence all responsibility lies with him/her. Influencing factors which are vehicle-related and infrastructure-related are often not accounted for, even though they are an inseparable part of the whole accident.

## THE JPRI APPROACH TO STUDYING AN ACCIDENT

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

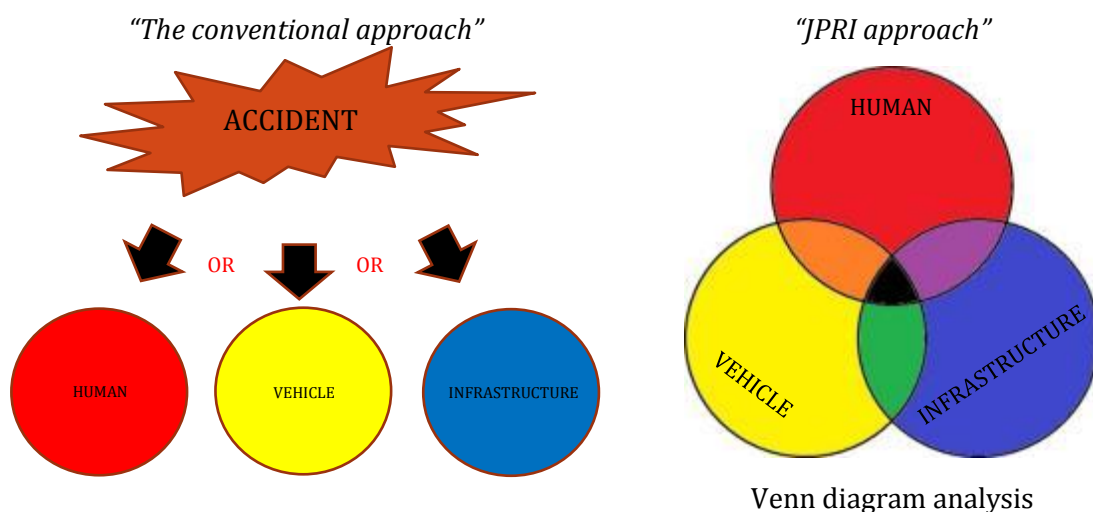


FIGURE 4: APPROACHES FOR ANALYZING ACCIDENT CAUSES.

Of course, not all accidents result in serious or fatal injuries, and even for accidents occurring in similar circumstances, the types and severities of injuries are often not the same. JPRI researchers have found that two accidents with similar contributing factors leading to the crash can have very different injury outcomes based on the contributing factors that influence injuries. ***This necessitates that accident occurrence be understood separately from the resulting injuries.*** Although injuries are the outcome of an accident, the causal factors for an accident need not be the same as those for the injuries sustained.

Hence, just as an accident is analyzed for human, vehicle and infrastructure factors that contributed to its occurrence, the resulting injuries are similarly analyzed for human, vehicle and infrastructure factors that influenced their occurrence and severity.

Below is a representation of the JPRI approach to analyzing contributing factors:

1. Factors influencing the occurrence of an accident.
2. Factors influencing the occurrence of an injury.

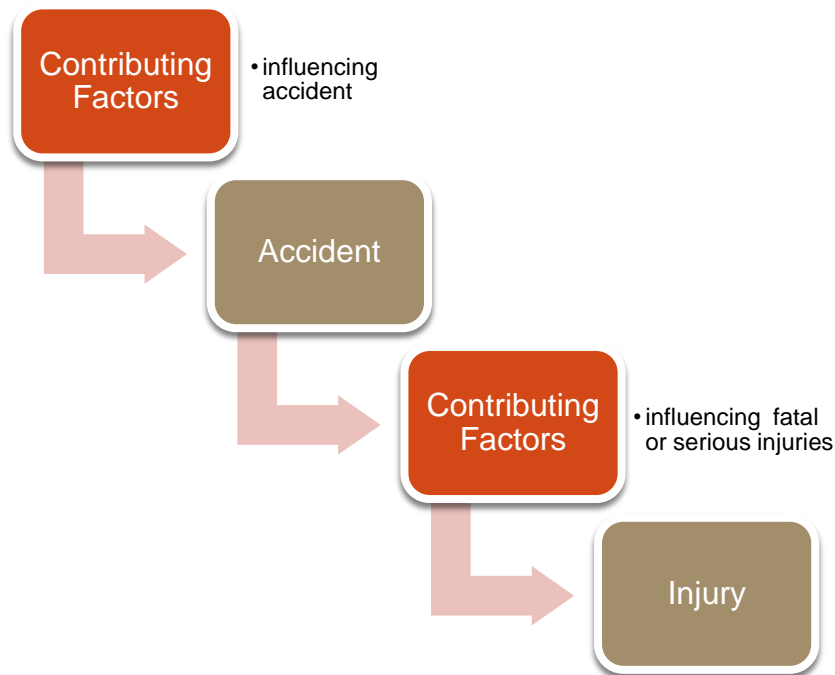


FIGURE 5: A REPRESENTATION OF THE CONTRIBUTING FACTORS ANALYSIS FOR ACCIDENTS AND FOR INJURIES.





Below are two accident cases that demonstrate the above methodology.

**Case 1:** A sleepy driver departs the roadway towards the roadside and goes down an open slope on his left. The vehicle has visible damage and is not drivable, but the driver sustained no injuries. The driver was wearing a seatbelt in this case.

**Case 2:** A sleepy driver departs the roadway towards the median and impacts a concrete barrier built within the median. The vehicle is damaged and not drivable. The passenger compartment has also been intruded due to the impact force from the barrier. The driver suffered fatal injuries. The driver was not wearing a seatbelt, and the passenger compartment intrusions aggravated the injuries.

In both cases, the circumstances leading to the accident are the same; sleeping and departing the roadway but the injury outcomes are very different. One driver is able to walk away from the accident, while in the other case, the driver dies.

AN EXAMPLE DEMONSTRATING VARIABILITY OF INJURY OUTCOMES  
FROM SIMILAR ACCIDENT CONTRIBUTING FACTORS.

	Case 1	Case 2
<b>Scene Photos –</b> Taken along the direction of vehicle's travel		
<b>Vehicle Photos –</b> Damages sustained by the vehicle		
Injury severity	No injury	Fatal
Contributing factors – Leading to an accident	Sleepy driver	Sleepy driver Narrow shoulder width
Contributing factors – Leading to an injury	Not applicable (No injury)	Manmade concrete barrier Seatbelt not used by occupants Passenger Compartment Intrusions

### 3 DATA ANALYSIS

The 214 accidents examined by JPRI were analyzed to give a brief understanding of the characteristics of accidents on the expressway.

#### DISTRIBUTION OF ACCIDENTS BY HIGHEST INJURY SEVERITY

The distribution of the total 214 road accidents by injury severity (based on the most severe injury sustained by any human involved in each accident) is shown in Figure 6. As can be seen, around one third of the accidents examined during the first year of this study resulted in fatal or serious injuries. In all, 68 accidents (by count) involved fatal or serious injury to at least one occupant or pedestrian.

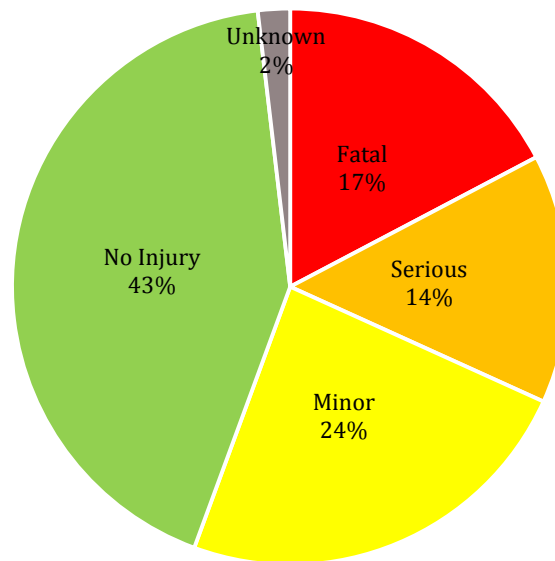


FIGURE 6: DISTRIBUTION OF THE 214 ACCIDENTS BY HIGHEST INJURY SEVERITY

#### Injury Severity Definitions

The following are the definitions used to classify accidents.

**Fatal Injury:** An accident involving at least one fatality. Any victim who dies within 30 days of the accident as a result of the injuries due to the accident 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 in which victims suffer minor injuries which are treated on-scene (first aid) or in a hospital as an outpatient.

**No Injury:** An accident in which no injuries are sustained by any of the involved persons. Usually only vehicle damage occurs as a result of the accident.



## DISTRIBUTION OF ACCIDENTS BY TIME OF OCCURRENCE

The 214 accidents used for the contributing factors study were plotted against time durations of 3 hours (Figure 7) to identify times when accidents occur. The data shows highest percentage of accidents (58%) occurred during the time period of 00:00 (midnight) to 08:59 hrs. The highest percentages of accidents resulting in fatal/serious injury occurred during the time periods of 03:00 to 08:59 hrs (35%) and 15:00 to 17:59 hrs (22%).

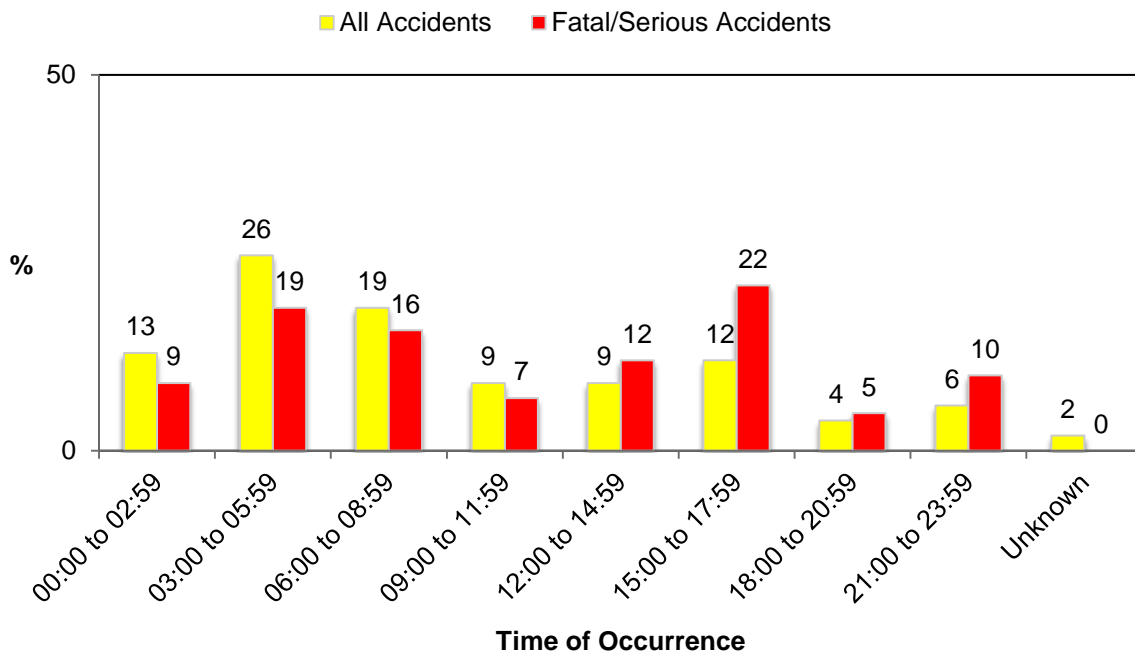


FIGURE 7: PERCENTAGE DISTRIBUTION OF ACCIDENTS BY TIME OF OCCURRENCE.

Please note that in the above figure and the next figure, “Fatal/Serious Accidents” refers to crash counts and not the numbers of injury victims or vehicles involved.

## DISTRIBUTION OF ACCIDENTS BY DAY OF WEEK

As shown in Figure 8, although accidents are distributed over all days of the week, Tuesdays, Thursdays and Sundays show slightly lower percentages, possibly due to reduction in the volume of traffic. However, Sundays show a higher percentage of fatal/serious accidents than do Tuesday or Thursday. Over the initial year of this study, Mondays and Wednesdays had the highest percentage of fatal/serious accidents, a trend that would be interesting to follow in the oncoming years. As the data on this roadway grows, it might also be instructive to match time of day to days of the week to see whether the fatal/serious Monday crashes, for example, follow the time periods seen for the year overall. If the highest percentage of fatal/serious crashes in any 3-hour period occurs between 15:00 and 17:59 hrs on Mondays but not on Wednesdays, the data may suggest links besides traffic volume.

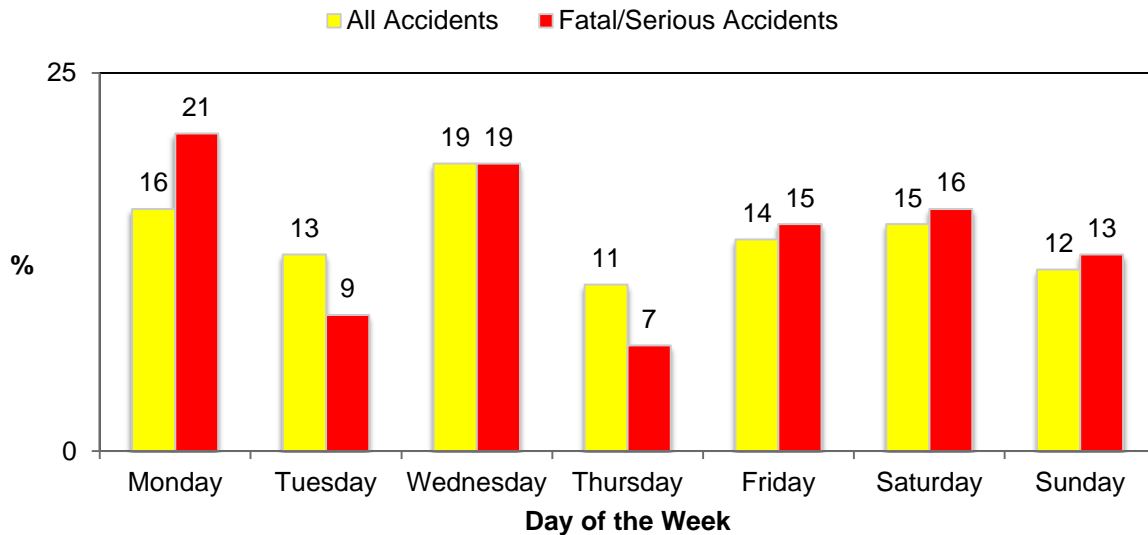


FIGURE 8: PERCENTAGE DISTRIBUTION OF ACCIDENTS BY DAY OF WEEK.

### VEHICLES/ROAD USERS INVOLVED

A total of 328 vehicles/road users (317 vehicles and 11 pedestrians) were involved in the 214 expressway accidents examined. Figure 9 shows the percentage distribution of the types of vehicles/road users involved in these accidents. Please note that the figure is based on a count of the vehicles and pedestrians involved in all the 214 accidents and not the number of occupants or accidents. In case of pedestrians, each pedestrian is a single count. Findings show that the type of vehicles/road users most often involved in accidents on the expressway are trucks (63%), followed distantly by cars (29%).

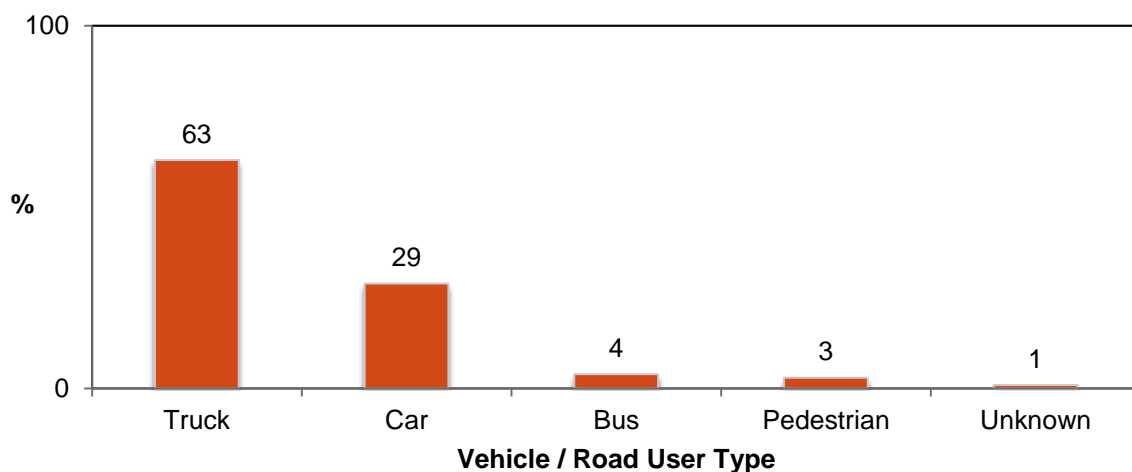


FIGURE 9: PERCENTAGE DISTRIBUTION OF VEHICLE/ROAD USER TYPE INVOLVED (N=328)

In total, 11 pedestrians were involved in the accidents examined; however, 8 of these pedestrians were involved in a single accident. These pedestrians were standing at a toll plaza due to a previous accident, following which another vehicle crashed into them.

## VEHICLES/ROAD USERS AFFECTED IN CRASHES WITH FATAL OR SERIOUS INJURY

Figure 10 shows the percentage distribution of vehicles/road users directly associated with a fatality or a serious injury due to the crash. Please note that percentages given for cars, trucks, and buses reflect a count of vehicles with at least one fatal victim or serious injury victim. Only in the case of pedestrians, the percentage reflects the number of persons counted.

As can be seen, the vehicles with the highest share of fatalities or serious injuries to occupants are cars. Cars constitute 58% of vehicles which had at least one fatal occupant, and 45% of vehicles which had at least one seriously injured occupant. Trucks, which have a high involvement in accidents, as seen above, have the second highest share of fatal or serious injuries. Trucks constitute 30% of vehicles which had at least one fatal occupant, and 37% of vehicles which had at least one seriously injured occupant.

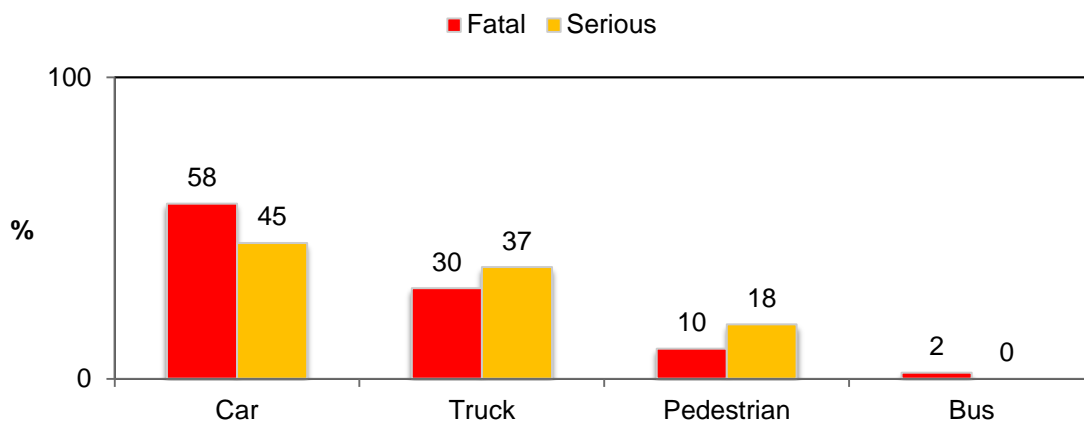


FIGURE 10: PERCENTAGE DISTRIBUTION OF VEHICLE/ROAD USER TYPES IN CRASHES WITH AT LEAST ONE FATALITY OR SERIOUS INJURY VICTIM. N(FATAL)=40 VEHICLES AND N(SERIOUS)= 38 VEHICLES.

The data not only indicates that cars and trucks are the two road users most frequently involved in accidents on the expressway (Figure 9), but also shows that cars and trucks are associated with more occupant fatalities or serious injuries than are any other road user types (Figure 10).

## ACCIDENT TYPES

Figure 11 shows the distribution of the 214 accidents (including the 68 fatal/serious accidents) as categorized by accident type. The ten accidents types used in coding for this study are listed below.

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. Run-off-road to the right.
9. Run-off-road to the left.
10. Accident of another kind.

*Detailed explanations for each accident type are provided in Appendix A.*

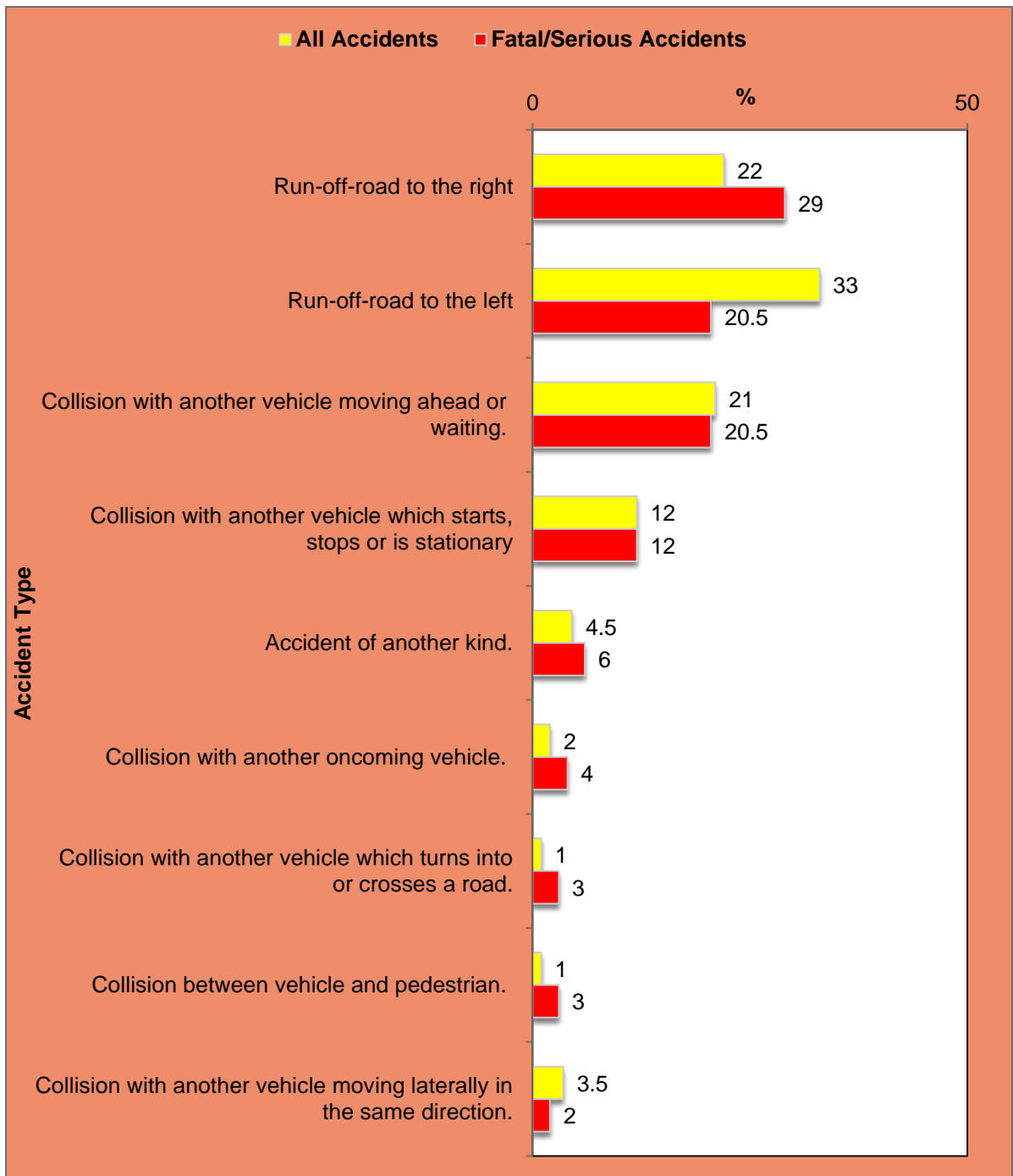


FIGURE 11: PERCENTAGE DISTRIBUTION OF ACCIDENTS BY ACCIDENT TYPE.

Figure 11 shows that “run-off-road” crashes account for 55% of accidents followed by collisions between vehicles travelling in the same direction (33%). It is interesting to note that vehicles running off road to the right (29%) have more fatal/serious injury accidents than vehicles running off road to the left (20.5%), even though there are more accidents involving vehicles leaving to the left. The category called “accident of another kind” involves crashes not covered by the other categories, such as truck jackknifing, fires, and rollovers on the carriageway.

## 4 CONTRIBUTING FACTORS ANALYSIS

To determine the contributing factors influencing the occurrence of each accident, 214 accidents were analyzed in detail.

### ANALYZING ACCIDENT AND INJURY CAUSATION

#### Factors Influencing Occurrence of Accidents (214 accidents)

A distribution by contributing factors (human/vehicle/infrastructure) for the 214 accidents analyzed over the first year of this study is shown in the Venn diagram (Figure 12). This diagram shows that human factors alone (57%) had the highest influence on the occurrence of accidents, followed by the combination of human and infrastructure factors (22.5%) and vehicle factors alone (16.5%).

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

Factor	All Combinations	Alone	With next largest influence
Human	<b>81.5%</b>	57%	+ <b>22.5%</b> Human/ <b>Infrastructure</b> = 79.5%
Vehicle	<b>19.5%</b>	16.5%	+ 2% Vehicle/Human = 18.5%
Infrastructure	<b>24.5%</b>	1%	+ <b>22.5%</b> Infrastructure/ <b>Human</b> = 23.5%

When the overlapping combinations are considered, infrastructure factors, which were far down on the list of influences (1%), move up past vehicle factors.

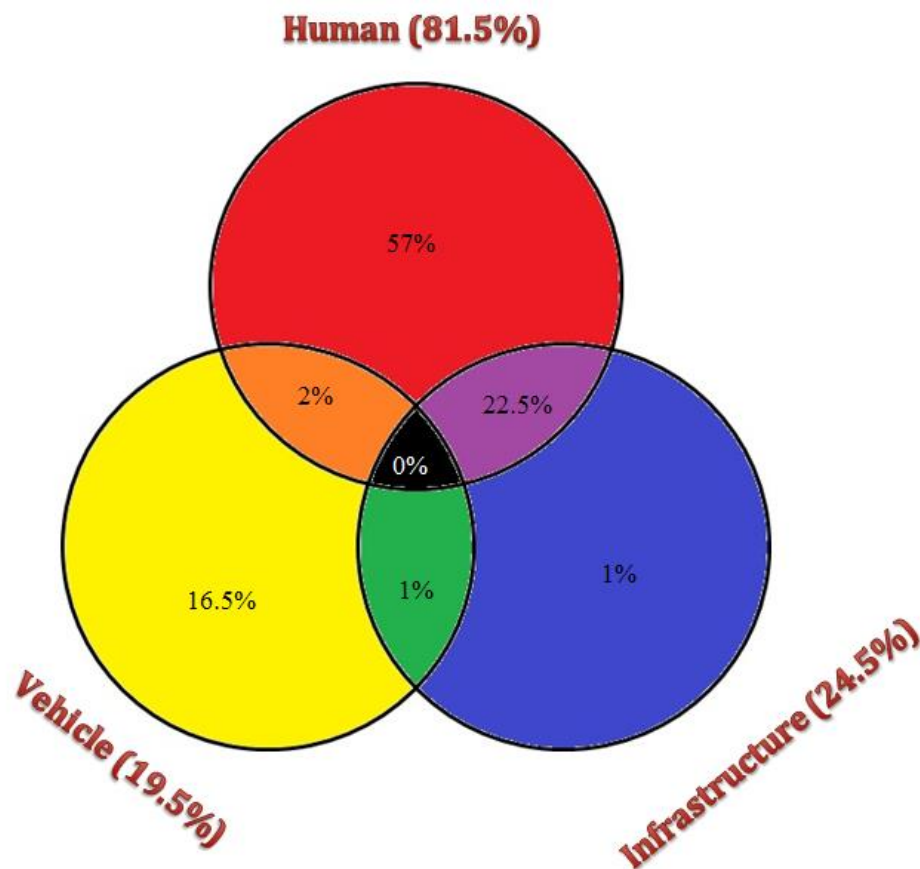


FIGURE 12: DISTRIBUTION OF 214 ACCIDENTS BY CONTRIBUTING FACTORS INFLUENCING THE OCCURRENCE OF THE ACCIDENT.



### Factors Influencing Occurrence of Injuries (68 fatal/serious accidents)

Of the 214 accidents, 68 accidents involved fatal or serious injury to at least one occupant or pedestrian. These 68 fatal or serious accidents were analyzed to determine the contributing factors influencing the occurrence of injury. The distribution by contributing factors (human/vehicle/ infrastructure) is shown in the Venn diagram (Figure 13). This diagram shows that vehicle factors alone (28%) had the greatest influence on a fatal/serious injury outcome, followed by a combination of human and vehicle factors (21%) and combination of vehicle and infrastructure factors (19%).

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

Factor	All Combinations	Alone	With next largest influence
Human	<b>50%</b>	10%	+ <b>21%</b> Human/ <b>Vehicle</b> = 31%
Vehicle	<b>80%</b>	28%	+ <b>21%</b> Vehicle/ <b>Human</b> = 49%
Infrastructure	<b>41%</b>	3%	+19% Infra./Vehicle = 22%

When the overlapping combinations are considered, infrastructure factors, which were again far down on the list (showing only a 3% influence), make a surprising showing. Human factors, too, show a robust influence when considered in combination, particularly with vehicle factors.

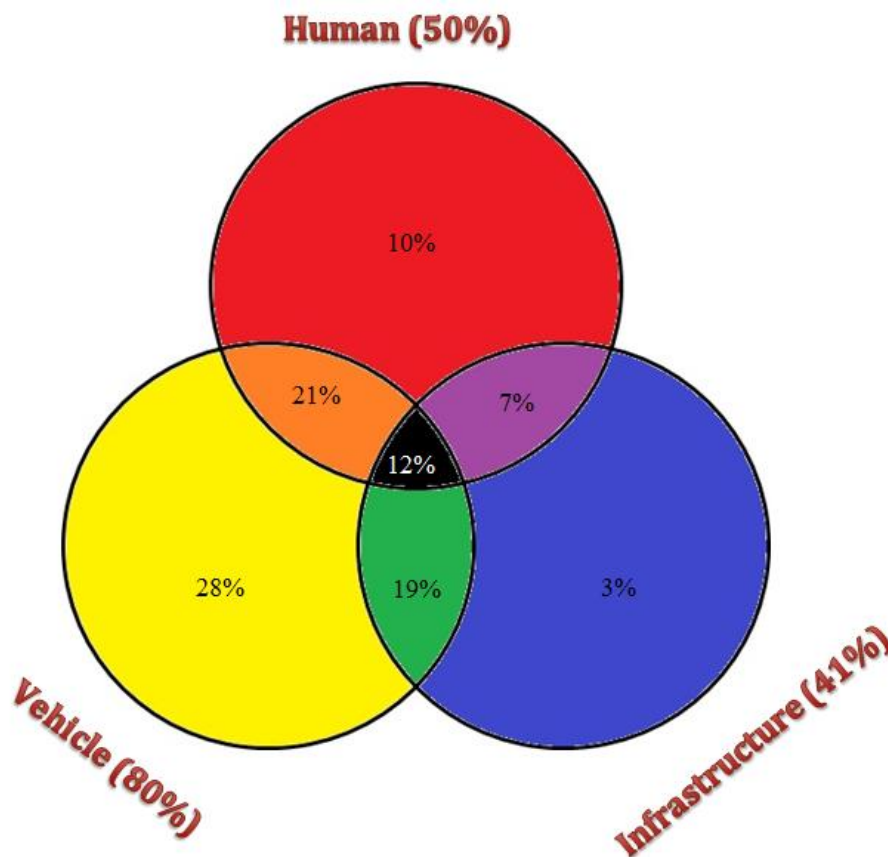


FIGURE 13: DISTRIBUTION OF 68 FATAL/SERIOUS INJURY ACCIDENTS BY CONTRIBUTING FACTORS INFLUENCING THE OCCURRENCE OF THE INJURY.

## HUMAN FACTORS INFLUENCING ACCIDENT OCCURRENCE

For the 214 accidents examined, the following are the contributing human factors determined to have influenced the occurrence of an accident. 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 human factors influencing accidents (81.5%).*

Contributing Human Factors (Accident Occurrence)	Number of Accidents	% Influenced
Driver Sleep / Fatigue (50 Trucks, 12 Cars, 1 Minitruck)	63	29%
Speeding - Excessive speed for conditions (21 Cars, 12 Trucks, 1 Minitruck, 1 Bus)	35	16%
Speeding - Exceeding speed limit (28 Cars, 1 Truck, 1 Minitruck, 1 Bus)	31	14%
Improper lane change (11 Trucks, 5 Cars, 1 Bus)	17	8%
Driving too slow for conditions (13 Trucks, 2 Cars)	15	7%
Following too closely	9	4%
Parked vehicle on road (full or partial)	8	4%
Use of wrong lane (includes overtaking in undivided roads)	6	3%
Parked vehicle off the road	5	2%
Overtaking from the left side of other vehicle	5	2%
Illegal road usage (includes travelling in the wrong direction)	4	2%
Driver under influence of alcohol	2	1%
Pedestrian dangerous behavior on roadway	2	1%

TABLE 1: CONTRIBUTING HUMAN FACTORS INFLUENCING THE OCCURRENCE OF 214 ACCIDENTS.

As can be seen, driver sleep/fatigue, speeding, improper lane change and driving too slow for conditions account for the largest percentage (74%) of the driver errors leading to an accident.

### Countering Human Factors that Contribute to Accidents

The top five human factors identified in Table 1 are described in brief in the following paragraphs, and information is provided on existing solutions to counter these human errors. Please note that the solutions identified here are merely suggestions. JPRI researchers are not experts in road engineering, vehicle design, driving regulation or enforcement. But the company is aware of solutions that have been implemented in other parts of the world and are already available; these are outlined here. What might actually work best for any specific situation is a

decision to be made by government engineers and agencies based on the types of crashes being seen, existing infrastructure design constraints and cost effectiveness.

**Driver Sleep / Fatigue – 29% (50 trucks, 12 cars, 1 minitruck)**

Continuous driving for many hours, particularly on long stretches at constant speed, can make drivers feel bored and sleepy. Add nocturnal hours or post-lunch hours, and the problem is aggravated. These combinations can cause drivers to fall asleep and drive off the roadway into the median or the shoulder area.



**At what time is this problem most prevalent?**

Truck drivers typically spend a lot of time driving at night. Hence, 92% of sleep/fatigue-influenced truck accidents were observed between 00:00 (midnight) and 9:00 hrs, as shown in Figure 14. In the case of car accidents, however, 75% of the sleep/fatigue accidents occurred during daylight hours.

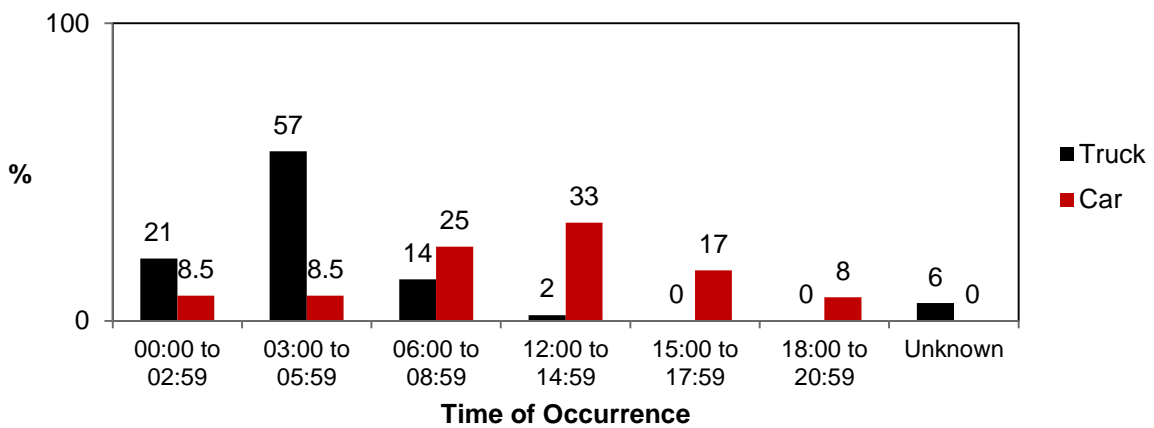


FIGURE 14: DISTRIBUTION OF SLEEP/FATIGUE ACCIDENTS FOR TRUCKS AND CARS BY TIME OF OCCURRENCE. N(TRUCKS) = 51; N(CARS) = 12.

**How can sleepy drivers be alerted?**

This problem has been observed world over and is not unique to the expressway. Below are some solutions, implemented successfully in other countries, which can be considered by road engineers and vehicle engineers for this problem.

**Road Engineering: Continuous Rumble Strips**

Continuous rumble strips are a road safety feature that alerts inattentive drivers to potential danger by causing a tactile vibration and audible rumbling, transmitted through the wheels into the vehicle’s frame. A continuous rumble strip is usually applied along an edge- or centerline to alert drivers when they drift from their lane. Rumble strips are effective (and cost-effective) for reducing accidents due to inattention or sleepiness, and they are also effective for keeping drivers in their lanes in low visibility conditions such as fog or dense rain. Shoulder rumble strips are most effective when part of a wide, stable shoulder for a recovery. That is, the driver



should have enough space to maneuver the vehicle back onto the road. Such strips may also prevent drivers from using the shoulder lane as an overtaking lane.

### Vehicle Engineering: Driver Attention Assist



The innovative Attention Assist system by Daimler (pictured at left) is part of a new wave of smart gadgets designed to give drivers a little extra help. Volvo offers a similar feature called Driver Alert Control, and other auto manufacturers have their own versions. The systems can detect when drivers start to become drowsy and will prompt them to take a break before it is too late. These use a variety of measures to determine whether a driver is nodding off, drifting in his/her lane, or changing his/her driving patterns, and they not only sound alerts but suggest the driver take a coffee break, and can even direct them

to the nearest way station for rest and refreshment. These are not yet standard features, though, so safety measures external to the vehicle might be desirable for the interim.

**Speeding: Excessive speed for conditions – 16% (21 cars, 12 trucks)**

**Speeding: Exceeding speed limit – 14% (28 cars, 1 truck)**

**Driving too slow for conditions – 7% (13 trucks, 2 cars)**

Having a wide and open highway under them, drivers tend to speed on the expressway. Even though the speed limit is set to 80 km/h, most vehicles, especially cars, are found travelling well over this speed limit.

*Technically speaking, speeding does not directly lead to an accident. However, the higher the speed, the lesser is the time available for the driver to react. Hence, in the event of a crash due to speeding, usually it is a sudden steering maneuver (to change lanes, avoid an obstruction, etc.), a burst tire at speed, or not enough time to react that leads to the accident.*

Driving too slow is likewise an indirect contributor to crashes. Other drivers (especially speeding drivers) can come up on a slow vehicle faster than expected, forcing an avoidance maneuver. There are sections of the expressway passing through ghats/mountains where trucks are unable to drive fast on the uphill gradient and tend to slow down a lot.

### **How to tackle the problems of speeding vehicles and slow moving vehicles?**

Even though the expressway has posted speed limits, drivers often ignore these or consider them appropriate for other vehicle types (e.g., a good speed for a heavy truck, but not for their responsive little car). Hence, there is an urgent need for scientific research to understand what drivers feel is a safe-speed based on the road features and the vehicle being driven. Many countries have improved on speed limits using speed management techniques such as one described below.

### **Step 1: Speed Data Collection**

The first step is to identify whether the posted speed limits are acceptable to the traffic. This can be established by conducting traffic speed studies to identify speeds by vehicle type (cars, trucks, buses, mini trucks, etc.) for a sample of vehicles. Then determine the 85<sup>th</sup> percentile speed (the speed below which 85% of the sample population is travelling on a stretch of road).

### **Step 2: Plan the speed limits**

With the speed data obtained, road engineers can plan for reliable and safe speed limits on various sections of the expressway. The speeds can differ by vehicle type or by the lane of travel.

### **Step 3: Driver communication and then, speed enforcement**

Any new speed limits need to be effectively communicated. In addition to speed limit posts, communication of changes in speed limits can be enhanced through road markings and traffic calming measures. For example, in sections where trucks slow down to climb a grade, signage could warn approaching drivers of the slow traffic lane ahead. In the ideal scenario, the road environment itself would psychologically influence the driver to follow a safe speed limit. Good speed enforcement is the final alternative to control driver speeds.



The World Health Organization, Global Road Safety Partnership (GRSP), FIA Foundation and World Bank have jointly created good practice manuals on many topics related to road safety. One of them is on “Speed Management” which is a good guide for any policymaker, road engineer, police officer or even the general public to understand how speeds can be controlled based on experiences from countries successful in doing so. [http://www.who.int/roadsafety/projects/manuals/speed\\_manual/en/](http://www.who.int/roadsafety/projects/manuals/speed_manual/en/)

### **Improper lane change – 8% (11 trucks, 5 cars, 1 bus)**

This problem is due to a driver either weaving diagonally across lanes (rather than moving through one after another in an orderly progression) or failing to check mirrors or indicate intention to other drivers before changing lanes, catching other drivers by surprise. Many motorists have been observed changing lanes without giving proper indication.

#### ***What can be done to keep drivers in their proper lanes or convince them to use indicators?***

Use of indicators to communicate to other drivers about the intention to turn or change lanes is important and must be encouraged for safe driving. Proper lane use can be enforced through visual evidence from CCTV cameras and fining motorists at toll plazas.

Co-passengers could help, too, by requesting that the driver use indicators and observe lane discipline. This is essential for the safety of all vehicle occupants and other road users.

#### **Vehicle engineering: Lane Departure Warning**

Much like the driver alert systems for drowsiness, and often incorporated as part of those, a lane departure warning system is designed to warn a driver when the vehicle begins to move out of its lane without a proper turn signal. Such systems have the added advantage of training drivers to use their indicators (to avoid the constant warnings).



## VEHICLE FACTORS INFLUENCING ACCIDENT OCCURRENCE

For the 214 accidents examined, the following are the contributing vehicle factors determined to have influenced the occurrence of an accident. 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 may not be equal to sum of vehicle factors influencing accidents (19.5%).*

Contributing Vehicle Factors (Accident Occurrence)	Number of Accidents	% Influenced
Brake fade (24 Trucks)	24	11%
Tire burst (7 Cars, 2 Buses, 2 Trucks)	11	5%
Steering defect (3 Trucks)	3	1%
Suspension defect (2 Trucks)	2	1%
Other defect	2	1%
Overloading	1	0.5%

TABLE 2: CONTRIBUTING VEHICLE FACTORS INFLUENCING THE OCCURRENCE OF 214 ACCIDENTS.

Of all vehicle factors contributing to an accident, truck brake fade influenced the most accidents (11%). Tire burst, too, was a contributing factor in a notable percentage of accidents (5%).

### Countering Vehicle Factors that Contribute to Accidents

This section offers a brief description of the top two vehicle-related accident-level contributing factors and provides a few possible solutions to counter these.

#### Brake fade – 11% (24 trucks)

“Brake fade” is the term used to describe the reduced braking ability that can occur if brakes are applied often or for a long period. Brake fade often occurs when a truck driver applies brakes continually or repeatedly on a long, steep downhill as the mass of the truck fights to gain speed, and the driver fights to restrain it. When braking ability diminishes and gravity is still providing acceleration, a crash is a likely outcome.

#### What can be done for truckers to avoid this problem?

##### Road engineering: Truck brake check areas

A brake check area is safety measure that allows truckers an area in which to pull safely off the road to check the operation of their brake systems. Typically, places to perform a brake inspection are located just before a long, steep downgrade. In the USA, some brake check areas are mandatory; failure to stop in the designated area, and to check the brakes, is a violation of the law.



### Road engineering: Runaway truck ramp

Runaway truck ramps are often provided on the same steep roads that have brake check areas. These runoff areas are typically sand or gravel filled and whenever possible run uphill off a long downhill stretch of road. They are designed to help large trucks that are having braking problems on long downgrades to come to a safe stop. Deep sand or gravel slows the truck's momentum rapidly but not abruptly. These systems save lives and expensive vehicles and cargo. The picture alongside shows a runaway truck escape ramp in China. (Source: Wikipedia)



### Tire burst – 5% (7 cars, 2 buses, 2 trucks)

The tire defects seen in the course of this study were associated with vehicles running at high speeds or due to poor maintenance of tires (tread depth very low, incorrect inflation pressure). While definitive investigation of tire bursts and defects requires detailed tire investigation, analysis and testing, which is outside of the scope of this study, researchers were able to confidently identify 11 accidents where a tire burst was a contributing factor.

### Solutions? First we need to identify causes.

A scientific study conducted with the cooperation of tire companies and the transport department can help identify specific problem areas causing defects that lead to tire failures. Such studies can also help in determining the necessary preventive measures that can be put in place by manufacturers and preventive maintenance that can be carried out by drivers to avoid tire related accidents.

### Tire bursts and Tire damage

During the course of the accident study, researchers came across many accidents where drivers claimed that a tire burst caused the vehicle to lose control and meet with an accident. JPRI researchers are trained to examine the scene and differentiate tire bursts from tire damage caused by impacts with objects such as curb stones, barriers, gutters, etc. Researchers were able to identify the accidents where a tire burst had actually occurred leading to an accident and separate them from those where tire damage had occurred. The picture on the left shows a tire burst with the telltale marks on the accident scene. The picture on the right shows tire damage caused due to impact of tires with curb stones.



## INFRASTRUCTURE FACTORS INFLUENCING ACCIDENT OCCURRENCE

For the 214 accidents examined, the following are the contributing infrastructure factors determined to have influenced the occurrence of an accident. 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 infrastructure factors influencing accidents (24.5%).*

Contributing Infrastructure Factors (Accident Occurrence)	Number of Accidents	% Influenced
Poor road marking/signage (11 Trucks, 8 Cars)	19	9%
Shoulder – Narrow (13 Cars, 3 Trucks, 1 Bus)	17	8%
Sharp curvature (10 Trucks, 5 Cars)	15	7%
Inadequate warning about accident/parked vehicle (11 Trucks, 2 Cars, 2 Buses)	15	7%
Shoulder – None	3	1%
Gap-in-median	3	1%
Vision obstruction due to trees/plantations	1	0.5%
Uphill Gradient	1	0.5%

TABLE 3: CONTRIBUTING INFRASTRUCTURE FACTORS INFLUENCING THE OCCURRENCE OF 214 ACCIDENTS.

Poor road marking/signage (9%), narrow shoulders (8%), sharp road curvatures (7%) and inadequate warning about accident/parked vehicles (7%) together influenced 31% of all accidents.

### Countering Infrastructure Factors that Contribute to Accidents

This section offers a brief description of the top contributing infrastructure factors that influence accidents on the expressway and some locations where they are prevalent.

#### Poor road marking/signage – 9% (11 trucks, 8 cars)

Road markings and signage are important means of communication between the roadway and the driver. They inform drivers about what to do based on their desired destination or direction of travel. The ability of a driver to see, read, comprehend and make decisions is largely dictated by the placement, size, visibility and illumination of the signboards. Like many roads in India, the expressway exhibits some problems with this vital information link. Figure 15 offers a few examples of poor road marking and signage which resulted in accidents.





Khopoli Exit

Poor road signage and a poorly visible height clearance bar is a major problem for truckers when they arrive at this exit. The exit comes immediately after a sharp right turn and for most trucks travelling in the left-most lane, it is difficult to make out which lane to travel in to continue their journey or if they should even take the exit.



End of Expressway - Towards Pune

Probably the best example of poor road marking is the end of the expressway towards Pune. A sharp right turn eventually joins the bypass road. Even though speed limits have been put up, most drivers are travelling at well over double the speed limits posted. Chevron signs posted are hardly sufficient to warn drivers to reduce speeds while travelling around this bend.



Kamshet Tunnel

Rumble strips put up right after a tunnel are quite a surprise for motorists who come out of the tunnel. No advance warnings are provided for drivers to expect them. This has resulted in rear ending of vehicles slowing down.

Fortunately, these were removed after some accidents occurred and the mistake was realized.

FIGURE 15: EXAMPLES OF POOR ROAD MARKING/SIGNAGE.

### **Shoulder: Narrow or None— 9% (13 Cars, 3 Trucks, 1 Bus)**

The “shoulder” is an area at the side of a road that allows vehicles space to pull partially or completely off the road for emergency stopping. It is not supposed to be used as a travel lane, although police and emergency response vehicles find wider shoulders useful for such when traffic backups make other access impossible. At a minimum, a shoulder should be available on the left side of the road (accessible to disabled vehicles from the slower lane). On wide highways, it is preferable to have shoulders on both sides of each directional carriageway (in the median as well as at the outer edges of the road) for additional safety.

The expressway has long sections of road with no shoulders (ghat section) or narrow shoulders, while in other sections the shoulders are wide only on the left side. The shoulders are narrow on the median side.

#### ***Why narrow or no shoulders are a problem?***

As discussed, shoulders are mainly to be used as an emergency stopping lane. For safety, it is essential that vehicles are able to stop inside a shoulder completely so that no part of the stopped vehicle is within the main road where vehicles are travelling. In sections of the expressway, where the shoulder narrows or is absent, this can become a potential cause of collisions. Narrow shoulders are also dangerous in places where the roadway is raised and vehicles forced onto the shoulder risk overturning due to drop offs.



Parked truck on a road section with no shoulder. A truck travelling in the left-most lane collided into it, resulting in fatalities and serious injuries.

Truck driver wanting to park his truck on the shoulder did not notice the shoulder narrowing; truck toppled over to the left. Fortunately, occupants were not injured.

The narrow shoulder on the right side (towards the median) along the entire stretch of the expressway creates a problem when drivers of fast moving vehicles steer onto the shoulder due to sleep or a sudden steering maneuver. The shoulder does not allow the driver enough time or space to steer back onto the road and regain control over the vehicle. Also, once a vehicle enters the median, the chances of impacting an object in the median are very high.





### Sharp Curvature – 7% (10 Trucks, 5 Cars)

The expressway has many sections of road with sharp curvatures which require the driver to reduce speed and steer carefully. Unfortunately, due to insufficient advance warning, drivers are not well prepared to steer through the curve carefully and end up understeering and departing the roadway. Figure 16 shows the locations where 15 accidents due to sharp curvature occurred.



FIGURE 16: EXAMPLES OF PROBLEMATIC CURVES ON THE EXPRESSWAY AND PERCENTAGE OF ACCIDENTS OCCURRING ON THEM (N=15)



### Inadequate warning about accident/parked vehicle – 7%

(11 Trucks, 2 Cars, 2 Buses)

When vehicles breakdown, what do the drivers do? Most drivers do not think of this much, until it happens to them. JPRI researchers found a number of vehicles broken down on the side of the road during the study. Most of the drivers and occupants are unaware of what to do in such a situation. If a vehicle parked on or near the roadway is not marked properly with advance warning signs, particularly in low visibility conditions or after a blind corner, an accident becomes a high probability.



Truck parked on the shoulder due to a tire puncture. Another truck hauling a semi-trailer (above) rear ended the parked truck.



Truck parked partly on the shoulder and partly on the road due to a tire puncture. Car (above) overtaking another vehicle from the left, rear ended the parked truck.

FIGURE 17: Trucks involved in accidents while parked on the shoulders. Inadequate illumination and/or inadequate warnings likely contributed to collisions.

#### ***What can be done to improve this condition?***

It is important for drivers to take care of a breakdown situation immediately when it happens and to carry proper warning devices in their vehicles so they can let other vehicles prepare for the situation. Some sensible rules to help expressway users keep themselves and their fellow travelers safe are provided below.

## RULES FOR EMERGENCY STOPPING ON THE EXPRESSWAY

### Park your vehicle at a safe spot.

The first thing to do is to drive the vehicle to the left-hand shoulder of the road. As you pull your vehicle off the road and onto the shoulder, try to find a safe spot to park the vehicle. Ensure that you are away from any curves in the road behind you. Not only does this help other vehicles to see you, but this placement pays off when you are ready to get back onto the road because you can spot oncoming traffic, giving you a chance to ease yourself back into traffic.

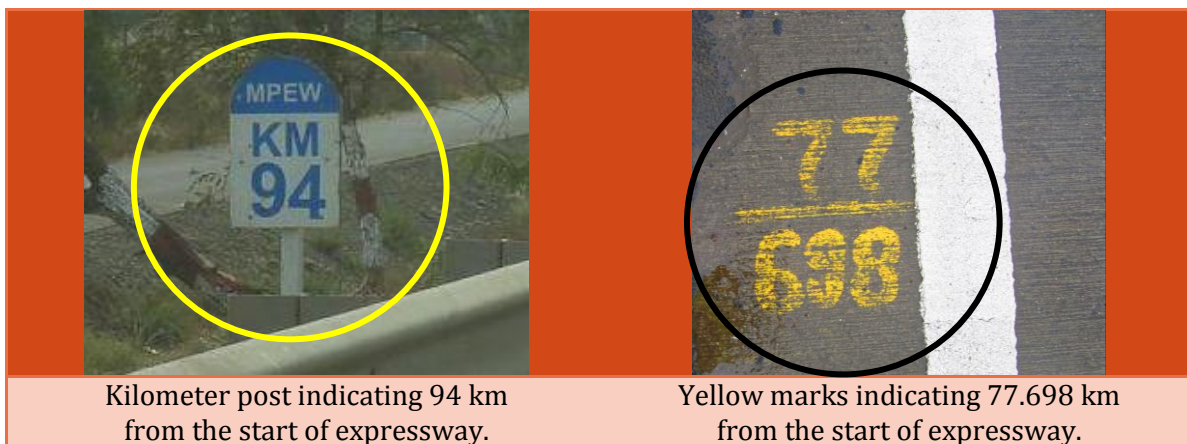
### Let other vehicles know that your vehicle is stationary.

- Turn on the hazard lights and turn the steering wheel of the vehicle such that the front wheels are pointed 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 vehicle 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). This way even if the broken down vehicle battery runs down or engine is not operational, 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. Keep in mind that a vehicle that is travelling at 80 km/h or about 23 meters per second, needs a few seconds to realize your position and take evasive action. Hence, keeping the warning triangle at least 50 meters before the vehicle is advisable.



### Getting assistance

- Immediately notify the highway police (9833498334) and the IRB control room (9822498224) 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. After all, 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.

FIGURE 18: FINDING OUT YOUR LOCATION ON THE EXPRESSWAY.

- To know your location on the expressway, check if there is 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. Figure 18 shows pictures of the kilometer post and the yellow markings next to the shoulder line.
- While waiting for the police or tow truck to arrive, please ensure that all occupants are standing well away from the vehicle. There have been incidents of parked vehicles being rear ended by an errant vehicle. People standing in front or behind parked vehicles have been killed. If there are many people in the vehicle and they would like to stand outside, ensure that all of them are standing well away from the vehicle to the side (if there is sufficient opening) or well in front of the vehicle (in case of barriers).

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

After you have parked your vehicle safely off the road and ensured that other drivers are warned well in advance of your vehicle being stationary, you can start working on your vehicle, if required, but follow a few simple rules. 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.

## HUMAN FACTORS INFLUENCING INJURY OCCURRENCE

For the 214 accidents examined, 68 accidents resulted in fatal or serious injuries. The following are the contributing human factors determined to have influenced the occurrence of an injury. The table shows both the number and the percentage of fatal/serious injury accidents influenced by each factor. *Please note that more than one factor can influence injury; hence, the sum of the percentage influence will not be equal to sum of human factors influencing injuries (50%).*

Contributing Human Factors (Injury Occurrence)	Number of Accidents	% Influenced
Seat belt not used (26 Cars, 4 Trucks, 1 Minitruck)	31	46%
Overloading of occupants (number of occupants > seating capacity) (3 Cars, 1 Truck)	4	6%
Occupants in cargo area	1	1%
Other	1	1%

TABLE 4: CONTRIBUTING HUMAN FACTORS INFLUENCING THE OCCURRENCE OF FATAL/SERIOUS INJURY IN 68 FATAL/SERIOUS ACCIDENTS.

As can be seen, lack of seat belt use and overloading of occupants influenced injury occurrence in 52% of fatal/serious injury accidents.

### Countering Human Factors that Contribute to Injury

#### Seat belt not used – 46% (26 cars, 4 trucks and 1 minitruck)

Seat belts are designed to secure occupants in a safe position within the vehicle in the case of an accident or sudden stop. Seat belts have been proven to reduce injury severity by preventing occupants being ejected from the vehicle entirely or from the seat and into hard objects such as the windshield. Seat belts should be worn by all occupants, including rear seat occupants. The photos shown at right were taken a few milliseconds after an impact with a barrier to show how belted and unbelted rear occupants move in an accident. Rear occupants can impact the driver and other front seat occupants even if these have airbags, causing serious (and avoidable) injury to all impacted persons. Hence, it is very important that all occupants in a vehicle wear seat belts.



**Belted rear occupant** held in position in a frontal impact.



**Unbelted rear occupant** moving forward and loading the front seat back. Notice how the front occupant has been moved forward.

### **Overloading of occupants — 6% (3 cars, 1 truck)**

A few accidents involved higher injury severity because of the number of occupants in the vehicle being greater than the actual seating capacity of the vehicle. This overloading can have serious consequences, particularly in an accident situation.

The National Road Safety Council of Jamaica provides some information on why occupants must not be overloaded beyond the seating capacity of the vehicle.

#### **Overloading a vehicle with occupants . . .**

- Impedes the driver's **ability to control** and maneuver the vehicle as the driver's operating space is reduced. This is why many drivers, especially with passengers, are seen driving with their hands hanging outside of the vehicles.
- With overloading, **seat belts** are often not used as the aim is to pack in as many persons as possible into the vehicle as you would sardines in a tin.
- With overloading, if the **collision** is to the front end, the pressure on the occupants is from the front and the back. This is because:
  - The front is crushed in sending pressure to the center.
  - Pressure from the back is created when the passengers in the back are thrown forward.
  - Occupants end up crushing each other.
- **Traction** of tires is reduced due to the weight in the car. This results in a 'washing' movement which makes the car unstable at high speeds.
- **Brakes** have to work harder due to 'the riding of brakes' and because the car is heavier due to overloading. Brakes overheat and lose their effectiveness to stop the car.
- The whole **suspension system** comes under stress and, over time, the weakest point can give way.
- The **engine** also comes under stress when the vehicle is overloaded, therefore:
  - More power is needed to overtake.
  - It takes longer to overtake and if one's judgment is poor, a collision can result if there is an oncoming vehicle.

Source: <http://www.nationalroadsafetycouncil.org.jm/articles/overloading.htm>

#### **How to control belt use and overloading?**

As most countries have learned, public education is the first step, followed by enforcement. At easy control points, such as at toll booths, cameras could make general observations to ensure that the number of occupants in any vehicle does not appear to exceed the number of seats, and might even be able to tell whether occupants are belted. Children, especially, should be counted as occupants and given proper seating space (child seats must be used) rather than accommodating them on laps of other occupants. Police could be notified of vehicles that appear to be in violation.



## VEHICLE FACTORS INFLUENCING INJURY OCCURRENCE

For the 214 accidents examined, 68 accidents resulted in fatal or serious injuries. The table below shows both the number and the percentage of fatal/serious injury accidents influenced by each factor. *Please note that more than one factor can influence injury; hence, the sum of percentage influence will not be equal to sum of vehicle factors influencing injuries (80%).*

Contributing Vehicle Factors (Injury Occurrence)	Number of Accidents	% Influenced
Passenger Compartment Intrusion – Other (20 Cars, 19 Trucks, 1 Minitruck, 1 Bus)	41	60%
Seatbelts not available/usable (10 Trucks, 1 Bus)	11	16%
Passenger Compartment Intrusion – Underride/Override (7 Cars, 2 Trucks)	9	13%
Pedestrian Impact/Run over	4	6%
Unsecured Cargo (3 Trucks)	3	4%
Protruding/Oversized cargo	1	1%
Retrofitted fuel kit	1	1%
Entrapment	1	1%

TABLE 5: CONTRIBUTING VEHICLE FACTORS INFLUENCING THE OCCURRENCE OF FATAL/SERIOUS INJURY IN 68 FATAL/SERIOUS ACCIDENTS.

As can be seen passenger compartment intrusions and lack of seat belts influenced injury occurrence in 89% of the fatal/serious accidents.

### Countering Vehicle Factors that Contribute to Injury

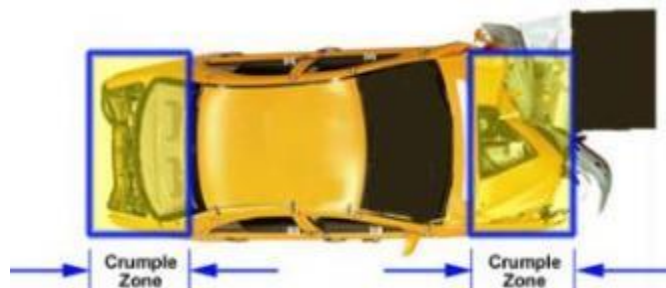
#### Passenger Compartment Intrusion – Other – 60%

(20 Cars, 19 Trucks, 1 Minitruck, 1 Bus)

#### Passenger Compartment Intrusion – Underride/Override – 13%

(7 Cars, 2 Trucks)

Passenger vehicles are usually designed so that, during an impact accident, the passenger cabin (where the driver and passengers sit) resist deforming. During crash testing, impact forces are applied under very specific conditions to the front or rear bumper areas (crumple zones) that have been designed to absorb crash energy by crumpling, and thereby reducing the magnitude of the impact forces by the time these reach the passenger compartment.





Unfortunately, current standardized crash tests, especially those developed in Europe and USA, are not always a good representation of the impact forces a vehicle observes in the real world in India.

**What is passenger compartment intrusion?**

It is observed that the frontal sections of cars are not engaged in many accidents, especially with collisions between cars and heavy vehicles. The impact often begins well above the bumper, and the impact forces bypass the frontal section and reach the passenger compartment in full force. This generally causes passenger compartment intrusions which reduce the survival space of occupants inside the cabin. Such forces may also cause external objects to contact the occupants directly, resulting in severe injuries. In such accidents, the positive effects of seat belts and airbags are also significantly reduced.

This problem is also prevalent in trucks (and buses) where the driver cabins are seen to collapse in an impact with another heavy vehicle or object. The accidents examined for this study, by percentages, for passenger intrusion in cars and trucks are presented in Figure 19.

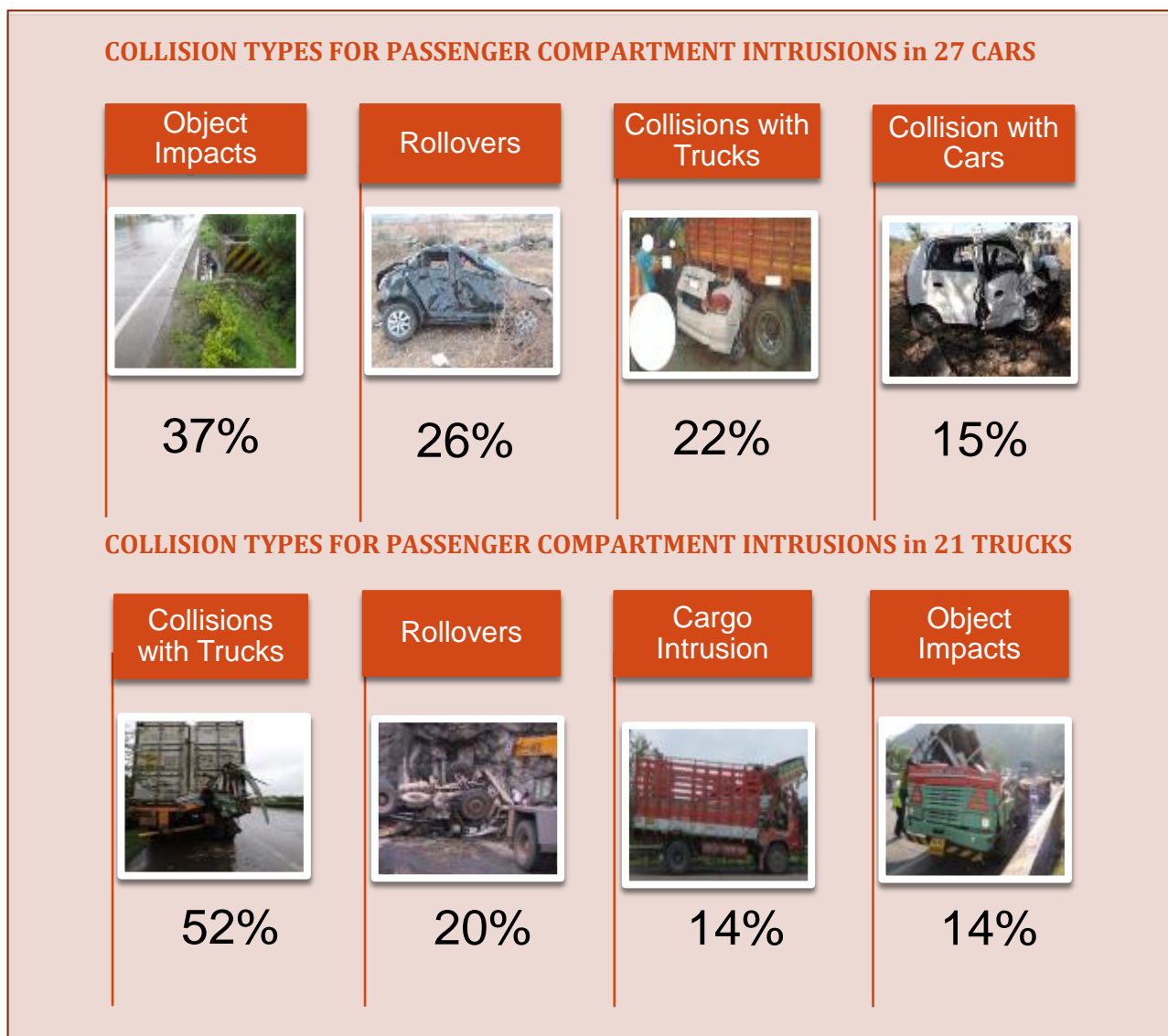


FIGURE 19: 'PASSENGER COMPARTMENT INTRUSION' COLLISION TYPES SEEN ON THE EXPRESSWAY.

### **What can be done to reduce intrusion risks?**

Passenger compartment intrusion is a serious issue and can reduce the effectiveness of passive safety systems such as seat belts and airbags. Collisions with trucks need to be studied to determine ways to make small and large vehicles compatible in a crash. In the same way object impacts and rollovers need to be studied to determine ways to make crashes between the roadsides and objects more crash friendly to existing vehicle designs. In addition, vehicle manufacturers (especially truck manufacturers) need to study these accidents in detail to determine how the impact forces can be effectively dissipated without compromising the passenger cabin.

### **Seatbelts not available/usable – 16% (10 Trucks and 1 Bus)**

Most trucks and buses in India do not have usable seatbelts. It has been proven worldwide that seatbelts are the cheapest and most effective safety systems in vehicles today. Hence, truck and bus drivers should ensure that their vehicles are fitted with good quality seat belts. Manufacturers and vehicle body builders too should ensure that their vehicles come with these effective safety systems.



**Truck with no seat belts**



**Bus with seat belts which appear unusable.**

## INFRASTRUCTURE FACTORS INFLUENCING INJURY OCCURRENCE

For the 214 accidents examined, 68 accidents resulted in fatal or serious injuries. The table below shows both the number and the percentage of fatal/serious injury accidents influenced by each factor. *Please note that more than one factor can influence injury; hence, the sum of the percentage influence will not be equal to sum of infrastructure factors influencing injuries (41%).*

Contributing Infrastructure Factors (Injury Occurrence)	Number of Accidents	% Influenced
Object impact - roadside/median - manmade structures (17 cars, 1 truck, 1 minitruck)	19	28%
Roadside - Steep slope/Drop off (5 trucks, 3 cars)	8	12%
Object impact - roadside - trees/plantations	3	4%
Object impact - Other	2	3%

TABLE 6: CONTRIBUTING INFRASTRUCTURE FACTORS INFLUENCING THE OCCURRENCE OF FATAL/SERIOUS INJURY IN 68 FATAL/SERIOUS ACCIDENTS.

As can be seen, man-made structures and trees/plantations along the side of the road or in the median and roadside steep slopes and drop offs influenced injury occurrence in 44% of the fatal/serious accidents. It should also be noted that most of the vehicles involved in the object impacts are cars.

### Countering Infrastructure Factors that Contribute to Injury

When a vehicle departs the roadway due to driver fatigue, sudden maneuver, speeding or loss of control, the vehicle enters the roadside or the median in what is termed a run-off-road crash. If sufficient area is not available for a driver to regain control and get back on to the road, then usually the vehicle collides with an object or rolls over due to uneven surfaces.

#### International Road Assessment Programme (iRAP) on run-off-road crashes:

Run-off-road crashes are common, especially in high-speed areas. They occur at bends and on straight sections of road. In high-speed environments they can have severe outcomes, particularly if an object is hit (for example trees, poles, pedestrians) or there is a steep embankment or cliff.

Research shows that the survival rate for hitting an object head-on reduces dramatically above 70 km/h, while a side impact into a pole or tree is greatly reduced at speeds above 40 km/h. Therefore, the consequences of running off the road above this speed will often be severe.

Source: <http://toolkit.irap.org/default.asp?page=crashtype&id=5>



**Object impact - roadside/median - manmade structures – 28%**

(17 cars, 1 truck, 1 minitruck)

**Object impact - roadside - trees/plantation – 4% (3 cars)**

Object impacts usually occur when a vehicle departs the roadway and enters into the roadside or median, following which the vehicle collides with an object. Figure 20 shows examples and percentages for objects impacted on the expressway during the first year study period.



FIGURE 20: EXAMPLES OF OBJECT IMPACTS ON THE EXPRESSWAY.

### ***What kinds of objects are impacted on the expressway?***

Most of the objects encountered along the expressway are manmade structures located on the roadside or median. These objects include concrete barriers, bridge walls, guard rails, sign posts, flower pots, curb stones, etc. Flower pots and curb stones may look harmless, but in the event of an impact, these can be quite devastating for vehicles and its occupants. Incidentally, many passenger compartment intrusions, which significantly reduce occupant safety, have been caused by collisions with these objects.

Hence, it is important to make these manmade structures more crash friendly and “forgiving”.

### ***How to make roadside manmade structures “forgiving”?***

To make manmade structures such as bridge walls and barriers more crash friendly and forgiving, devices such as crash barriers and impact attenuators can be positioned in front of these rigid objects. These devices are designed to reduce the damage to both the structures and to the vehicles and their occupants. Impact attenuators, for example, are primarily designed to absorb the impact of a frontal collision with minimal damage to the structure it is protecting or the vehicle. Some function like crumple zones in a vehicle, others offer a more resilient resistance, keeping their ability to protect even after they have been impacted. Various types of barriers, in contrast, are designed to redirect the vehicle away from the hazard or provide a solid defense against being breached. These photos offer examples of impact attenuators that are designed to ensure that the severity of impact with manmade structures, including guard rails, is reduced.





### Roadside - Steep slope/Drop off – 12% (5 trucks, 3 cars)

The expressway includes numerous sections with bridges over canals and mountain regions with steep drop offs. It has been noted that adequate barriers are not provided to prevent vehicles from tipping over and plummeting down slopes or into hillsides, as these crash scene photos show.



### **Need for Clear Zones!**

Another way to avoid such impacts is to not have any immovable objects in the space around roads. This is not always possible, but can be planned in the design stage itself. This concept, called clear zones, is being used in many countries around the world.

According to the US Federal Highway Administration: "A Clear Zone is an unobstructed, traversable roadside area that allows a driver to stop safely, or regain control of a vehicle that has left the roadway. The width of the clear zone should be based on risk (also called exposure). Key factors in assessing risk include traffic volumes, speeds, and slopes. Clear roadsides consider both fixed objects and terrain that may cause vehicles to rollover."

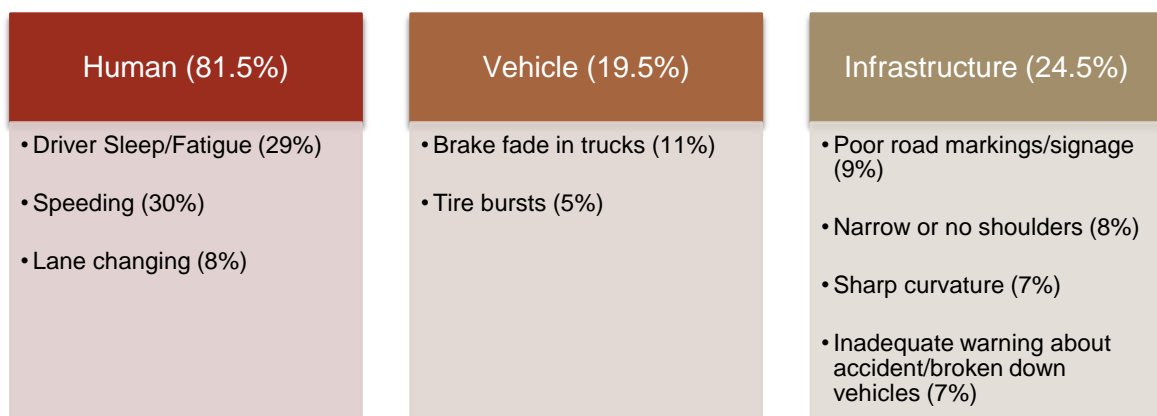
Source: [http://safety.fhwa.dot.gov/roadway\\_dept/clear\\_zones/](http://safety.fhwa.dot.gov/roadway_dept/clear_zones/)



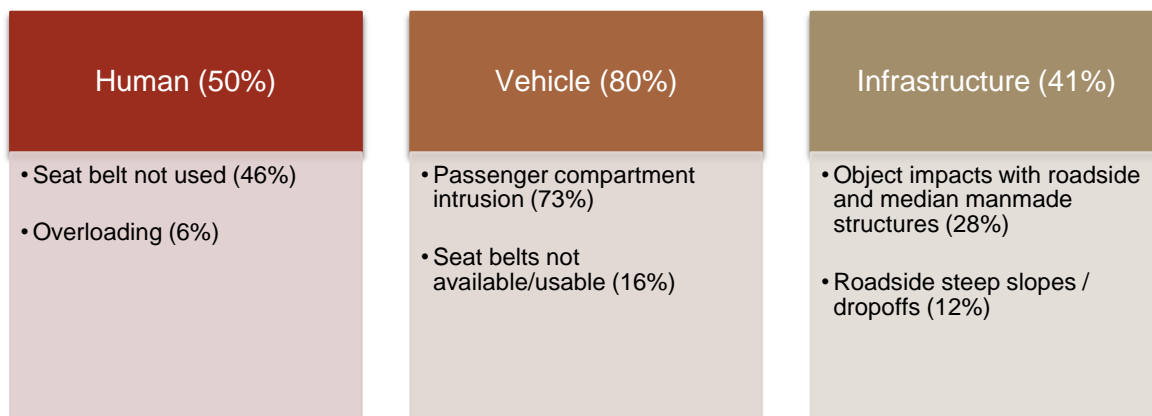
## 5 CONCLUSIONS

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

1. Trucks are highly involved in accidents on the expressway. Of all the vehicles/road users involved in accidents on the expressway, 63% are trucks.
2. Cars and trucks are the most affected road user types in accidents on the expressway.
  - Cars constitute 58% of vehicles which had at least one fatal occupant, and 45% of vehicles which had at least one seriously injured occupant.
  - Trucks constitute 30% of vehicles which had at least one fatal occupant, and 37% of vehicles which had at least one seriously injured occupant.
3. Run-off-road accidents are the accident type seen most frequently on the expressway, followed by collisions between vehicles travelling in the same direction
  - Vehicles leaving the carriageway to the left and right sides accounted for 55% of all the accidents examined.
  - Collisions with vehicles moving ahead, stopped or moving laterally in the same direction accounted for 33% of all the accidents examined.
4. Human factors have the most influence on the occurrence of all accidents, and vehicle factors have the most influence on the occurrence of fatal/ serious injury accidents.
  - Human factors alone (57%) had the highest influence on the occurrence of accidents, followed by the combination of human and infrastructure factors (22.5%) and vehicle factors alone (16.5%).
  - Vehicle factors alone (28%) had the greatest influence on a fatal/serious injury outcome, followed by a combination of human and vehicle factors (21%) and combination of vehicle and infrastructure factors (19%).
5. The main contributing factors leading to accidents on the expressway are:



6. The main contributing factors leading to fatal/serious injuries are:



7. The following actions are likely to reduce the number of accidents on the expressway:

- **Improve road markings and signage.**  
(Poor marking/signage was an infrastructure contributing factor in 9% of accidents.)
- **Provide advance warning before sharp curves.**  
(Insufficient warning was an infrastructure contributing factor in 7% of accidents.)
- **Educate the public about how to deal with breakdown/accident vehicles.**  
(Inadequate warning about such vehicles was an infrastructure contributing factor in 7% of accidents. In addition, parking a vehicle on the road was a human error contributing factor in 4% of accidents.)
- **Implement a speed management program to control speeding: match speeds to conditions, warn drivers of changes, and then enforce posted limits.**  
(Driving too fast for conditions or exceeding limits was a human error contributing factor in 30% of accidents.)
- **Install continuous rumble strips on the road margins to help prevent run-off-road accidents caused due to driver sleep/fatigue.**  
(Sleepy driving was a human error contributing factor in 29% of accidents.)
- **Provide a brake check area or a truck lay-by where truckers can check brakes or rest and wait while their brakes cool off.**  
(Brake fade was a vehicle contributing factor in 11% of accidents.)

8. The following actions are likely to reduce the number of accidents that result in fatality or serious injury on the expressway:

- **Enforce seat belt use and prohibit overloading of occupants in vehicles, particularly cars.**  
(Failure to use seat belts [46%] and overloading vehicles with passengers [6%] were, together, human error contributing factors in 52% of fatal/serious accidents on the expressway.)
- **Provide crash barriers to make rigid objects on roadside and median more crash-friendly and forgiving when impacted.**  
(Object impact was an infrastructure contributing factor in 32% of fatal/serious accidents on the expressway.)

- **Provide better crash barriers on the roadside, especially at sections with steep slopes and drop offs, to prevent rollovers.**  
(Roadside – steep slope/drop off was an infrastructure contributing factor in 12% of fatal/serious accidents on the expressway.)
- **Ensure availability of effective seat belts for trucks and buses.**  
(Seat belts not available or useable were a vehicle contributing factor in 16% of fatal/serious accidents on the expressway.)

Implementation of even a few of the measures suggested above should result in a significant reduction in the number of accidents and injuries on the expressway.

In addition, changes in vehicles, such as shifting to trucks, buses and cars with better passenger compartment integrity and crash compatibility (a vehicle contributing factor in 73% of fatal/serious accidents on the expressway), could make a big difference in injury outcome but would take many years to implement.

## APPENDIX A: ACCIDENT TYPE DEFINITION

**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 accident 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 Accident Type No. 5.

**02. Collision with another vehicle moving ahead or waiting.**

Accidents 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 Accident Type No. 1.

**03. Collision with another vehicle moving laterally in the same direction.**

Accidents 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.**

Accidents 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.**

Accidents 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 Accident 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 not considered to be pedestrians. Collisions with those persons are recorded under Accident Type No. 10-

**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 Accident Type No. 10.

**08. Run-off-road to the right.**

**09. Run-off-road to the left.**

These kinds of accidents do not involve a collision with other road users. There may, however, be further parties involved in the accident, e.g., if the vehicle involved in the accident veered off the road trying to avoid another road user and did not hit him.

**10. Accident of another kind.**

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

## APPENDIX B: ACCIDENT-PRONE SECTIONS

The Mumbai-Pune Expressway has kilometer posts running from Mumbai toward Pune. The locations of all accidents, including lane direction and mile post number, were collected during the crash investigations. Below is a representation of all accidents, plotted against the location the accident occurred (kilometer post) on the expressway. Of the 214 accidents, 113 accidents examined occurred in Pune direction, while 101 accidents occurred in the Mumbai direction. As can be seen, the ghat section of the expressway in the direction towards Mumbai, and the section of the expressway after the Kamshet tunnel are highly accident prone.

