ROAD WORK ZONE SAFETY PROBLEM AND ASSOCIATED RISK FACTORS IN BANGLADESH: AN AUGMENTED ANALYSIS INTEGRATING CRASH AND OBSERVATIONAL DATA

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ABSTRACT

Road work zone is an inevitable traffic mobility impediment. It poses a challenge to traffic operation and management and, thus, creates potential safety hazards for road users. The safety of a road work zone demands special attention, as unanticipated traffic situations may attune unexpected crash phenomena. Therefore, appropriate and pellucid information and guidance to road users is a fundamental requirement in a work zone. Bangladesh, however, needs to improve these provisions and standard safety measures. It is essential to understand the current best practices, characteristics, and probable causes of work zone crashes to develop standards for the country. The study aims to evaluate the features of crashes that took place at the road work zones in Bangladesh during 1998-2015 by analyzing the crash records maintained by Bangladesh Police. The characteristics analysis of crashes revealed that most of the crashes occurred were fatal in nature. Moreover, overspeed and reckless driving were responsible for major proportion of crashes at work zones. Furthermore, in-depth field investigations of the existing work zones have been conducted to depict the real traffic safety scenario of the work zones. Absence of advance warning signs, safety barriers, pedestrian facilities, and negligence of worker safety issues were found to be the common safety deficiencies during field investigations. The findings of this study will provide adequate guidelines regarding effective mitigation of those safety deficiencies, and ensuring proper safety at the road work zones in Bangladesh.

Keywords: *road safety, work zone, traffic mobility, road crash, Bangladesh*

1. INTRODUCTION

Road construction, maintenance and utility works are imperative and inevitable for any road network. However, a road work zone can pose significant dangers to both road users and workers unless proper planning and management are maintained. Statistics reveal that the risk of a fatal or severe road crash is three times greater within a road work site compared to an equivalent road section (Directorate General of Highways of Indonesia, 2012). Due to the considerable disruption caused by road works to the free movement of vehicles and road users, it becomes imperative to prioritize safety for road users and workers as well as ensure the smooth mobility of vehicles across the work zone.

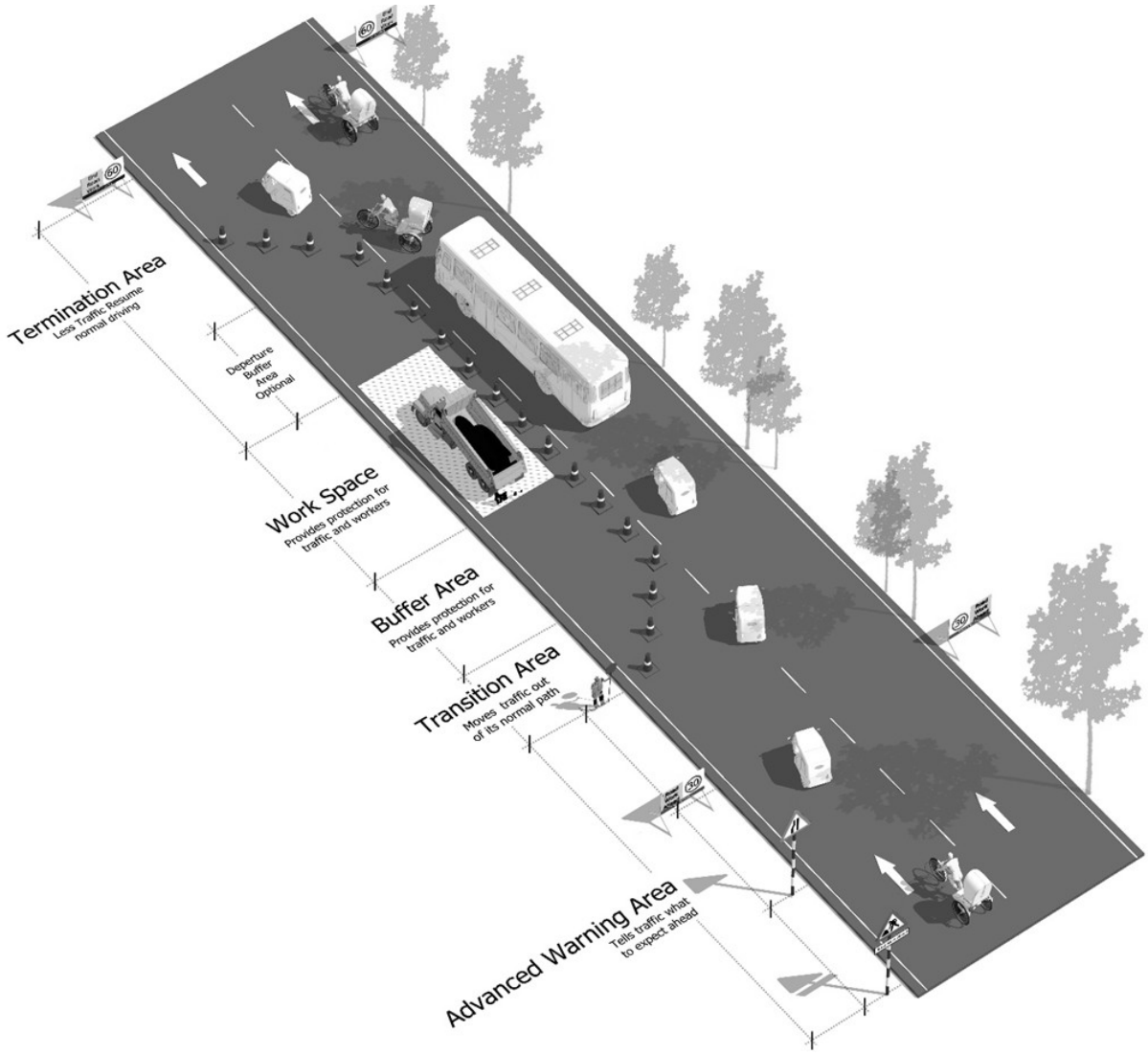

Figure 1: Typical template diagram illustrating five segements of a road work zone; (source: Dhaka Transport Coordination Authority, 2022)

Work zone safety and mobility is considered as a significant safety concern in many developed and developing countries, however, this has been mostly overlooked in Bangladesh. In most of the cases, there is lack of safety measures for ensuring safety to the motorists, pedestrians and workers at road work zones of Bangladesh. Absence of advance warning signs prior to the work zone is the most common and crucial safety issue that creates surprise situation for the motorists. As a result, the crash potential as well as crash severity is increased. Moreover, installations of appropriate pedestrian facilities for ensuring safe movement of pedestrians across the road work zones are also mostly

ignored. Lack of training of workers and flaggers, negligence to use Personal Protective Equipment (PPE) by workers, improper traffic management, lack of application of traffic control devices at work zones and absence of work zone checklists and template diagrams are other noteworthy reasons for the lack of safety measures in the work zones of this developing country. In brief, neither the safety nor the mobility issue is taken into appropriate consideration at the road work zones. Recently, a number of dreadful accidents have occurred at work zones of some ongoing mega projects in Bangladesh that have severely shocked the whole country. It is to be noted that there was no manual or guideline on work zone safety and mobility in Bangladesh for a long time. The first guideline on work zone safety in Bangladesh, titled "Work Zone Safety and Mobility Guideline" was published in 2022 through a collaborative effort between the Accident Research Institute (ARI) and the Dhaka Transport Coordination Authority (DTCA). This guideline has provided several comprehensive checklists, safety management issues and standard template drawings to provide proper guidance for ensuring proper safety at work zones considering the local context of Bangladesh. Most importantly, it has recommended to apply the 'zone concept' to dividing the whole work zone into five individual but interrelated segments to allow free traffic flow and ensure adequate safety of all road users and workers of a work zone. These segments are termed as advance warning area, transition area, buffer area, work space and termination area (Dhaka Transport Coordination Authority, 2022). Figure 1 shows a typical template diagram of a road work zone where these five segments along with the primary objectives of each of the segments are illustrated.

Road work zone safety and mobility issue of Bangladesh has not received too much attention to the researchers till now. In this context, this study aims to present the characteristics analysis of crashes that occurred at road work zones, and to depict the real traffic safety scenario based on in-depth field investigations of several existing work zones in Bangladesh.

2. BACKGROUND STUDY

In Bangladesh, no study has been done yet on work zone safety and mobility. From this perspective, this research is a novel topic related to road safety in Bangladesh. Several studies have been reviewed to understand the global context of work zone safety. It was found that work zone safety is a significant concern of road safety around the world.

Garber & Zhao (2002) investigated the characteristics of work-zone accidents that occurred in the Virginia state of United States of America (USA) during the period of 1996 to 1999. The results indicated that the 'activity area' of work zone was the major location of work-zone crashes, and rear-end crash was found to be the predominant crash type. The results also indicated that the proportion of sideswipe crashes (vehicles moving in the same direction only) in the 'transition area' is considerably higher than that in the 'advance warning area' of work zone. Pigman et al. (2006) analyzed the work zone crashes in the Kentucky state of USA and found that the highest reduction in speed was achieved when there was presence of police at the work zone. As a part of the study a guideline titled 'Guidelines for traffic control in short duration/mobile work zones' was introduced as well. Li (2010) conducted questionnaire surveys on experts on highway work zone safety in the USA, and proposed an eight-step process for the conduction of work zone safety audits that could be performed at pre-construction stage, construction stage, and post-construction stages of a project respectively. It was expected that the proposed framework could be helpful for developing comprehensive guidelines for work zone safety audits. Vaitkus et al. (2018) analyzed 77 work zone crashes those occurred during the years 2012-2016 in Lithuania to reveal that violation of the speed limit at roadwork zones is a common phenomenon, and active traffic calming measures including speed cameras or dummy cameras help to maintain the speed limit. It was also found that at the end of work zones, the rumble strips have no effect on vehicle speed. Vyas & Varia (2023) conducted a study to analyze the impacts of overdelay, travel time, noise and air quality, queue length, and travel congestion caused by road work zones in India. An investigation by Das et al. (2023) revealed that work zone related crashes in the USA was increased by 13% between 2016 and 2020. Al-Bayati (2023) analyzed work zone accidents during the period of 1992 to 2020 in USA to reveal that 45% incidents were caused by

vehicle intrusion, whereas 55% incidents were caused inside workspace by the use of construction equipment or worker fault. A combination of inappropriate temporary traffic control setup and unsafe behavior of vehicle drivers was found to be the predominant direct cause of vehicle intrusion injuries, and the absence of Internal Traffic Control Plans (ITCP) was the primary cause of injuries inside workspace. The study, therefore, recommended improving the training program to ensure the proper setup of temporary traffic control as well as ITCP.

Despite the significant importance of research and investigation on work zone safety in Bangladesh, it is disheartening no study has been conducted on this topic for a long time. To this end, this study will present the characteristics analysis of road work zone crashes, and to demonstrate the actual traffic safety situation of the existing work zones based on comprehensive field investigations in Bangladesh.

3. METHODOLOGY

The study aims to evaluate the features of crashes that took place at the work zones in Bangladesh during 1998 to 2015. It is to be noted that the crash data after 2015 is not available at present due to software complications and other management issues. Nonetheless, the crash history of these 18 years could provide an adequate representation of overall scenario of work zone crashes in Bangladesh. The Microcomputer Accident Analysis Package-5 (MAAP5) software is used to analyze the work zone crashes reported in the Accident Report Form (ARF) of Bangladesh Police. Each ARF is examined specifically for the attribute labeled as 'under repair' to identify the instances of work zone crashes. The crash data is used to conduct the characteristics analysis to identify the features and patterns of work zone crashes. Furthermore, several in-depth field investigations are conducted on the existing work zones of Bangladesh. The investigations were carried out at the ongoing working areas viz. the BRT project, MRT project and Metro-rail project in Dhaka city, and several national highways and rural roads around the nearby districts of Dhaka. These field investigations have led to identify many crucial safety deficiencies those exist at road work sites.

4. RESULTS AND DISCUSSION

This section will present a detailed analysis of characteristics of work zone crashes, and observational findings based on in-depth field investigations to depict the actual safety scenario of existing road work zones of Bangladesh.

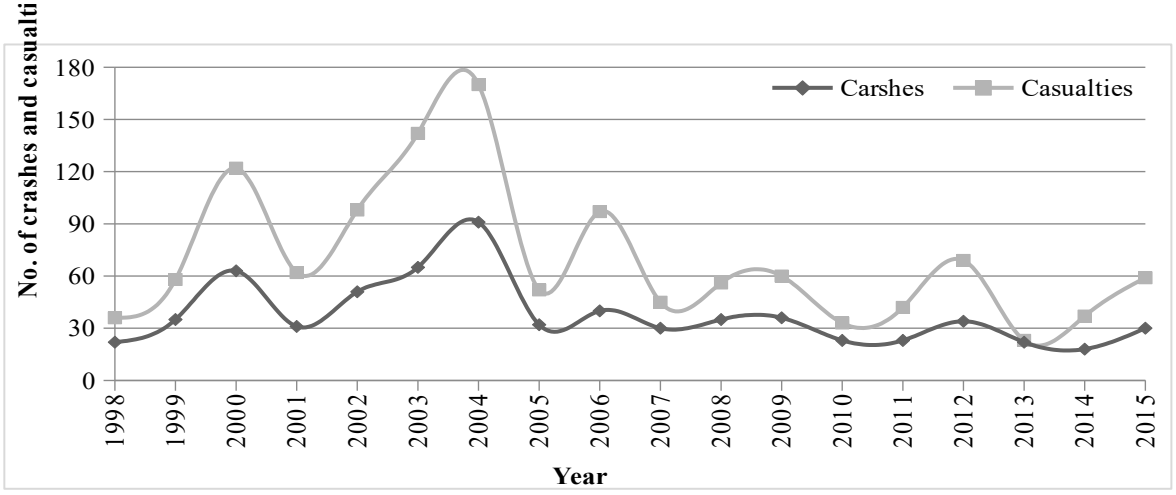

Figure 2: Distribution of accident and casualties due to crashes at work zones of Bangladesh

4.1 Characteristics Analysis of Work Zone Accidents

Crash statistics of 18 years i.e. during the period of 1998 to 2015 reveal that 681 accidents and 1261 casualties occurred at road work zones in Bangladesh. Out of 54878 overall road accidents of the country, 681 accidents occurred at work zones which is almost 1.2% of overall crashes. Although, the percentage may be seemed as nonsignificant, however, considering the context of extent of work zones, this percentage is an alarming issue. This is due to the fact that the number of work zone is usually very few on roads and do not exist for a long period (except some mega projects). Figure 2 illustrates the distribution of number of accidents and casualties during the period of 1998 to 2015. It is evident that, yearwise trend of casualties follows almost the same trend of accidents. The highest accidents as well as casualties occurred in 2004, and the second highest occurred in 2003. It is also observed that, the number of work zone crashes continue to occur near to the figure of 30, and the number of casualties remained below 70 since 2005.

Analysis of crash severity from the collected data reveals that, 76.4% crashes were fatal, 16.3% crashes involved grievous injuries, 5.4% crashes involved simple injuries and the rest 1.9% crashes involved property damages only. Among all casualties, 50.7% people died, 29.5% people were grievously injured and 19.8% people experienced simple injury. Apart from that, analysis of contributory factors of these crashes shows that reckless driving and overspeeding are responsible for 44.6% and 42.7% crashes respectively. These two factors also highly contribute to the predominant proportion of fatal crashes- which could be due to the absence of appropriate advance warning signs at work zones.

Table 1: Cross-tabulation of road class and crash type of work zone crashes

Crash type	**Road Class**					**Total**
	National Highway	Regional Highway	Feeder road	Rural road	City road	
Hit Pedestrian	73	37	59	57	41	267
Head-on	48	5	12	5	9	79
Rear-end	30	8	20	7	5	70
Overturn	50	23	37	27	1	138
Side-sweep	29	5	9	5	7	55
Collision (right angle)	1	0	0	1	0	2
Hit object on road	3	3	1	1	1	9
Hit object off road	6	2	4	1	1	14
Hit parked vehicle	6	0	1	0	0	7
Others	18	4	4	11	3	40
Total	264	87	147	115	68	681

Table 1 presents the cross-tabulation of crash type and road class during the work zone crashes. Considering the crash type exclusively, it is evident that 267 crashes occurred by hitting pedestrians which is almost 39.2% of overall crashes. Lack of providing adequate pedestrian facilities across work zones could be the most potential reason for such considerable proportion of hit pedestrian crashes. Moreover, 138 (24.7%) crashes occurred due to overturing of vehicles at road work zones. Lack of adequate advance warning signs could be the main factor for the occurrence of such accidents. Apart from that, head-on collision (11.6%), rear-end collision (10.3%), and side-sweep crash (8.1%) are among the noteworthy crash types at work zones. On the other hand, considering the road class exclusively, it is seen that national highway is the most vulnerable category of road due to

occurrence of 264 (38.8%) crashes. Lack of adequate advance warning signs and not following temporary traffic plans on busy and high-speed national highways could be the main factor for such significant proportion of accidents. Besides, 147 (21.6%) and 115 (16.9%) crashes took place on feeder and rural roads respectively. Now, considering the cross-tabulation it is evident that 73 (10.7%) hit pedestrian crashes occurred on national highways. Besides, feeder roads and rural roads have experienced 59 (8.7%) and 57 (8.4%) hit pedestrian crashes respectively. Apart from that, vehicle overturning and head-on collisions on national highways led to occurrence of 50 (7.3%) and 48 (7.0%) crashes respectively.

Table 2: Cross-tabulation of weather and light condition during work zone crashes

Light Condition	Weather condition				Total
	Fair	Rainy	Foggy	Windy	
Day	406	38	12	1	457
Dawn/dusk	77	7	15	1	100
Night (lit)	24	4	2	0	30
Night (unlit)	71	11	12	0	94
Total	578	60	41	2	681

Table 2 presents the cross-tabulation of weather and light conditions during the work zone crashes. Considering the light condition exclusively, it is seen that out of 681 crashes, 457 crashes occurred during daytime which is almost 67.1% of total crashes. Apart from that, 100 (14.7%) and 94 (13.8%) crashes occurred during dawn/dusk and night (unlit) conditions respectively. On the other hand, considering the weather condition exclusively, it is observed that 578 (84.9%) crashes occurred during fair weather. Besides, 60 (8.8%) and (6.0%) 41 crashes occurred during rainy and foggy weather respectively. Now, considering the cross-tabulation it is evident that 406 (59.6%) crashes occurred during daytime and fair weather condition which is a matter of great concern. The main reason behind such high percentage of crashes could be due to lack of adequate warning signs, and not following temporary traffic plans. Moreover, 77 (11.3%) and 71 (10.4%) crashes occurred during fair weather & dawn/dusk, and fair weather & night (unlit) conditions respectively.

4.2 Observational Findings based on Field Investigations

As mentioned earlier, Up till now no study has investigated the work zone safety issues in Bangladesh. In this regard, this study has involved many in-depth filed investigations of work zones in and around Dhaka city. Some of the examples involve on-going mega projects inside Dhaka city and other road repair and maintenance works around some nearby districts of Dhaka.

Figure 3: Typical scenarios of absence of advance warning signs at work zones in Bangladesh

4.2.1 Lack of appropriate signs

During the investigations it was a common observation that, appropriate advance warning sign from adequate distance was absent. Advance warning signs including 'road work ahead', 'lane closed' and speed restriction signs were not found. This creates confusion among drivers and creates the potential for traffic conflict or even a crash in extreme case.

4.2.2 Lack of appropriate safety barriers

Absence of delineators and safety barriers was also a common phenomenon (even for mega projcet works of Bangladesh) which could increase the crash severity significantly. Moreover, for overhead construction works, adequate protection to restrict falling objects to ensure safety of pedestrians and use of proper fall protection gears by workers was also not found as well.

Figure 4: Common scenarios of absence of appropriate safety barriers at work zones

During the investigation, it was also observed that rocks, concrete blocks and tree branches were used in some work zones for delineation purpose which is extremely unsafe. In few cases, the practice of using traffic cones was found, however, those were not placed in proper manner. The cones were placed just before the work zone which were unable to guide the traffic properly. To ensure the movement of traffic without conflict, the cones should be placed to make proper taper for merging the vehicles. In this regard, the 'zone concept' of work zone should be followed as outlined in Figure 1. This concept allows to segregate the whole work zone into five segments to allow free traffic flow and ensure adequate safety of road users at work zones. These zones are termed as advance warning area, transition area, buffer area, work space and termination area.

4.2.3 *Exposure of construction and repair materials without adequate protection*

Dumping and storage of construction and repair materials e.g. sand, gravel, blocks, rocks, excavated materials, steel bars or rods etc. on the road without any protection were common practices in the work zones. Moreover, these materials were not found to be conspicuous, and thus create extreme hazard for the users, especially on high-speed road at night-time for two or three-wheelers like motorcycles, CNG autorickshaws and so on. Moreover, after completion of works, most of the work zones are not maintained and repaired properly to be like the initial state. Too much sand, gravel, and mud are left on the road pavements. These create serious sliding hazards for different road users, particularly for the motorcyclists.

Figure 5: Typical scenarios of exposure of construction and repair materials without adequate protection

4.2.4 *Absence of pedestrian facilities*

It was also found that the needs of pedestrian are neglected or ignored at road work sites. In most of the cases, there is no space for the pedestrians, and they were forced to move along with traffic without any protection since the walking space or footpaths were found to be used for road works activities. Actually, the contractors or supervisors are not conscious of pedestrian safety hazards and do not consider the need of pedestrian facilities. Ultimately, the pedestrians are compelled to walk across the work zone in a very risky manner which is a common scenario.

Figure 6: Common scenarios of absence of pedestrian facilities at work zones

4.2.5 *Negligence of worker safety issue*

The workers were not found to use Personal Protective Equipment (PPE) in most of the cases (except few mega projects) during the investigation. Moreover, they were also found to work in risky manner due to lack of adequate training. Therefore, all workers should be provided with proper PPE before starting work and get proper training on regular basis. Moreover, the placement of traffic controller or flagger was also observed to be in wrong position at work zone. Additionally, they were not provided with standard 'Stop' or 'Slow' bat. This is a very crucial issue, especially for high-speed roads to prevent crash and subsequent casualties.

Figure 7: Common scenarios of negligence of safety by workers at work zones in Bangladesh

5. CONCLUDING REMARKS

5.1 Research Findings

This section will present the major findings of the study. The findings of the characteristics analysis of road work zone crashes in Bangladesh are listed below.

- Almost three of every four crashes at work zone were fatal, and one of every two people among the casualties had died.
- Over-speed and reckless driving of vehicles are responsible for 87.3% work zone crashes in Bangladesh.
- Hit pedestrian is the leading type of crash having a share of 39.2%.
- 38.8% crashes at road work zones occur on national highways of Bangladesh.

- Almost three of every five work zone crashes occur during daytime and fair weather conditions.

The observational findings based on field investigations of existing work zone crashes in Bangladesh are listed below.

- In most cases of field investigations, it was found that the advance warning signs were not installed prior to the work zone which is a very risky practice.
- The safety barriers were not installed around the work space in most of the work zones. In very few cases traffic cones were found, although, those were placed in wrong or non-standard manner.
- The construction and repair materials were mostly found to be exposed without any protection which is an unsafe practice.
- Pedestrians were observed as being compelled to walk in risky manner on the road along with traffic across work zone due to lack of pedestrian facilities.
- Most workers were not found to wear proper PPE and have lack of adequate training.

5.2 Conclusion

Road work zone safety and mobility issue has been highly neglected in Bangladesh till now. In this regard, the findings of the study have revealed that there are significant deficiencies in terms of ensuring safety of road users and workers, and traffic mobility in work zone. In most cases, it is ignored that a work zone is an inherently vulnerable area that needs specific treatment. Therefore, the safety and mobility plan must be integrated with the early stages of the utility, maintenance and repair work plan of a road. In this regard, the project supervisors and contracts need to follow the standard template diagrams and checklists to ensure the safety of motorists, pedestrians and workers.

To conclude, this study will serve as an eye-opener for comprehending the real scenario of work zone crashes through characteristics analysis of crash data and detailed field observations. It is, therefore, highly expected that the findings of the study will help to improve the condition of the road work zones in Bangladesh in terms of mobility and safety.

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