Determination of crash barrier runout lengths for expressways in India based on crash data analysis.

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ABSTRACT

An analysis of crash data from the Mumbai Pune Expressway between October 2012 and September 2016 (4 years) showed that 51% of the crashes (390 out of 773) investigated were run-off from road crashes. Of the 390 run-off road crashes, 66% (256 out of 390) had an object impact subsequent to the vehicle leaving the carriageway. For the purpose of this study, 70 crashes involving run-off road vehicles impacting trees, overhead bridge pillars, underpasses and concrete structures were selected and studied. It was found that collectively these 4 roadside/median hazards contributed to 11% of fatalities and 7% of seriously injured victims. Further analyses of the 70 crashes also showed that crash barriers were provided only in 6% (4 out of 70) of the crash locations. In all the 4 locations where crash barriers were available during the time of impact, the length of the installed crash barriers was not effective in preventing the run-off vehicles from impacting the roadside/median obstacles. The objective of this study is to determine the minimum upstream length of guardrails required for these roadside/median hazards on the expressway using crash data analysis. The findings of the analysis recommended a desired minimum runout lengths of 60 meters, 46 meters, 47 meters and 47 meters of guardrail installation for the hazards concrete structures, trees, overhead bridge pillars and underpasses respectively.

Keywords: crash barriers, upstream length, crash data analysis

INTRODUCTION

Researchers have been conducting on-site crash investigations and in-depth scientific crash data collection and analysis on the Mumbai Pune Expressway (MPEW) since October 2012. This scientific initiative is being conducted with the cooperation of the Maharashtra State Highway Police and the Maharashtra State Road Development Corporation. Crash investigators are notified of road accidents on the expressway either by the police or by the expressway control room. As soon as a notification is received, a team of crash investigators visit the scene and conduct a scene examination, and vehicle examination. This is followed up by injury data collection and victim interviews, whenever possible. The data is coded in a scientific database and any personal information such as victim names, contact numbers, vehicle registration numbers, etc. are anonymized. The scientific crash investigation is conducted with the objective of identifying and quantifying all the infrastructure, vehicle and human factors contributing to accidents and injuries on the expressway. The crash data collected from October 2012 to September 2016 is the base data used for the analysis of this study and consists of 773 road traffic crashes that resulted in a total of 500 fatal and over 1600 seriously injured victims.

Analysis of the 773 road traffic crashes indicate that 51% (390 out of 773) of the road traffic crashes examined were run-off road crashes, while 66% (256 out of 390) of these run-off road crashes involved an impact with a roadside/median obstacle subsequent to the vehicle running-off the roadway. Figure 1 shows the distribution of the roadside/median obstacles that were impacted by run-off road vehicles in the 256 crashes.

For each of these obstacles, the resulting injury severity of the crash was also available in the data. This was used to determine a fatal/serious injury rate for each obstacle based on the below formula:

$$Injury\ severity\ rate\ (\%) = \frac{Number\ of\ crashes\ involving\ fatal\ or\ serious\ injury}{Total\ number\ of\ crashes} \times 100$$

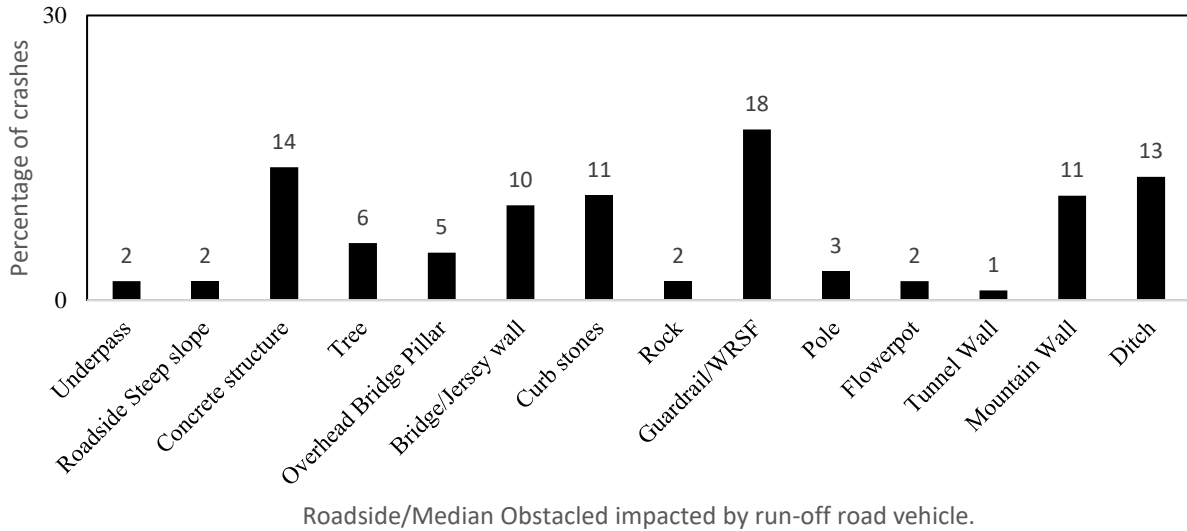The injury severity rate calculated for each of these roadside/median obstacles has been show in Figure 2.

Roadside/Median Obstacled impacted by run-off road vehicle.

FIGURE 1 Distribution of crashes by type of roadside/median obstacle impacted (N = 256)

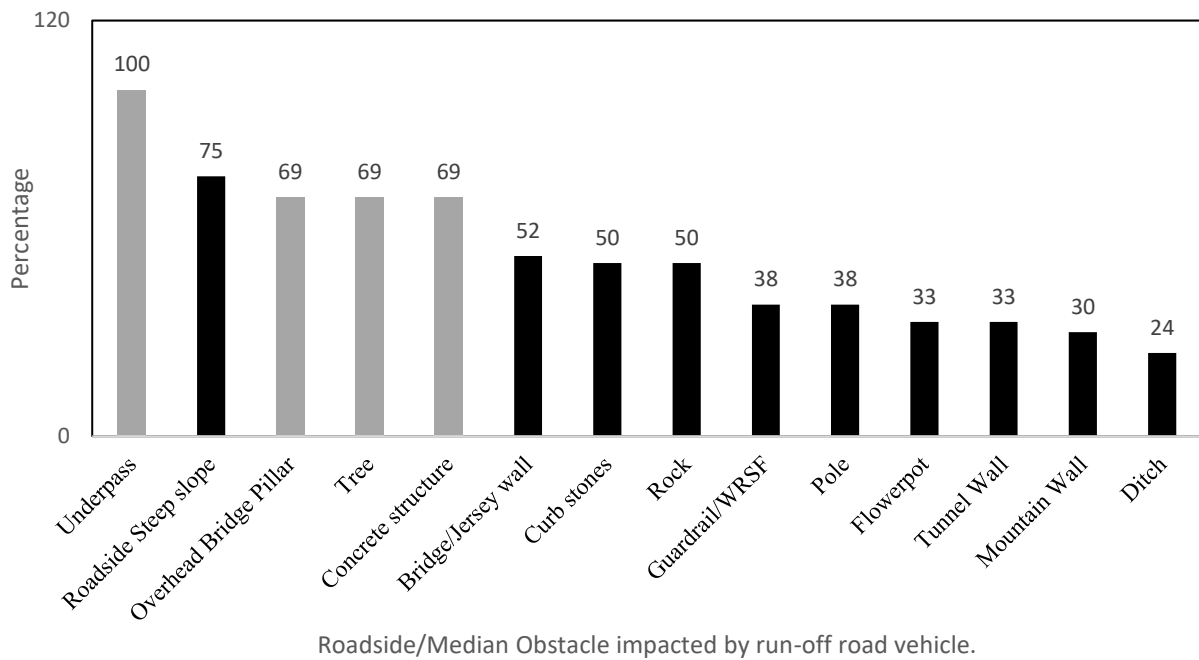Roadside/Median Obstacle impacted by run-off road vehicle.

FIGURE 2 Distribution of Injury Severity Rate by roadside/median obstacle impacted

It was decided to focus on the four roadside/median obstacles: Underpass, Overhead Bridge Pillar, Trees and Concrete Structures as they are major hazards that cause fatal/serious injuries to occupants of run-off road vehicles. Figure 3 shows some examples of these obstacles on the expressway. These four obstacles were involved in 70 crashes. Of these 70 crashes, 69% (48 out of 70) was found to have resulted in at least one fatal/serious injury victim. These 48 crashes resulted in a total of 53 fatalities (11% of 500 fatalities) and 115 seriously injured victims (7% of 1600+ seriously injured victims). Hence, it is evident that crashes involving run-off road vehicles impacting with these four roadside/median obstacles is a significant contributor to fatalities and serious injuries on the Mumbai Pune Expressway.
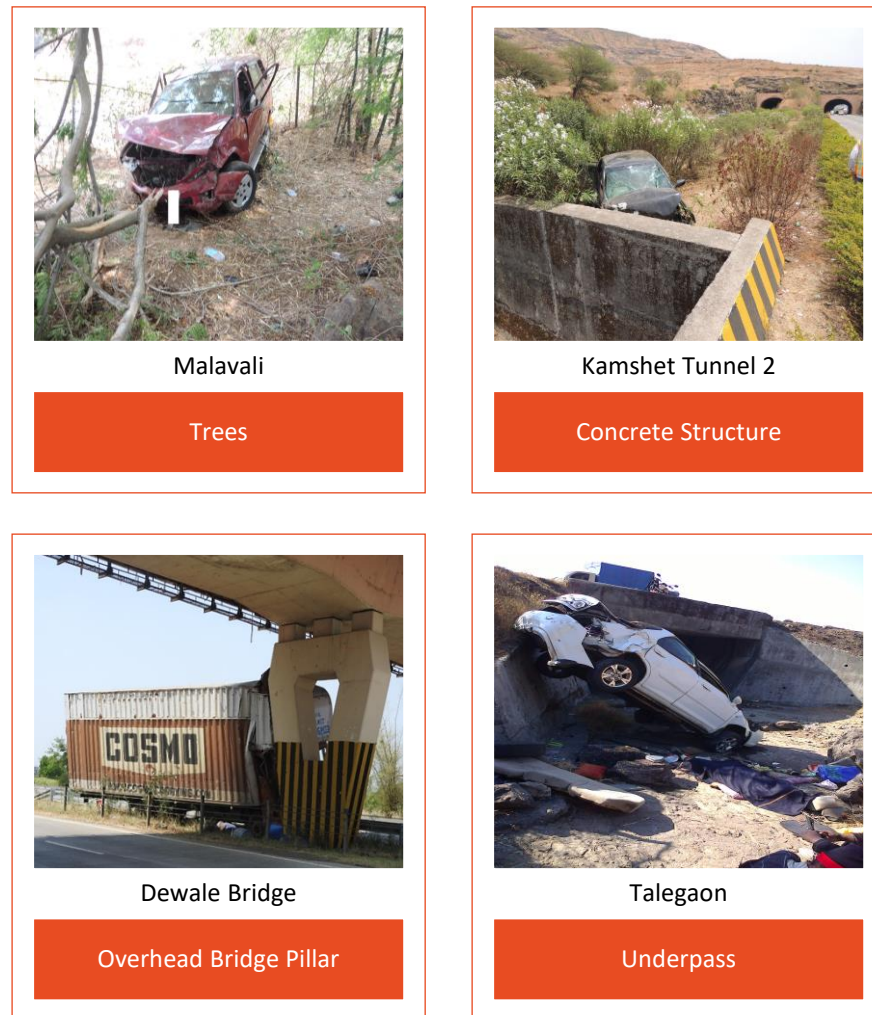

Malavali	Kamshet Tunnel 2
Trees	Concrete Structure
Dewale Bridge	Talegaon
Overhead Bridge Pillar	Underpass

FIGURE 3 Roadside/Median obstacles which are the focus for this study

The IRC in its manual, IRC:SP:99-2013 (*1*), has a detailed section on installation of crash barriers for preventing vehicles from impacting roadside/median obstacles. The section 10.7.1 of this IRC specification manual states that:

"*Roadside safety barriers shall be provided at the following locations:*

a. *On embankments where recoverable slope up to a distance of clear zone applicable for the design speed.*
b. *On the retaining/reinforced earth wall abutting the paved/earthen shoulder.*
c. *Along all horizontal curves having radii upto 2000m for complete length of curves including transitions and 20 m further before and after the curve.*
d. *In front of roadside obstacles like bridge piers, abutments and railing ends, roadside rock mass, culverts, pipes and headwalls, cut slopes, retaining walls, lighting supports, traffic signs and signal supports, trees and utility poles.*"

Similarly the section 10.7.2 for Median barrier states that:

"Median barriers shall be provided at the following locations:
a. *At the center of flush type medians*
b. *At both ends of bridges, Road Over Bridges and grade separated structures in continuation of crash barriers on structures*
c. *To shield fixed objects. If necessary, median barriers shall be flared to encompass a fixed object, which maybe a light post, foundation of overhead signs, bridge pier etc.*
d. *In the depressed medians having width less than 15 m."*

Both the sections mention that crash barriers need to be provided for all roadside/median obstacles that can be a hazard to vehicles leaving the carriageway. The section on the placement of the crash barriers, 10.7.7, mentions that,

"The barrier shall be extended at full height not less than 30 m in advance of the hazard on the approach side, and shall continue at full height for 7.5 m beyond the hazard on the departure side. The minimum length of wire rope fence shall be 50 m."

IRC hence specifies a minimum length of upstream barrier installation of 30 meters along-with a downstream length of minimum 7.5 meters for any installation of metal beam crash barriers. The minimum upstream length has been fixed to be equal to 50 meters for wired rope safety fence barriers.

In the 70 crashes identified for this study, only 4 crash locations had a crash barrier installed covering the roadside/median obstacle. This indicates that even the existing code is not being followed properly. The upstream runout length for wire rope safety barrier and metal guardrails is fixed to a minimum of 50 meters and 30 meters respectively. Of these 4 crash locations 3 locations had a metal guardrail covering the object while 1 location had a wire rope safety barrier covering the roadside/median obstacle. Of the 3 crash locations that had metal guardrails covering the roadside/median obstacle, all the 3 locations had a guardrail runout length of less than 30 meters. In the 1 location that had wire rope safety barrier covering the roadside/median obstacle the runout length was less than 50 meters. This indicates that IRC codes are not being followed while implementing road designs. Also, observations show that there is no scientific basis on the estimation of minimum runout lengths, which seem to be fixed arbitrarily.

The objective of this paper is to identify the minimum desired runout length of crash barriers to be installed before a roadside/median obstacle based on crash data analysis.

METHODOLOGY

The 70 crashes involving the four roadside/median obstacles - Trees, Concrete Structure, Overhead Bridge Pillar and Underpass - were examined further as follows:

1. **Measurement of distance between the face of the hazard and the point of vehicle departure.**

As part of on-site crash investigations, crash investigators create a to-scale scene diagram for every crash that is examined. The scene diagram provides information on vehicle trajectory, vehicle departure point, hazard location and dimensions. The scene diagram was used to determine the point of departure of the vehicle. The distance between the point of vehicle departure and the face of the impacted obstacle was then measured along the roadway.
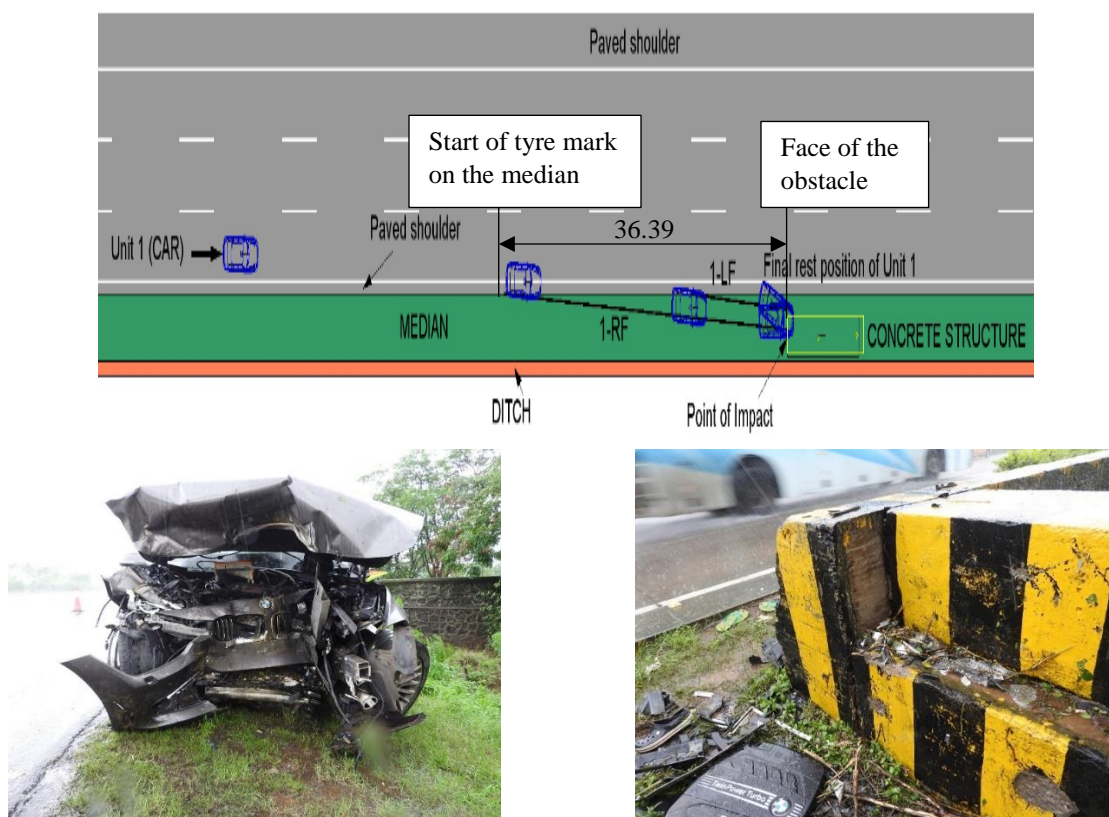
FIGURE 4 Procedure for measurement of distance between point of vehicle departure and the face of the impacted obstacle, along the roadway

2. **Cumulative frequency distribution of the measured distances.**

A cumulative frequency distribution of the measured distances was created for each obstacle type. The distance that covered 85% of the sample of crashes involving impact with a particular obstacle type was considered as the minimum runout length of guardrail required for that obstacle type.

RESULTS

Based on the methodology described in the earlier section, the distances measured and the cumulative frequency plots obtained are as shown below in figures 6, 7, 8 and 9 for Concrete Structures, Trees, Overhead Bride Pillars and Underpasses respectively.
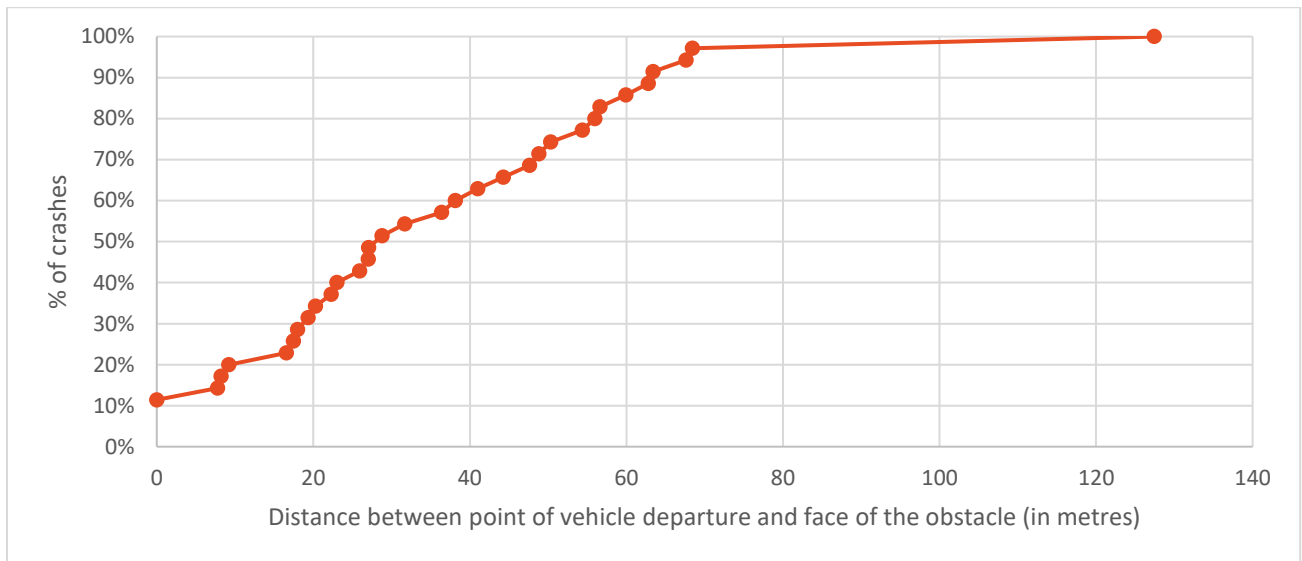
For Concrete Structures:

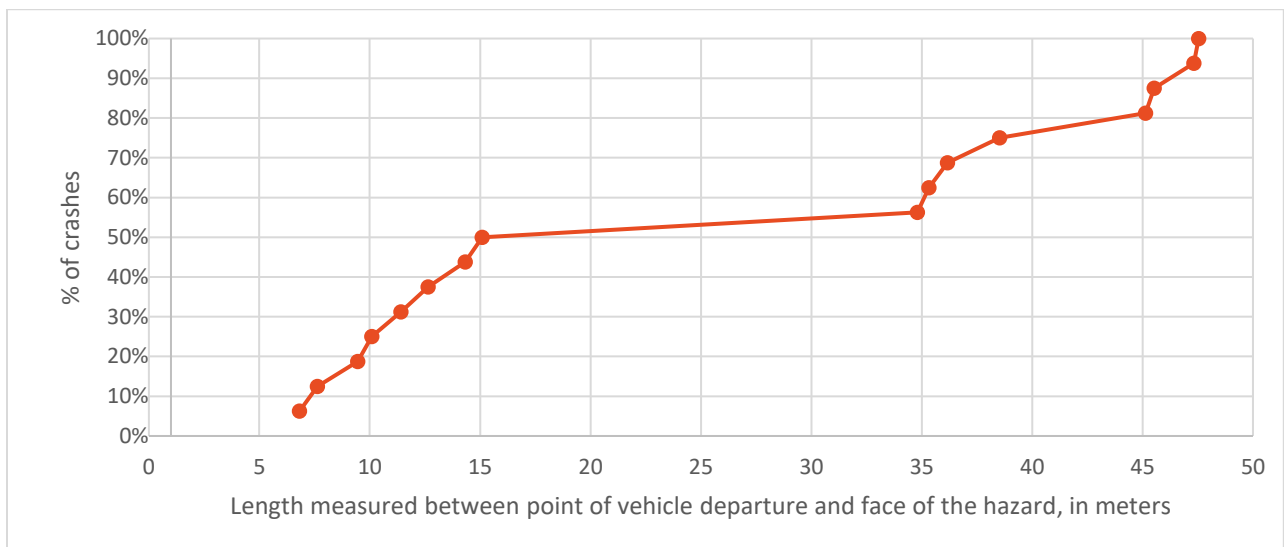**FIGURE 5 Cumulative Frequency Distribution of runout lengths measured for concrete structures (N = 35)**

For Trees:

FIGURE 6 Cumulative Frequency Distribution of runout lengths measured for Trees (N = 16)

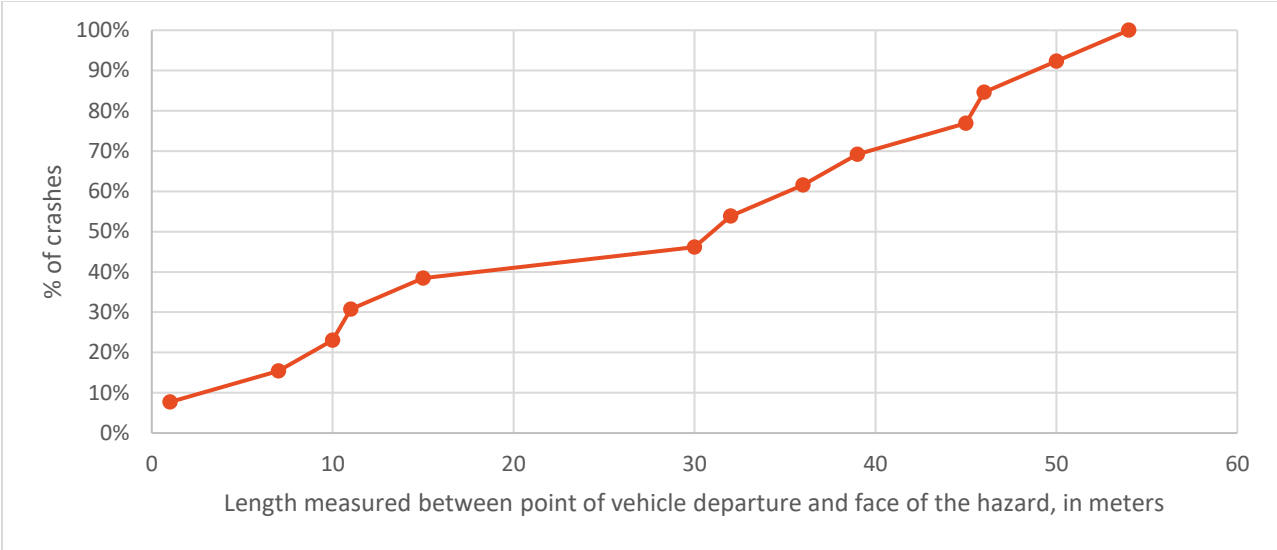**For Overhead Bridge Pillars:**

FIGURE 7 Cumulative Frequency Distribution of runout lengths measured for Overhead Bridge Pillars (N = 13)
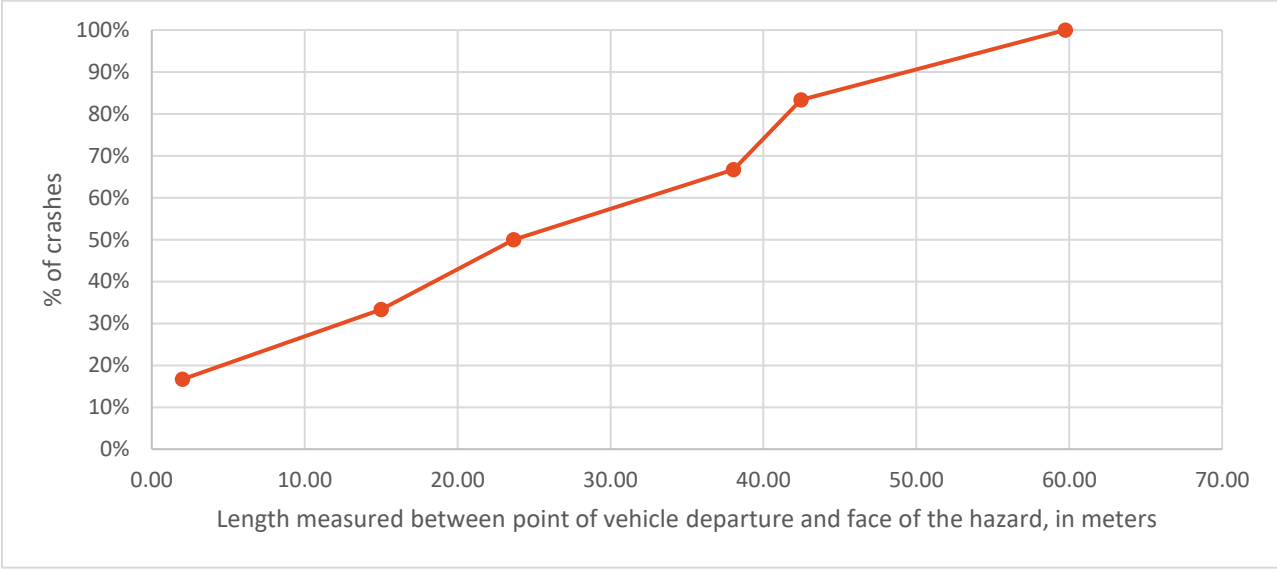
For Underpasses:

FIGURE 8 Cumulative Frequency Distribution of runout lengths measured for Underpasses (N = 6)

Based on the above plots, the results have been tabulated in Table 1 below.

TABLE 1 Runout lengths for guardrails based on the type of roadside/median 0bstacle

TYPE OF OBSTACLE	NUMBER OF CRASHES	DISTANCE (rounded off to next metre) REQUIRED TO MITIGATE		% OF CRASHES COVERED BY A RUNOUT LENGTH OF 30 METRES
		85% OF CRASHES	100% OF CRASHES	
Concrete Structures	35	60	128	51%
Trees	16	46	48	50%
Overhead Bridge Pillars	13	47	54	46%
Underpasses	6	47	60	50%

CONCLUSIONS

The runout lengths of guardrail required for preventing 85% of crashes involving a run-off road vehicle on the expressway impacting the roadside/median obstacles - Concrete Structures, Trees, Overhead Pillars and Underpasses - are 60 metres, 46 metres, 47 metres and 47 metres respectively. The IRC specified minimum runout length of 30 metres is not being followed, but even if followed would prevent only about 50% of these crashes. This study provides a scientific basis for determination of minimum runout length requirement for guardrail installations and can be used to update the IRC codes.

ACKNOWLEDGEMENT

REFERENCES

[1] *IRC:SP:99-2013: Manual of Specifications and Standards for Expressways.* Indian Road Congress, 2013