Speed Characteristics of Road Users in Work Zones on Indian Highways

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Abstract: The study examined Measures of Effectiveness (MOE) of vehicle speeds and its comparison with posted speed limits in Advance Warning Zone (AWZ), Working Zone (WZ) and Terminal Transition Zone (TTZ) on NH-8 in India. Results indicate that (1) Except slow moving vehicles, all the fast moving vehicles exceeded the posted speed limit of 40 km/h in AWZ and WZ; (2) 85^{th} percentile speeds of Cars/Jeeps, Two-wheelers, Standard Trucks, Mini Trucks, and Buses are much higher than speed limit in AWZ and WZ; (3) mean speeds of fast moving vehicles are more than speed limit in AWZ and WZ; (4) there is no significant difference in the speed of vehicles in AWZ, WZ and TTZ at 95% confidence interval. This study strongly recommends the use of active traffic calming measures like Rumble Strips on Highway Work Zones.

Keywords: Work zone, traffic management, speed limit, highway safety.

1. INTRODUCTION

The importance of safety within road work zones has been recognized at International level. Crash rates on highway work zones have been found to be higher than other locations in many countries like U.S., New Zealand, Turkey, etc. This safety concern has been a focus of both government organizations and researchers in India. The issue of highway work zones fatalities near urban areas has long been an issue receiving much attention. This is so because most of the highways are being constructed close to urban areas or cities which increase the risk of being involved in a fatal crash. This is an important consideration for India since government has launched a major highway expansion programme of Golden Quadrilateral project covering 5,846 km length. A recent study of NH-28 in India shows the inadequacy of current traffic management and safety practices at work zones. One of the important objectives of Traffic Management Plans (TMPs) is to ensure safe speed in working zones. However, effectiveness of current practices on speed management has not been documented.

Work zone safety has been a major concern of engineers, government agencies, and the public for decades because of inevitable disruption of regular traffic flows. In India, more efforts are required by government agencies, contractors and utility companies to improve the safety and mobility for construction zone traffic. Handling traffic in work zones is challenging because the work activity presents an abnormal and often disruptive environment to the motorist.

With plans for developing more than 50,000 km of high-speed roads without access control and adequate safety provisions, the consequent safety hazard is likely to be a potential threat to the entire country on the scale of an epidemic. It is the management of speed that has become one of the challenges for policymakers and road safety professionals around the world.

Fatalities in road accidents in India constitute 8-10 per cent of global road deaths. This phenomenon is like a silent disaster happening every day and it is worse than any other natural or man-made disaster. Table 1 shows that more than 50% of the road accidents in India occurred on National Highways (NHs) and State Highways (SHs) and nearly 64% of fatal accidents occurred on NHs and SHs only which creates an alarming situation to take immediate action to prevent accidents on highways.

Table 1. Total number of road accidents, persons killed and injured in India based on road classification (2009)*

Road Classification	Total	National Highways	State Highways	Other Roads
No. of accidents	4,86,384	1,42,511 (29.30)	1,15,992 (23.85)	2,27,881 (46.85)
No. of persons killed	1,25,660	45,222 (35.99)	34,093 (27.13)	46,345 (36.88)
No. of persons injured	5,15,458	1,52,816 (29.65)	1,31,517 (25.51)	2,31,125 (44.84)

Note: Figures within parenthesis indicate share in total accidents, killed and injured in the respective road categories.
*Source: Status paper on Road Safety in India, Ministry of Road Transport & Highways, Government of India, 2010

2. LITERATURE REVIEW

Deaths and injuries at work zones are caused by a variety of factors, like speeding traffic, inadequate visibility of signs, poor road surface condition, inadequate traffic control, improper management of material, equipment, and personnel in work zones, not paying attention to work zone signs or flaggers indicating slow down, distraction by cellular phone calls, conversations and activities at roadside (Lindly et al. 2002). Speed is one of the most significant factors in road crashes. Speed of a driver is affected by factors which include driver age, gender, attitude, and perceived risks of law enforcement or crash. Therefore, different drivers choose different speeds for the same conditions. Other factors influencing speed are weather, road and vehicle characteristics, speed zoning, speed adaptation, and impairment. Benekohal and Wang (1994) compared the speeds of vehicles in the advance warning zone with the speeds within the construction zone. The study found that in advance warning zone the vehicles moving at higher initial speeds reduced their speeds more than did vehicles with lower initial speeds as they entered the construction work zone. These same vehicles, however, kept higher speeds in the work zone when compared to the speeds of vehicles in the lower initial speed groups. About one-third of the drivers who were "extremely" speeding reduced their speeds and kept reducing them as they travelled in the work zone. However, about one-third of those who were "excessively" speeding reduced their speeds initially, but increased them in the work zone and then reduced them when they reached the work space. Mattox III et al. (2007) demonstrated that the speed-activated sign reduced mean speed, 85th-percentile speeds, and percentages of vehicles exceeding the speed limit. The research has shown that the speed-activated sign considerably helped in lowering vehicle speeds in short-term work zones. To control traffic speed in work zones, Allpress and

Leland Jr (2010) designed an experiment on roadwork site in New Zealand where drivers were required to decrease their speed from 100 to 50 km/h. 25,200 motorists participated in the study, out of which approximately 4,000 were buses and trucks and 21,200 were cars or motorcycles. The results showed that both uneven and even cone arrangements greatly reduced vehicle speeds compared to baseline. The traffic slowed down to 10 km/h. The uneven arrangement of cones used in the experiment was found to be very effective against speeding in roadwork sites. Benekohal et al. (1993) showed that although drivers decreased their speeds to the minimum when they reached the work space, 65% of automobiles and 47% of trucks still exceeding the speed limit in the traffic space adjacent to the work space. The study showed that as drivers travelled into the work zone, their speeds first decreased, then slightly increased, and finally reached their minimum value adjacent to the work space. After passing the work space, speeds continuously increased until vehicles left the study section.

One of the most effective work zone speed reduction measures is stationary or mobile police enforcement. Kamyab et al. (2003) studied the effectiveness of extra enforcement on increasing safety in work zones. An electronic survey was conducted among 50 state DOTs and seven turnpike agencies by e-mail. 28 state DOTs responded whereas there was no response from turnpike agencies. Results showed that 85% of responding states found the extra enforcement effective in reducing speeds, and 69% believed that safety was improved with the enforcement presence. Five states had quantifiable results whereas six states indicated some adverse effects from police presence due to congestion. The study also showed the effect of police enforcement on I-35/80 in Iowa. During the construction work, no extra enforcement occurred. The next year law enforcement was conducted in 4-9 hour shifts resulting in decreasing trend in crashes.

Schrock et al. (2002) attempted to identify areas of improvement and innovative practices worthy of further development. 20 state law enforcement agencies were contacted by telephone to determine the method used in work zone enforcement in their respective states. The questions included funding for work zone enforcement, techniques used by law enforcement at work zones, locations in or near work zones where officers are typically stationed. It was concluded that officers can be more effective when specialized programmes within state highway authorities and state law enforcement agencies are developed. The retired officers and local police officers can be used in case of shortage of available officers.

A study was done by Brewer et al. (2006) on changeable message sign with radar, speed display trailer and orange-border speed limit sign to determine effective measures to motivate and encourage drivers to observe posted speed limits in work zones. Speed control devices were evaluated on the basis of measure of effectiveness (MOEs) which included mean speed, 85^{th} percentile speed, standard deviation of speed and percentage of vehicles complying with the speed limit. The findings indicated that devices with the ability to display drivers' speed were more effective in reducing speeds and improving work zone speed limit compliance. In the absence of enforcement, drivers have a tendency to drive as fast as they feel comfortable. Firman et al. (2010) found that Portable Changeable Message Sign (PCMS), either turned on or off, was effective in reducing vehicle speeds in two-lane work zones. The temporary traffic sign was more effective in reducing the speeds of passenger car and semitrailer.

Tiwari (2004) found that speed breaker is a more effective option in controlling the speed of vehicles than the traffic calming measures employed. Drivers speed up to their desired speed when they saw no worker or construction activity. Passenger cars were found to travel at significantly higher speeds than trucks during no construction and construction both. Though construction activity significantly reduced the speeds of passenger cars and heavy vehicles, their speeds were still higher than the posted speed limit. Static signs were ineffective at reducing speeds unless construction activity was in place (Bham et al., 2011).

Speed limit signs are not only ineffective, they can make drivers skeptical of the validity of signs posted at other WZs in case of no construction activity in long WZs (Outcalt, 2009).

3. SUMMARY OF RESEARCH PROBLEM

As detailed in the previous sections, excessive traffic speed in work zones, both in India and around the world, contributes to road fatalities. In light of this pressing issue, researchers conducted a field study in traffic control zones with main focus on work zones on National Highway NH-8 in India. The study examined Measures of Effectiveness (MOE) of vehicle speeds, including mean speeds, 85^{th} percentile speeds and percentage of vehicles exceeding the speed limit, in Advance Warning Zone (AWZ), Working Zone (WZ) and Terminal Transition Zone (TTZ). Statistical analysis for speeds of vehicles was done using Student's t-test at 95% confidence interval.

4. FIELD DATA COLLECTION AND METHODOLOGY

4.1 Setting

The study was carried out on National Highway 8 (NH-8) between Delhi and Jaipur which included widening of the existing four lanes (divided) into six lanes. NH-8 connects the Indian capital city of New Delhi with the Indian financial capital city of Mumbai. This highway is part of the Golden Quadrilateral project undertaken by National Highways Authority of India (NHAI). Eight sites were selected in such a manner that four sites were located on Delhi-Jaipur section and four on Jaipur-Delhi section.

The normal regulatory speed limit of AWZ and WZ was 40 km/h at all the eight sites. Due to construction activity, only two lanes were opened to the traffic in WZ whereas in AWZ and TTZ, all the three lanes were opened to the traffic. The AWZ was 1 km long where the information was conveyed through a series of traffic signs along the length of the zone. A "Men at Work" sign warning road users of the approaching hazard was erected 1 km from the start of the WZ. A 40 km/h speed-limit sign was placed a further 500m after the initial warning sign. A "Diversion" sign was erected in the approach transition zone to inform the road users to take diversion ahead. The WZ itself lasted for approximately 1 km. A "Deep Excavation" sign informing about the nature of work was also erected in the WZ, after which motorists were informed that work had finished and the speed limit was raised back to 90 km/h. The path of the traffic was very clearly delineated through the traffic control zone using New Jersey barriers to avoid vehicle intruding into the work area. A typical traffic management plan of the worksite can be seen in Figure 1.

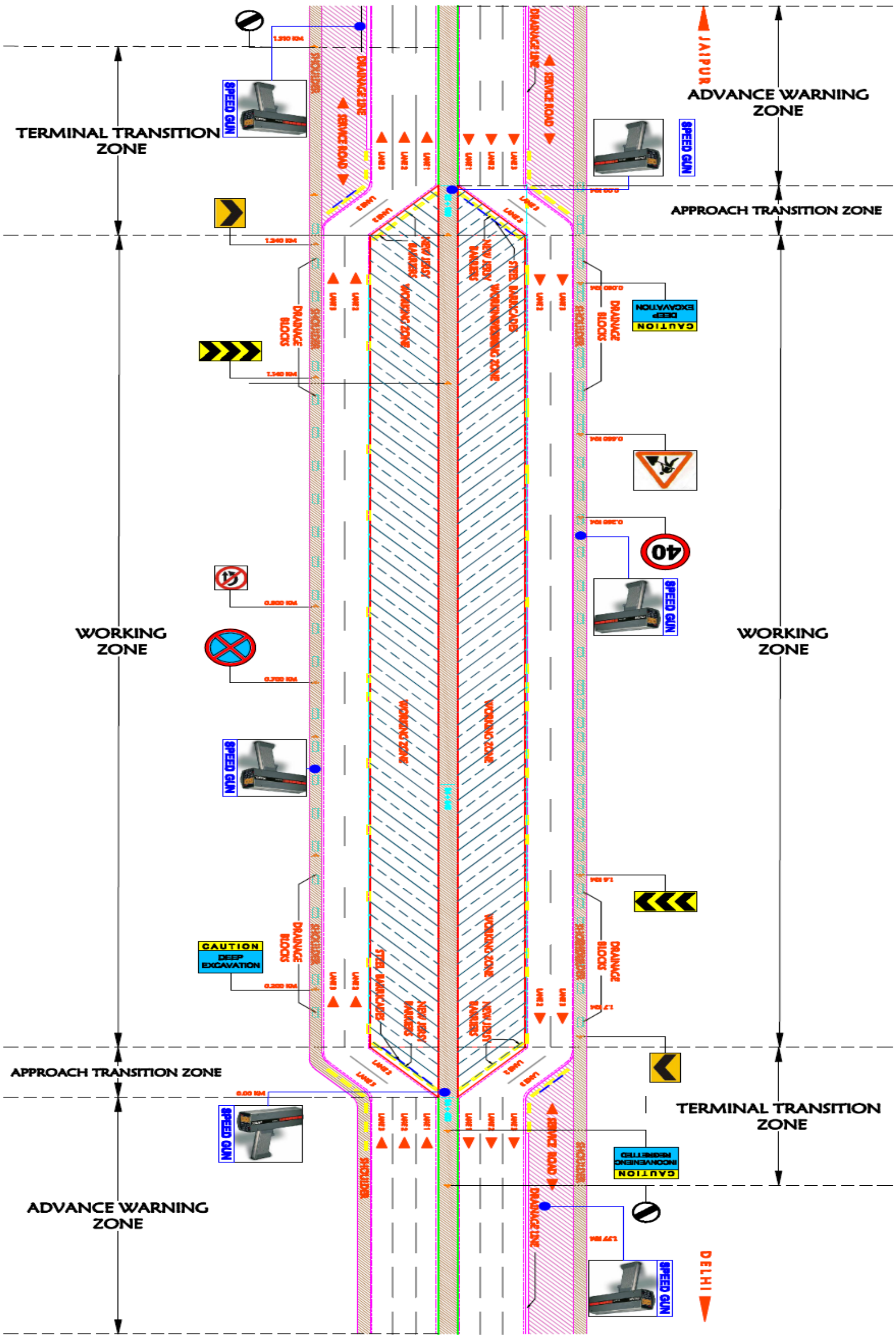

Figure 1: Typical Traffic Management Plan of worksite

4.2 Apparatus

Tracking of individual vehicle speeds was accomplished by the use of lidar gun. The speeds of opposing vehicles were not recorded. Schematic location of lidar guns is shown in Figure 1. The position of observers with reference to Figure 1 is as follows:

- At the start of Approach Transition Zone to capture speed of vehicles travelling in the Advance Warning Zone
- In Working Zone after speed limit sign at a distance varying from 100m to 600m to capture the speed of the vehicles travelling in the Working Zone
- In Terminal Transition Zone at a distance varying from 100m to 200m to capture the speed of the vehicles travelling in the Terminal Transition Zone

4.3 Procedure

The data were collected for three traffic control zones, i.e., Advance Warning Zone (AWZ), Working Zone (WZ) and Terminal Transition Zone (TTZ) during daytime for two days (weekdays). The data collection times were determined based on the feasibility of collecting 30 minutes of speed data for each zone.

Vehicles were classified in seven groups: Car/Jeep, Two-wheeler, Standard Truck, Mini Truck, Bus, Three-wheeler and Tractor. The measures of effectiveness included three speed parameters: mean speeds, 85^{th} percentile speeds and percentage of vehicles exceeding the speed limit. t-tests were performed to determine whether the difference in the mean values of the speeds of Cars/Jeeps, Two-wheelers and Standard Trucks were statistically significant in three traffic control zones.

5. RESULTS

The speed characteristics discussed in the this section shows that the vehicles were travelling at much higher speeds than the posted speed limit in working zones ignoring the unambiguous and clear information conveyed by traffic signs (passive measures) as described in section 4.1.

5.1 Mean Speed

Tables 2 and 3 present the results of mean speed of vehicles in AWZ and WZ respectively. Mean speeds of fast moving vehicles are more than posted speed limit in AWZ and WZ both. It can be observed that the vehicles travelled at higher mean speeds (more than posted speed limit) in WZ than in AWZ at some of the study locations, i.e., construction activity had no effect on the speed of vehicles in WZ. Also, Cars/Jeeps drove at very high speeds followed by Buses and other modes.

Table 2. Mean speed (km/h) of vehicles in AWZ

Mode/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Car/Jeep	73	74	68	67	64	68	67	55
Two-wheeler	54	51	50	49	42	39	45	40
Standard Truck	48	47	47	44	44	48	45	43
Mini Truck	40	53	73	60	56	48	50	55
Bus	63	67	57	66	50	57	62	48
Three-wheeler	47	38	38	47	37	37	-	26
Tractor	22	33	32	37	25	33	33	23

- Count = 0

Table 3. Mean speed (km/h) of vehicles in WZ

Mode/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Car/Jeep	73	67	69	53	58	61	59	60
Two-wheeler	53	51	44	45	45	51	43	42
Standard Truck	45	43	46	37	41	42	43	44
Mini Truck	58	51	48	46	45	53	50	50
Bus	68	64	53	51	41	54	59	46
Three-wheeler	39	34	36	42	46	-	-	33
Tractor	27	22	36	25	19	39	28	25

- Count = 0

5.2 85th Percentile Speed

Tables 4 and 5 show the results of 85th percentile speed of vehicles in AWZ and WZ respectively. 85th percentile speeds of Cars/Jeeps, Two-wheelers, Standard Trucks, Mini Trucks, and Buses are much higher than the posted speed limit of 40 km/h in AWZ and WZ at all the study locations.

Table 4. 85th percentile speed (km/h) of vehicles in AWZ

Mode/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Car/Jeep	84	84	77	79	74	82	81	66
Two-wheeler	57	57	62	58	49	49	48	46
Standard Truck	54	54	59	51	48	54	50	51
Mini Truck	57	57	73	60	65	56	58	67
Bus	72	72	71	72	63	66	71	63
Three-wheeler	45	45	45	51	39	41	-	26
Tractor	35	35	38	38	26	36	33	24

- Count = 0

Table 5. 85th percentile speed (km/h) of vehicles in WZ

Mode/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Car/Jeep	84	79	77	71	73	71	71	71
Two-wheeler	59	64	51	51	53	56	52	48
Standard Truck	53	48	54	42	46	49	48	50
Mini Truck	68	58	53	52	50	56	58	54
Bus	71	71	63	59	44	55	64	54
Three-wheeler	41	40	41	45	46	-	-	35
Tractor	32	25	41	28	24	42	38	28

- Count = 0

5.3 Percentage Vehicles Exceeding Speed Limit

Tables 6 and 7 present the percentage of vehicles travelling above the speed limit in AWZ and WZ respectively. Nearly 100% of Cars/Jeeps and more than 50% of Two-wheelers, Standard Trucks, Mini Trucks and Buses exceeded the posted speed limit of 40 km/h in both AWZ and WZ at all the selected sections.

Table 6. Percentage vehicles exceeding posted speed limit (40 km/h) in AWZ

Mode/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Car/Jeep	100	100	100	100	97	96	97	95
Two-wheeler	85	100	75	80	65	33	85	50
Standard Truck	80	90	71	85	90	87	82	94
Mini Truck	50	100	100	100	85	92	85	100
Bus	100	100	80	100	60	92	100	80
Three-wheeler	68	50	60	100	30	50	-	-
Tractor	100	-	-	-	60	-	-	-

- Count = 0

Table 7. Percentage vehicles exceeding posted speed limit (40 km/h) in WZ

Mode/Site	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Site 8
Car/Jeep	100	100	100	77	90	100	95	100
Two-wheeler	85	85	32	75	85	100	67	75
Standard Truck	65	75	60	30	60	62	73	62
Mini Truck	89	95	90	90	70	100	100	100
Bus	78	100	100	89	65	100	100	65
Three-wheeler	25	20	32	65	100	-	-	-
Tractor	-	-	-	-	-	-	-	-

- Count = 0

5.4 T-test Results

Table 8 provides the results of t-test comparing speeds in AWZ vs. WZ and WZ vs. TTZ.

Table 8. T-test equality of means @ 95% level of confidence

Site	Mode	Advance Warning Zone vs. Working Zone		Working Zone vs. Terminal Transition Zone	
		t-statistic	p-value	t-statistic	p-value
1	Car/Jeep	0.068	0.946*	-0.484	0.630*
	Two-wheeler	0.137	0.892*	-0.118	0.907*
	Standard Truck	2.621	0.012	-2.596	0.012
2	Car/Jeep	2.660	0.010	5.563	0.000
	Two-wheeler	-0.164	0.871*	0.980	0.340*
	Standard Truck	2.621	0.012	3.260	0.002
3	Car/Jeep	-0.312	0.756*	3.016	0.004
	Two-wheeler	1.586	0.132*	-1.032	0.310*
	Standard Truck	1.586	0.132*	-0.086	0.932*
4	Car/Jeep	3.390	0.001	-1.039	0.304*
	Two-wheeler	-0.562	0.598*	-0.328	0.750*
	Standard Truck	4.722	0.000	-0.026	0.979*
5	Car/Jeep	1.655	0.104*	-2.179	0.034
	Two-wheeler	-0.870	0.393*	0.226	0.823*
	Standard Truck	2.340	0.021	-0.100	0.921*
6	Car/Jeep	2.648	0.010	1.363	0.178*
	Two-wheeler	-3.384	0.003	1.270	0.220*
	Standard Truck	3.485	0.001	-1.686	0.096*
7	Car/Jeep	2.896	0.005	3.009	0.004
	Two-wheeler	0.629	0.539*	1.582	0.135*
	Standard Truck	1.860	0.067*	2.630	0.011
8	Car/Jeep	-1.721	0.093*	1.991	0.050
	Two-wheeler	-0.785	0.545*	0.134	0.895*
	Standard Truck	-0.207	0.836*	2.017	0.048

*NOT significant at 95% level of confidence

The p-values obtained from the t-tests show that construction activity had no significant effect on the speed of vehicles at a 95% level of confidence.

6. SUMMARY AND CONCLUSIONS

The results of this analysis indicate that except slow moving vehicles like three-wheelers and tractors, the speeds of all fast moving vehicles including cars/jeeps, two-wheelers, standard trucks, mini trucks and buses were above the speed limit and vehicles traveled faster in AWZ and WZ. 85^{th} percentile speeds of cars/jeeps (71 km/h to 84 km/h), two-wheelers (48 km/h to 64 km/h), standard trucks (42 km/h to 54 km/h), mini trucks (50 km/h to 68 km/h), and buses

(44 km/h to 71 km/h) were much higher than speed limit in AWZ and WZ. Mean speeds of fast moving vehicles were more than speed limit in AWZ and WZ. In WZ, mean speed of cars/jeeps varied from 53 km/h to 73 km/h whereas for standard trucks and buses, mean speed varied from 37 km/h to 46 km/h and 41 km/h to 68 km/h respectively. There was no significant difference in the speed of vehicles in AWZ, WZ and TTZ at 95% confidence interval. Another interesting observation was that for all work zone sites, the mean speed of cars/jeeps was higher than other vehicles in WZs.

Based on the study results, it was concluded that the speed of traffic in WZ is of great concern. Passive traffic calming measures including speed limit signs, cones, road markings, etc. are not very effective in controlling speeds of vehicles in WZs. Construction activity as well as the existing Traffic Management Plans had no significant effect on the speeds of vehicles in working zones. Therefore, it is very important to consider active traffic calming devices to ensure safe speeds in WZs. Passive traffic calming measures should be combined with other active traffic calming measures like rumble strips, speed humps, etc. Traffic Management Plans (TMPs) are only passive traffic calming measures. TMPs alone cannot be able to manage safe speeds in WZs.

In a country like India, people live on the sides of the highway and cross the road to reach nearby villages for work, education, etc. Hence, for the safety of the villagers crossing the road, workers engaged on sites and vehicles moving on the road, there is a need to change the policy by implementing measures like rumble strips/speed humps in work zones on highways.

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