Mumbai – Pune Expressway
Road Accident Study

Analysis of 155 Accidents examined from January to December 2016

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Mumbai – Pune Expressway Road Accident Study

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Our sincere appreciation and gratitude to all the officers of Maharashtra State Highway Police, officers of the Pune Rural, Raigad and Navi Mumbai Police and the Traffic Aid Posts (TAPs) for their support and cooperation. We are also grateful to the tow truck drivers and IRB personnel who notify us of accidents.

We are also thankful to SaveLIFE Foundation, Maharashtra State Road Development Corporation (MSRDC) and IRB Infrastructure Developers Ltd. for their cooperation in this study. We are appreciative of the fact that they are also using the data from this report for their initiative towards making the Mumbai-Pune Expressway a “Zero Fatality Corridor”.

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:

<table>
<thead>
<tr>
<th>Robert Bosch GmbH</th>
<th>Nissan Motor Company</th>
<th>Daimler AG</th>
<th>Renault SAS</th>
<th>Hyundai Motor Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honda Car India</td>
<td>Autoliv, Inc.</td>
<td>Maruti-Suzuki, Inc.</td>
<td>JP Research, Inc.</td>
<td></td>
</tr>
<tr>
<td>Toyota Motors Corp.</td>
<td>Tata Motors Limited</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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. 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 stake holders of the Mumbai – Pune Expressway (including motorists) in helping make all of our expressway journeys safer.
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 94.6 km long and is witnessing a large number of traffic crashes, fatalities and serious injuries.

This report presents findings of the contributing factors analysis done by JP Research India (JPRI) for accidents that occurred on the Mumbai-Pune Expressway and were examined by JPRI during the year 2016. This report is a follow-up to the earlier two reports on this study. The first, published in December 2013, covered 214 accidents that occurred between October 2012 and October 2013. The second, published in December 2014, covered 372 accidents studied cumulatively for the period between October 2012 and October 2014.

BACKGROUND
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 accident data collection on the Mumbai – Pune Expressway. The proposal was accepted, and since 7 October 2012, JPRI researchers have been examining accidents on-site as soon as they are informed of a crash by the police or other agents. Four years of the ongoing Mumbai – Pune Expressway study has been successfully completed.
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 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 and crash vehicles and detailed coding of the injuries sustained by the accident victims (Figure 2). 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 accident data forms, which are used to build a scientific 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 the following sections).

![Figure 2: JPRI Accident Researchers Performing On-Scene Crash Investigations](image-url)
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 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 scientific database.

What is the objective of this report?
JPRI examined and analyzed 155 road traffic crashes in detail, covering the period from January through December 2016. This report provides an in-depth analysis of these accidents, as well as an analysis of the various factors influencing accidents and injury occurrences 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. (JPRI) 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 1,50,000 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.

JPRI 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, JPRI 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 JPRI, our overriding objective is to understand Indian roads, traffic and road users in ways that can be used to save lives: ours and yours.

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. An automotive accident data collection system – based on the models used in Europe/US, but modified to suit Indian road scenario – has been initiated by a consortium of automobile original equipment manufacturing (OEM) 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, Pune, Ahmedabad, Kolkata and Jaipur, 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 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 automotive crash data for research and analysis of root causes of India's road traffic issues.

*Contact information for JPRI and RASSI is provided in Appendix A.*
2 METHODOLOGY

ACCIDENT DATA SAMPLE AND DATA ANALYSIS

JPRI researchers examined a total of 155 expressway crashes in the year 2016. These accidents involved a total of 256 road users (240 vehicles and 16 pedestrians) and resulted in 118 fatal victims and about 300 serious injury victims.

How were these accidents found?

On intimation of occurrence of any road traffic crashes to the IRB control room, they inform JPRI researchers about it. Along the course of the study, JPRI accident research team also came upon many accidents on the expressway that had not been reported to the IRB control room or the Police TAPs. These non-reported accidents were usually minor or no injury, but occasionally involved serious injuries. These 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 stations up to 2 weeks after the accident.

Although JPRI makes efforts to investigate all the road traffic crashes occurring on the MPEW, there are chances that serious-to-minor accidents might still have been missed.

Why are “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 no-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.
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 tyres, 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 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 or influencing 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.

![Venn diagram analysis](image)

**Figure 3: 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 occurrence of 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.

Figure 4 is a representation of the JPRI approach to analyzing the factors influencing the occurrence of an accident as related to, but separate from, the factors influencing the occurrence of an injury. Note that while this approach can be used even when injuries are slight to moderate, in the case of this study, the focus was on serious/fatal injuries only.

**Figure 4: A Representation of the Contributing Factors Analysis, Separating Influences on Accidents and Injuries**

**Case Study**

The following is a case study that demonstrates the above methodology.

**Accident 1:** A bus was travelling towards Pune on the left-most lane of the Expressway. Driver fell asleep causing the bus to leave the roadway to the left side. Beyond the left shoulder, bus impacted wired rope safety barrier (WRSB) causing it to deflect back on the road. Due to steering maneuver of the driver after the WRSB impact and the deflection provided by the WRSB, the vehicle rolled over and started sliding on the road surface. The vehicle while still sliding, went to right side of the road and impacted the WRSB on the median before finally coming to rest on the road itself. Occupants of bus suffered minor injuries.

**Accident 2:** A bus was travelling towards Mumbai on the Expressway on the right most lane. Driver fell asleep causing the bus to enter the median on the right. Bus crossed median and entered the opposite travel direction where it impacted another bus. Due to the impact, 1 occupant of second bus, who had leaned out of the emergency window during the impact, was fatal while few occupants of first bus suffered serious injuries. The first bus moved ahead after the impact and came to rest after impacting a mountain wall to the left of the second bus’s travel direction.
<table>
<thead>
<tr>
<th>Scene Photos – Taken along the direction of vehicle’s travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Photos – Damages sustained by the vehicle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accident 1</th>
<th>Accident 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scene Photos</td>
<td>Scene Photos</td>
</tr>
<tr>
<td>Vehicle Photos</td>
<td>Vehicle Photos</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Injury severity</th>
<th>Minor</th>
<th>Fatal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contributing factors – Accident</td>
<td>Driver Sleepy</td>
<td>Driver Sleepy</td>
</tr>
<tr>
<td>Contributing factors – Injuries</td>
<td>Not applicable (Minor injury)</td>
<td>Occupant leaning out of window (for fatal victim)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Object Impact – Mountain wall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passenger Compartment Intrusions (for seriously injured victims)</td>
</tr>
</tbody>
</table>

**Figure 5: Example demonstrating variability of injury outcomes from similar accident contributing factors**
Both accidents involved similar vehicles (buses) in similar conditions wherein the vehicles left the road due to driver fatigue. However the injury outcomes were different in both the cases. In the first accident, occupants were able to walk away from the accident with very minor to no injuries, while in the latter, there was a fatality and a few seriously injured victims.

As the figure 5 demonstrates, the event that primarily led to the occurrence of the accident was similar in both accidents: leaving the roadway. In the first case however the vehicle was prevented by the WRSB from leaving the carriageway. The vehicle had little damage and occupants suffered just minor bruises. In the other case, the vehicle left the roadway and impacted another vehicle on the oncoming lane. It then went ahead to have 2 more impacts with other objects on the median and off the roadway (concrete structure in median, and mountain wall). While the fatality in the case was primarily because of the occupant of the impacted vehicle leaning out of the emergency exit door, the serious injuries in both the vehicles was because of the passenger compartment intrusions and the object impacts. In this case, had there been an effective barrier to prevent the impacting vehicle from leaving the road into the median and then onto the oncoming lane, the injury outcomes would have been less severe.

This case study not only shows the effectiveness of WRSBs, but also shows how such a barrier can reduce the influence of other factors that can cause injuries to vehicle occupants.

**Effectiveness of wire rope safety fence barriers in reducing crashes and injuries.**

In a study, conducted by Monash University Accident Research Center (Australia), to determine the effectiveness of wire rope safety fence barriers, it was found that these barriers have a significant reductive effect on crashes.

“On individual routes that produced statistically significant findings, flexible barriers were estimated to reduce all casualty crashes by between 75% and 77%, and serious casualty crashes by between 76% and 77%. Targeted off-road and head-on crashes were reduced by between 79% and 85% (casualty crashes), and 83% and 87% (serious casualty crashes).”

3 DATA ANALYSIS

The 155 road traffic crashes examined by JPRI for the year 2016 under the ongoing Mumbai – Pune Expressway study were analyzed to determine the characteristics of accidents on the expressway.

DISTRIBUTION OF ACCIDENTS BY HIGHEST INJURY SEVERITY

The distribution of the 155 road traffic crashes by injury severity (based on the most severe injury sustained by any human involved in each accident) is shown in Figure 6.

**Figure 6: Distribution of 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 155 accidents were plotted against time durations of 6 hours (figure 7) to identify times of occurrence. The data shows highest percentage of accidents (34%, 54 accidents by count) occurred between 06:00 to 11:59 hrs. The highest percentages of accidents resulting in fatal/serious injury occurred during the time periods of 00:00 to 05:59 hrs and 06:00 to 11:59 hrs (31.5%, 31 accidents by count).

![Figure 7: Percentage Distribution of Accidents by Time of Occurrence](image)

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

VEHICLES/ROAD USERS INVOLVED

A total of 256 vehicles/road users (240 vehicles and 16 pedestrians) were involved in the 155 expressway crashes examined in the year 2016. Figure 8 shows the percentage distribution of the types of vehicles/road users involved in these accidents.

![Figure 8: Percentage Distribution of Vehicle/Road User Type Involved](image)

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. For purposes of this report, all persons injured on the expressway outside of a vehicle are considered as pedestrians.
Findings show that the type of vehicles/road users most often involved in accidents on the expressway are cars (41%, 105 by count) and trucks (40%, 103 by count); these are also the most common road users seen on the expressway.

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

Figure 9 shows the percentage distribution of vehicles/road users based on the highest injury severity of the vehicle occupants / pedestrians. 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 does the percentage reflect 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 54% (36 cars by count) of vehicles which had at least one fatal occupant and 71% (57 cars by count) of vehicles which had at least one seriously injured occupant. Trucks, which have almost the same involvement in accidents as that of cars, as seen in figure 8, have the second highest share of fatal or serious injuries. Trucks constitute 21% (14 trucks by count) of vehicles which had at least one fatal occupant, and 18% (14 trucks, by count) of vehicles which had at least one seriously injured occupant.

Pedestrians account for only 6% of the 256 road users involved in the 155 expressway crashes analyzed for this study (see figure 8); however, figure 9 shows that they account for 16% (11 pedestrians, by count) of fatal road users and 5% (4 pedestrians, by count) of road users in serious injury accidents.

ACCIDENT TYPES

Figure 10 shows the distribution of the 155 accidents (including the 99 fatal/serious accidents) as categorized by accident type. The ten accident types used in coding for this study 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.

JP Research India Pvt. Ltd. | Mumbai – Pune Expressway Road Accident Study (2016)
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 (involves crashes not covered by the other categories, such as truck jack-knifing, fires, and rollovers on the carriageway).

As can be seen from figure 10, “run-off-road” crashes account for 52% of all accidents and 51% of fatal/serious injury accidents. “Run-off-road” crashes constitute nearly half the accidents on the expressway. This indicates that a large number of crashes involve a vehicle driving off the road as a result of the driver losing control of the vehicle due to over speeding or due to sleep/fatigue. These accidents are followed by collision with another vehicle “moving ahead or waiting”, accidents of another kind, collision with another vehicle “which starts, stops or is stationary” and collision with another vehicle “moving laterally in the same direction”. Together they constitute 40% of all accidents and 43% of fatal/serious injury accidents.
4 CONTRIBUTING FACTORS ANALYSIS
To determine the contributing factors influencing the occurrence of accidents, each of the 155 road traffic crashes were analyzed in detail. In addition, the contributing factors influencing the occurrence of serious or fatal injury in 99 of these crashes were also analyzed in detail.

ANALYZING ACCIDENT AND INJURY OCCURRENCE
Factors Influencing Occurrence of Accidents (155 accidents)
A distribution by contributing factors (human/vehicle/infrastructure) for the 155 road traffic crashes analyzed for this study is shown in the Venn diagram (Figure 11). This diagram shows that human factors alone (66%) had the highest influence on the occurrence of accidents, followed by the combination of human and infrastructure factors (20%).

![Venn Diagram showing the percentage distribution of accidents by contributing factors.](image)

**Figure 11: Distribution of 155 Accidents by Contributing Factors influencing the Occurrence of Accidents**

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

<table>
<thead>
<tr>
<th>Factor</th>
<th>Alone</th>
<th>All Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>66%</td>
<td>93%</td>
</tr>
<tr>
<td>Vehicle</td>
<td>5%</td>
<td>12%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>3%</td>
<td>24%</td>
</tr>
</tbody>
</table>

When the overlapping combinations are considered, infrastructure factors, which were far down on the list of influences (3%), moves up past vehicle factors.
Factors Influencing Occurrence of Injuries (99 fatal/serious accidents)

Of the 155 crashes, 99 crashes involved fatal or serious injury to at least one occupant or pedestrian. These 99 fatal or serious crashes 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 12). This diagram shows that vehicle factors alone (34%) had the greatest influence on a fatal/serious injury outcome, followed by combination of human and vehicle factors (27%) and combination of human, vehicle and infrastructure factors (16%).

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

<table>
<thead>
<tr>
<th>Factor</th>
<th>Alone</th>
<th>All Combinations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human</td>
<td>9%</td>
<td>57%</td>
</tr>
<tr>
<td>Vehicle</td>
<td>34%</td>
<td>84%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>1%</td>
<td>29%</td>
</tr>
</tbody>
</table>

When the overlapping combinations are considered, infrastructure factors, which were again far down on the list (showing only a 1% influence), make a surprising showing. Human factors, too, show a robust influence when considered in combination, particularly with vehicle factors.
HUMAN FACTORS INFLUENCING ACCIDENT OCCURRENCE

For the 155 crashes 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 (93%). Also factors with negligible counts have not been included in the table for analysis.

<table>
<thead>
<tr>
<th>Contributing Human Factors (Accident Occurrence)</th>
<th>Number of Accidents</th>
<th>% Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improper lane change / lane usage (26 Cars, 11 Trucks, 2 Buses, 2 Mini-truck, 5 Unknown Vehicle)</td>
<td>47</td>
<td>30%</td>
</tr>
<tr>
<td>Speeding - exceeding speed limit (41 Cars, 4 Trucks)</td>
<td>45</td>
<td>29%</td>
</tr>
<tr>
<td>Driver – Sleep/Fatigue/Drowsiness (27 Trucks, 14 Cars, 1 Bus)</td>
<td>42</td>
<td>27%</td>
</tr>
<tr>
<td>Speeding - excessive speed for conditions (8 Cars, 7 Trucks, 2 Buses)</td>
<td>17</td>
<td>11%</td>
</tr>
<tr>
<td>Driver Inattention (11 Cars, 1 Mini-truck, 1 Bus)</td>
<td>13</td>
<td>8%</td>
</tr>
<tr>
<td>Overtaking on left side of vehicle (8 Cars, 1 Truck)</td>
<td>9</td>
<td>6%</td>
</tr>
<tr>
<td>Parked vehicle on road (Full or Partial) (6 Trucks, 1 Car, 1 Bus)</td>
<td>8</td>
<td>5%</td>
</tr>
<tr>
<td>Driving too slow for conditions (2 Trucks, 1 Mini-truck, 1 Bus)</td>
<td>4</td>
<td>3%</td>
</tr>
<tr>
<td>Following too closely (2 Buses, 1 Car, 1 Truck)</td>
<td>4</td>
<td>3%</td>
</tr>
</tbody>
</table>

**Table 1: Contributing Human Factors Influencing the Occurrence of 155 Accidents**

As can be seen from Table 1, improper lane change, speeding, driver sleep/fatigue and overtaking from the wrong (left) side account for the largest percentage 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. However, the company is aware of solutions that have been implemented in other parts of the world and are readily available; have been 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.
**Speeding: exceeding speed limit — 29%**  
(*41 Cars, 4 Trucks*)

**Speeding: excessive speed for conditions — 11%**  
(*8 Cars, 7 Trucks, 2 Buses*)

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 larger is the distance travelled by the driver during reacting and braking. 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 tyre, or insufficient distance to allow the driver to react and avoid the collision that leads to the accident.*

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

Even though the expressway has posted speed limits, drivers often ignore these or consider them inappropriate for the vehicle they are driving (e.g., 50km/h is a good speed for a heavy truck, but not for their responsive lighter 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\textsuperscript{th} 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.  
Improper lane change — 30%
(26 Cars, 11 Trucks, 5 Unknown Vehicles, 3 Buses, 2 Minitrucks)

Overtaking from left side of other vehicle — 6%
(8 Cars, 1 Truck)

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 or wrongly overtaking another vehicle ahead in its travel lane from the left, catching other drivers by surprise. Many motorists have been observed changing lanes or overtaking from left 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: Forward Collision Warning

In addition to the lane departure warning systems previously mentioned, engineered warning systems designed to monitor the road ahead for collision possibilities are available on some vehicles. These provide object recognition and detect relative speeds between a vehicle and objects on the road. If the closing speed represents a risk of an impending collision, drivers are alerted. In some models, the vehicle will even assist with sudden braking or steering, depending on the information given by the vehicle sensors and the electronic control module's comparison algorithms. Such warning systems serve not only to detect improper lane changes by others but also to alert the driver in case of improper lane usage or the presence of any fixed/moving objects on the carriageway.

Driver sleep / fatigue — 27%
(27 Trucks, 14 Cars, 1 Bus)

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, 67% of sleep/fatigue-influenced truck accidents were observed between 00:00 and 06:00 hrs, as shown in Figure 13. In the case of car accidents, however, 71% of the sleep/fatigue accidents occurred during daylight hours.
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 designed to alert 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.

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. These vehicle systems can alert the drivers when they depart a dedicated lane without proper indication and hence effectively countercheck both driver drowsiness as well as improper lane usage/change.
VEHICLE FACTORS INFLUENCING ACCIDENT OCCURRENCE

For the 155 crashes 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 (12%). Also factors with negligible counts have not been included in the table for analysis.

<table>
<thead>
<tr>
<th>Contributing Vehicle Factors (Accident Occurrence)</th>
<th>Number of Accidents</th>
<th>% Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Defective Tyres (9 Cars, 2 Trucks)</td>
<td>11</td>
<td>7%</td>
</tr>
<tr>
<td>Defective Brakes (2 Trucks, 1 Bus)</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>Absence of reflectors (3 Truck)</td>
<td>3</td>
<td>2%</td>
</tr>
</tbody>
</table>

TABLE 2: CONTRIBUTING VEHICLE FACTORS INFLUENCING THE OCCURRENCE OF 155 ACCIDENTS

Of all vehicle factors contributing to an accident, defective tyres of passenger vehicles (cars) influenced the most accidents (7%).

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.

**Defective Tyres (Tyre burst) — 7% (9 Cars, 2 Trucks)**

The tyre defects seen in the course of this study were associated with vehicles running at high speeds and/or running on poorly maintained tyres (tread depth very low, incorrect inflation pressure). While definitive investigation of tyre bursts and defects requires detailed tyre investigation, analysis and testing, which is outside of the scope of this study, researchers were able to confidently identify 11 accidents where a tyre burst was a contributing factor. Around half of the car accidents involving tyre burst also had “over speeding” as contributing factor to accidents.

**Solutions? First identify causes.**

*A scientific study conducted with the cooperation of tyre companies and the transport department can help identify specific problem areas causing defects that lead to tyre failures. Such studies can also help in determining the necessary preventive measures that can be put in place by manufacturers and retailers (particularly storage practices) and preventive maintenance that can be carried out by drivers to avoid tyre-related accidents.*
Defective Brakes — 2%  
(2 Trucks, 1 Bus)

Even though the contributing factor of ‘Defective Brakes’ only accounted for 2% of the road traffic crashes (3 crash counts in number), it is an important phenomenon to be noted. In all the 3 crashes the defect in the brakes was due to a phenomenon called as ‘Brake Fading’

“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.

All the 3 crashes that occurred in the year 2016 due to brake fading happened on the downhill ghat section of the Mumbai corridor of the expressway.

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

**Road engineering: Truck brake check areas**

A brake check area is a safety measure that allows truckers an area 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 photo shows a runaway truck escape ramp in China. (Source: Wikipedia)
INFRASTRUCTURE FACTORS INFLUENCING ACCIDENT OCCURRENCE

For the 155 crashes 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%). Also factors with negligible counts have not been included in the table for analysis.

<table>
<thead>
<tr>
<th>Contributing Infrastructure Factors (Accident Occurrence)</th>
<th>Number of Accidents</th>
<th>% Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder – Narrow/None (10 Cars, 2 Trucks, 2 Buses, 1 Mini-truck)</td>
<td>15</td>
<td>10%</td>
</tr>
<tr>
<td>Sharp Road Curvature (5 Trucks, 2 Cars, 2 Buses)</td>
<td>9</td>
<td>6%</td>
</tr>
<tr>
<td>Inadequate Warning about accident/parked vehicle (3 Cars, 2 Buses, 1 Truck)</td>
<td>6</td>
<td>4%</td>
</tr>
<tr>
<td>Slippery Road Surface (2 Cars, 1 Truck)</td>
<td>3</td>
<td>2%</td>
</tr>
<tr>
<td>Work-zone (1 Truck, 1 Bus)</td>
<td>2</td>
<td>1%</td>
</tr>
</tbody>
</table>

**Table 3: Contributing Infrastructure Factors Influencing the Occurrence of 155 Accidents**

Shoulder – Narrow/None (10%), Sharp Road Curvatures (6%), Inadequate warning about accident/parked vehicles (4%) and Slippery Road Surface (2%) together influenced 22% of all accidents.

Countering Infrastructure Factors that Contribute to Accidents

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

**Shoulder - Narrow / None — 10% (10 Cars, 2 Trucks, 2 Buses, 1 Mini-truck)**

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.

![Due to encroachment of another vehicle into its travel lane, this vehicle (Bus) had to steer to the right. Due to the narrow shoulder on the right, the vehicle impacted the jersey wall on the side and came to rest there. No occupants were injured.](image)

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 — 6% (5 Trucks, 2 Cars, 2 Buses)**

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 14 shows the locations where the 9 accidents due to sharp curvature occurred.
Inadequate warning about accident/parked vehicle — 3% (3 Cars, 2 Buses, 1 Truck)

When vehicles break down, what do the drivers do? Most drivers do not give this any thought, 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 indicators such as emergency road flares or reflective “breakdown” signs, particularly in
low visibility conditions or after a blind corner, an accident becomes a high probability, as the examples in Figure 15 showcase.

Figure 15: 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?

The government needs to put in an effective accident/breakdown management system which will allow the road authorities to be informed about an accident/breakdown as soon as it happens. This will help them take precautionary measures to ensure that drivers passing by are informed well in advance about the traffic conditions ahead, and thereby prevent any collisions with accident/breakdown vehicles on the roadway. Some countries have created emergency systems (flashing lights, fold-out signs) that could be activated by stranded motorists. This could also be incorporated into the roadside infrastructure along the more dangerous sections.

In the absence of such a system in the expressway, 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. In addition, a public information campaign to warn of the dangers of stopping without warning, and to provide sensible advice, such as the following, could help expressway users keep themselves and their fellow travelers safe.
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 (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 tyre changing. Call them and ask for help, especially at night. They are here to help you and keep you safe.
- 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 in accidents with parked/broken down vehicles. Stand 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.
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 tyre, do not attempt to change it unless you can get to the side of the road and the tyre is on the side of the vehicle that is safely away from traffic.

Slippery Road Surface – 2%
(2 Cars, 1 Truck)
The road can get slippery due to water accumulating on its surface. Even though there are drains available all along the expressway to drain away the rain water, there are certain locations where due to the geometry of the surface some water gets accumulates causing the road to become slippery.

If there’s a lot of water on the road, including standing water in puddles, even more severe loss of friction can occur. In these cases, a car's tyres can completely lose contact with the road surface as they surf along on a thin layer of water. When this occurs, it's called hydroplaning, and it can be very dangerous.

Figure 16: An Expressway Accident Influenced by Slippery Road Surface

It must however be noted that even though slippery road surface is an infrastructure issue, poor tyre conditions can aggravate the chance of crash occurrences. It is imperative that vehicle users
maintain their tyres well. Extra care needs to be taken regarding maintenance of tyres during monsoons as the road conditions remain wet for most of the time in this season.

In 2003, the British Rubber Manufacturers Association (BRMA) commissioned MIRA to study the effects of tread depth on stopping distances. The study was carried out on MIRA’s test track in Nuneaton (England), and 5 different tread depths were tested - 6.7mm, 4.1mm, 2.6mm, 1.6mm (the legal minimum) and 0.9mm. Vehicles were mounted with equipment to record time, speed, and distance. The tests were carried out on two different surfaces at the testing track, hot rolled asphalt and smooth concrete. In order to ensure the accuracy of the results, the tests were repeated several times. The stopping distance from 80kmph was recorded at each of these tread depths and the points plotted on a graph of stopping distance versus tread depth. A line was drawn through the points to show the trend between stopping distance and tread depth, from which information could be taken.

The test results are displayed in the graph above. The stopping distance is different for the two road surfaces due to their different water retention properties. From the graph of results, it can be seen that the stopping distances in the wet start to increase dramatically at tread depths of below 3mm.

At the legal minimum tread depth of 1.6mm, the stopping distance is increased by 36.8% on the hot rolled asphalt and 44.6% on the smooth concrete.

HUMAN FACTORS INFLUENCING INJURY OCCURRENCE

For the 155 crashes examined, 99 crashes 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 (57%).

<table>
<thead>
<tr>
<th>Contributing Human Factors (Injury Occurrence)</th>
<th>Number of Accidents</th>
<th>% Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seat belt not used (55 Cars, 1 Minitruck)</td>
<td>55</td>
<td>57%</td>
</tr>
<tr>
<td>Overloading of occupants (1 Car, 1 Truck)</td>
<td>2</td>
<td>2%</td>
</tr>
</tbody>
</table>

Table 4: Contributing Human Factors Influencing the Occurrence of Fatal/Serious Injury in 99 Fatal/Serious Accidents

As can be seen from Table 4, lack of seat belt use and overloading of occupants influenced injury occurrence in 57% of fatal/serious injury accidents.

Countering Human Factors that Contribute to Injury

**Seat belt not used — 57% (55 Cars, 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.

In fact, even those protected by driver and passenger airbags need to wear seat belts, as shown in Figure 22. It is possible for an unrestrained occupant to move out of the effective protection zone of the airbag and sustain serious (preventable) injury. Hence, it is very important that all occupants in a vehicle wear seat belts.
The illustration to the left showcases how seat belts are important for effective usage of airbags in mitigating injuries in vehicular frontal collisions.

As shown, seat belts restrict the movement of an occupant during the collision, which facilitates the proper inflation and deflation of airbags. Unrestrained occupants can hinder the proper functioning of the airbag, resulting in serious injuries.

**Figure 17: Why Seat Belts Should Be Worn Even in Vehicles with Airbags.**

**Overloading of occupants — 2% (1 Car, 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. As is recognized the world over, such overloading can have serious consequences, particularly in an accident situation.

A clear and detailed listing of the dangers, as posted online by the National Road Safety Council of Jamaica, is provided below (next page).

**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.
From the NATIONAL ROAD SAFETY COUNCIL, Jamaica

______________________________

Why Vehicles Must Not Be Overloaded

Beyond Their Seating Capacity

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 tyres 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](http://www.nationalroadsafetycouncil.org.jm/articles/overloading.htm)
VEHICLE FACTORS INFLUENCING INJURY OCCURRENCE

For the 155 crashes examined, 99 crashes 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 (84%). Also factors with negligible counts have not been included in the table for analysis.

<table>
<thead>
<tr>
<th>Contributing Vehicle Factors (Injury Occurrence)</th>
<th>Number of Accidents</th>
<th>% Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Compartment Intrusion - Other (32 Cars, 11 Trucks, 6 Buses, 1 Minitruck)</td>
<td>50</td>
<td>51%</td>
</tr>
<tr>
<td>Ejection (15 Cars, 5 Buses)</td>
<td>20</td>
<td>20%</td>
</tr>
<tr>
<td>Seatbelts not available (9 Trucks, 5 Buses, 3 Cars, 1 Minitruck)</td>
<td>18</td>
<td>18%</td>
</tr>
<tr>
<td>Passenger Compartment Intrusion – Underride/Override (12 Cars, 2 Trucks, 1 Bus)</td>
<td>15</td>
<td>15%</td>
</tr>
<tr>
<td>Run-over (4 Trucks, 2 Cars, 1 Bus)</td>
<td>7</td>
<td>7%</td>
</tr>
<tr>
<td>Unsecured Cargo (4 Trucks, 1 Car)</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Entrapment (3 Trucks, 1 Car, 1 Bus)</td>
<td>5</td>
<td>5%</td>
</tr>
</tbody>
</table>

Table 5: Contributing Vehicle Factors Influencing the Occurrence of Fatal/Serious Injury in 99 Fatal/Serious Accidents

As can be seen from the table, passenger compartment intrusions (due to underride/override and other) influenced injury occurrence in 65% of the fatal/serious accidents.

Countering Vehicle Factors that Contribute to Injury

**Passenger compartment intrusion – other — 51% (32 Cars, 11 Trucks, 6 Buses, 1 Minitruck)**

**Passenger compartment intrusion – underride/override — 15% (12 Cars, 2 Trucks, 1 Bus)**

Passenger vehicles are usually designed so that, during an impact accident, the passenger cabin (where the driver and passengers sit) resists 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, 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 suffers in the real world in India.
**What is passenger compartment intrusion?**
Reduction in the occupant survival space is termed 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 18.

![Collisions Types for Passenger Compartment Intrusions in 44 Cars](image)

**Collisions Types for Passenger Compartment Intrusions in 44 Cars**
- Collisions with Trucks: 41%
- Rollovers: 25%
- Object Impacts: 25%
- Collision with Cars: 9%

![Collisions Types for Passenger Compartment Intrusions in 13 Trucks](image)

**Collisions Types for Passenger Compartment Intrusions in 13 Trucks**
- Collisions with Trucks: 62%
- Object Impacts: 31%
- Rollovers: 8%

*Figure 18: ‘Passenger Compartment Intrusion’ Collisions 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. Rear underride guards can be required (and placement enforced) on trucks and trailers of a certain height, for example. While not a perfect solution, it theoretically directs the point of impact to the smaller vehicle’s crumple zone rather than into the cabin. Object impacts and rollovers, too, need to be studied to determine ways to make 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.

Ejection – 20%  
(15 Cars, 5 Buses)  

‘Ejection’ is the phenomenon of a vehicle occupant being ejected out of the vehicle, either completely or partially, due to the impact forces acting on them during the crash. On further analysis of the 10 crashes that had ejection as one of their injury causing factors, it was found out that all these 10 crashes involved rollover as one of the crash events. The distribution of ejection medium for ejected occupants in these crashes can be found out in figure 19.

![Figure 19: Distribution of Crashes with Ejection as an Injury Causal Factor, By Ejection Medium](image)

These crashes were also checked for availability and usage of seat-belts in the vehicles involved. In 70% of these crashes, vehicle occupants did not use seat-belts, and in the balance 30%, seat belts were not available for use.
INFRASTRUCTURE FACTORS INFLUENCING INJURY OCCURRENCE

For the 155 crashes examined, 99 crashes 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 (29%). Also factors with negligible counts have not been included in the table for analysis.

<table>
<thead>
<tr>
<th>Contributing Infrastructure Factors (Injury Occurrence)</th>
<th>Number of Accidents</th>
<th>% Influenced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object Impact - Roadside/Median - Manmade Structures (14 Cars, 5 Trucks, 2 Buses)</td>
<td>21</td>
<td>21%</td>
</tr>
<tr>
<td>Object Impact - Roadside - Trees/Plants (4 Cars, 1 Bus)</td>
<td>5</td>
<td>5%</td>
</tr>
<tr>
<td>Object Impact - Roadside – Other (2 Cars, 2 Trucks)</td>
<td>4</td>
<td>4%</td>
</tr>
<tr>
<td>Roadside - Steep Slope/Drop off (1 Car, 1 Truck, 1 Bus)</td>
<td>3</td>
<td>3%</td>
</tr>
</tbody>
</table>

**Table 6: Contributing Infrastructure Factors Influencing the Occurrence of Fatal/Serious Injury in 99 Fatal/Serious Accidents**

As can be seen from the table, man-made structures and trees/plants along the side of the road or in the median, and roadside steep slopes and drop offs influenced injury occurrence in 33% 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.

- **Object Impact - Roadside/Median - Manmade Structures — 21%**
  - (14 Cars, 5 Trucks, 2 Buses)
- **Object Impact - Roadside - Trees/Plants — 5%**
  - (4 Cars, 1 Bus)
- **Object Impact - Roadside - Other — 4%**
  - (2 Cars, 2 Trucks)

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 study period.

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, curb stones, etc. Some of these may look harmless, but in the event of an impact, these can be quite devastating for vehicles and 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”.

<table>
<thead>
<tr>
<th>Object Impact</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roadside / Median Concrete Structures</td>
<td>37%</td>
</tr>
<tr>
<td>Trees</td>
<td>17%</td>
</tr>
<tr>
<td>Mountain Wall</td>
<td>13%</td>
</tr>
<tr>
<td>Jersey Barrier</td>
<td>10%</td>
</tr>
<tr>
<td>Kerb Stones</td>
<td>10%</td>
</tr>
<tr>
<td>Overhead bridge pillar</td>
<td>10%</td>
</tr>
<tr>
<td>Metal Guardrail</td>
<td>3%</td>
</tr>
</tbody>
</table>

**Figure 20: Distribution of Object Impact accidents on the Expressway; by type of object impacted**

JP Research India Pvt. Ltd. | Mumbai – Pune Expressway Road Accident Study (2016)
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 are, in contrast, 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.

Figure 21: Examples of Impact Attenuators

For roadside trees, it is imperative that a proper crash barrier be provided all along the road edge if a clear zone cannot be provided off the road edge.
Roadside - Steep Slope/Drop off — 3%
(1 Car, 1 Truck, 1 Bus)

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 the crash scene photos in Figure 22 show.

Figure 22: Examples of Steep Slope/Drop off Crashes on the Expressway

The Value of 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 to retrofit, but can be planned for in the design stage. 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.”

5 CONCLUSIONS

Based on the 155 accidents investigated by JPRI accident researchers on the Mumbai – Pune Expressway for the year 2016, this study concludes the following:

1. The 155 crashes examined in 2016 include 63 fatal crashes (41%) and 36 serious injury crashes (23%). These crashes resulted in 118 fatal victims and about 300 serious injury victims.

2. Cars and trucks are highly involved in accidents on the expressway. Together they form over 80% of the vehicles involved in accidents on the expressway.

3. Cars and trucks are the most affected road user types in accidents on the expressway.
   - Cars constitute 54% of vehicles which had at least one fatal occupant, and 71% of vehicles which had at least one seriously injured occupant.
   - Trucks constitute 21% of vehicles which had at least one fatal occupant, and 18% of vehicles which had at least one seriously injured occupant.

4. 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 running-off the roadway to the left and right sides accounted for 52% of all the accidents examined.
   - Collisions with vehicles moving ahead, stopped or moving laterally in the same direction accounted for 30% of all the accidents examined.

5. The top contributing factors influencing the occurrence of accidents on the expressway are:

<table>
<thead>
<tr>
<th>Human (93%)</th>
<th>Vehicle (12%)</th>
<th>Infrastructure (24%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speeding (40%)</td>
<td>Defective Tyres (7%)</td>
<td>Narrow / No Shoulder (10%)</td>
</tr>
<tr>
<td>Lane changing (30%)</td>
<td>Brake fade (2%)</td>
<td>Sharp Road Curvature (6%)</td>
</tr>
<tr>
<td>Driver sleep/fatigue (27%)</td>
<td>Absence of reflectors (2%)</td>
<td>Inadequate warning about accident/broken down vehicle (4%)</td>
</tr>
</tbody>
</table>

6. The top contributing factors influencing the occurrence of fatal/serious injuries on the expressway are:

<table>
<thead>
<tr>
<th>Human (57%)</th>
<th>Vehicle (84%)</th>
<th>Infrastructure (29%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seatbelts not used (57%)</td>
<td>Passenger compartment intrusion (66%)</td>
<td>Object impact (30%)</td>
</tr>
<tr>
<td>Overloading of occupants (2%)</td>
<td>Ejection (20%)</td>
<td>Road side - steep slope/drop off (3%)</td>
</tr>
<tr>
<td></td>
<td>Lack of seat belts (18%)</td>
<td></td>
</tr>
</tbody>
</table>
7. The following actions are likely to reduce the number of accidents on the expressway:

- Implement a speed management program to control speeding: match speeds to conditions, warn drivers of changes, and then enforce posted speed limits.
  (Driving too fast for conditions or exceeding limits was a contributing human factor in 40% of accidents.)

- Educate drivers regarding proper lane change behavior and later conduct enforcement for curbing improper lane change maneuvers by drivers.
  (Improper lane change was a contributing human factor in 30% of the accidents.)

- Educate the public about how to deal with breakdown/accident vehicles.
  (Inadequate warning about such vehicles was a contributing infrastructure factor in 4% of accidents. In addition, parking a vehicle on the road was a contributing human factor in 5% of accidents, and tyre burst, which often leads to inconvenient, barely off-road parking, was a contributing vehicle factor in 7% of accidents. The use of clean and effective red reflectors in the back of the vehicle also needs to be promoted, as they increase the conspicuity of the parked/broken down vehicles at night.)

- Promote the use of the expressway authority helplines for breakdown/accident vehicles.
  (The expressway authority must encourage drivers to call and inform of breakdown/accident vehicles immediately so that the emergency roadside assistance teams can provide necessary help quickly and also cordon off the lanes to ensure safe passage of traffic.)

- Provide reflective signage and chevron markers before sharp curvatures to warn drivers in advance.
  (Accidents at sharp curvatures constitute 6% of all accidents examined on the expressway.)

- Provide a brake check area or a truck lay-by where truckers can check brakes and/or rest and wait while their brakes cool off.
  (Brake fade was a vehicle contributing factor in 2% 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 27% of accidents.)

- Provide at least 3m width of shoulders on both sides of the roadway to allow drivers of run-off road vehicles to regain control.
  (Narrow/no shoulders were the contributing factors in 10% of the accidents.)

8. The following actions are likely to reduce the number of fatalities and serious injuries on the expressway:

- Enforce seat belt use and prohibit overloading of occupants in vehicles, particularly in cars.
  (Failure to use seat belts [57%] and overloading vehicles with passengers [2%] were, together, major contributing human factors in fatal/serious accidents on the expressway. The contributing vehicle factor of ejection [20%] was also primarily an outcome of non-
usage of seatbelts.)

- Provide impact attenuators to make rigid objects on roadside and median more crash-friendly and forgiving when impacted. Also provide crash barriers, in such locations, on both roadside and the median to avoid vehicles leaving the carriageway. (Object impact—all types—was a contributing infrastructure factor in 30% 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 a contributing infrastructure factor in 3% of fatal/serious accidents on the expressway.)

- Ensure that pedestrians/motorcyclists are kept away from the high speed traffic of the Expressway. (Run-over was a contributing factor for fatal/serious injuries in 7% of cases. The runover cases investigated in the year 2016 include pedestrians alone. However, it is also possible for motorcyclists to be run-over and hence the enforcement needs to be present to ensure that pedestrians and motorcyclists are kept away from the high-speed traffic of the MPEW.)

- Ensure availability of effective seat belts for trucks and buses. (Seat belts not available or useable was a vehicle contributing factor in 18% 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 66% of fatal/serious accidents on the expressway), and effective seat belts, could make a big difference in injury outcome but would take many years to implement.
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: 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 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 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 C: 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 155 crashes, 87 crashes occurred in Mumbai direction, while the remaining 68 crashes occurred in the Pune 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 towards Pune are highly accident prone.