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- RESEARCH ARTICLE -

Assessment of Work Zone Safety

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Abstract

The increase in number of vehicles and deterioration of the existing facilities necessitates the need to improve the existing roadways and to build additional highways hence creating more work zones in cities around the globe. Two work zones one on a rural road and one on an urban road were studied to identify potential hazards in work zone and determine the most dangerous area of the work zone using risk concentration level. Confusing signs, use of dangerous devices for road closure, missing buffer, missing tapers, use of non-retro reflective devices, unprotected work area, dangerous flagging, missing safety alarms for heavy machineries, speed, aggressive driving and improper pedestrian access are the most dangerous hazards in work zone having a very high risk level. Transition area was found to be the most dangerous area of the work zone with a very high risk concentration level followed by working area with high risk concentration level, then advance warning area with medium risk concentration and finally termination area also with medium risk concentration. Proper installation and maintenance of temporary traffic control devices, use of safety attires by workers, fitting all moving machineries with safety alarms, use of retro reflective devices, protecting work activities, providing buffers for workers, and law enforcement will improve safety of the work zones.

Keywords:
Work zone, Safety, Potential hazards, Temporary Traffic Control Devices, Risk-Concentration
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Introduction

Work zone is the section of roadway occupied by work which affect traffic flow and road users as those areas of carriage way in advance of the working area for the advance warning signs, channelizing devices for transition of traffic movement, the activity area where actual work is

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taking place and the termination zone where drivers are informed to return to their normal operations (Yue et al, 2009). Number of registered vehicles has increased by 16% from 2010-2013 worldwide (World health Organisation, 2015). Between 1970 and 2013, vehicle use in Nigeria has increased from 145,000 to 1,498,000 (Atubi & Gbadamosi, 2015). This increase coupled with deterioration of the existing highway facilities necessitate the need to upgrade and build more roads in order to enhance traffic flow and safety of the road users hence increasing number of work zones putting life of motorist, road workers and other vulnerable road users at risk.

Research to date is limited, but demonstrates firstly that the presence of work zones increases risk on the roads, secondly, that working on the roads is one of the most dangerous occupations and thirdly, that improved safety practices can reverse these scenarios (Kýzýltaþ, 2001). In Finland and Slovenia motorists are up to five times more likely to get hurt when travelling through a work zone than non-work zone area (Shi et al, 2008). In Germany, approximately one quarter of collisions occurring on national highways occur in work zones (European Transport Safety Council (ETSC), 2011). In the United Kingdom, about 20% of road workers had suffered some injury caused by passing vehicles in the course of their careers and 54% had experienced a near miss with a moving vehicle (UK highways agency, 2006). In the United States over 1,000 people die and more than 40,000 people are injured each year as a result of motor vehicle accidents in work zones (Mahoney et al, 2007). Research in the United States shows that, majority of fatalities that occur in road construction work zones involve a worker being struck by a piece of construction equipment or other vehicle. A worker in this industry is likely to be struck by a piece of construction equipment inside the work zone than by passing traffic (Yingfeng & Yong, 2009). The major factors contributing to work zone crashes are driver expectation, roadside hazard, driver behaviour, unsuccessful mitigation strategies, roadway characteristics, environmental conditions, secondary congestion caused by roadway incident and combined effect (ETSC, 2006). In Nigeria, work zone crashes are not recorded separately making work zone crash analysis difficult (Umar, 2014). Therefore, conventional approach for determining the risk associated with areas of work zone cannot be used as data is not readily available. In this research, risk concentration level was used to assess the safety in each of the work zone areas.

The objective of the research is to identify potential hazards in work zones and determine the most dangerous section of the work zone using the risk concentration value. The research will also provide possible countermeasures that will enhance safety of work zones in Nigeria.

Materials and Methods

Description of the Study Area

Two construction work zones were selected for conducting this research. Road section on a rural roadway and an intersection on an urban road.

Kano- Maiduguri Road: The road section is a rural highway connecting the Kano city with many states in the North Eastern part of Nigeria as shown in Figure 1. The road is undergoing reconstruction in which it is been changed from the 2-lane single carriage way to a 4-lane divided highway. The total length the road is 591km. For the purpose of this study only the first 38km of the road was considered, (Kano – Wudil) which is known as a dangerous road section from the traffic safety point of view. On average accident occurs every 4-days and fatality in every 2-accidents (Umar, 2004). In this particular road section, a 15 km of a new road was constructed adjacent to the existing roadway. Traffic was diverted to this newly constructed carriageway giving the contractor room to reconstruct the existing road which will become one carriage way of the road. The project has a duration of 111 month and average daily traffic through the work zone of 23,000veh/day.

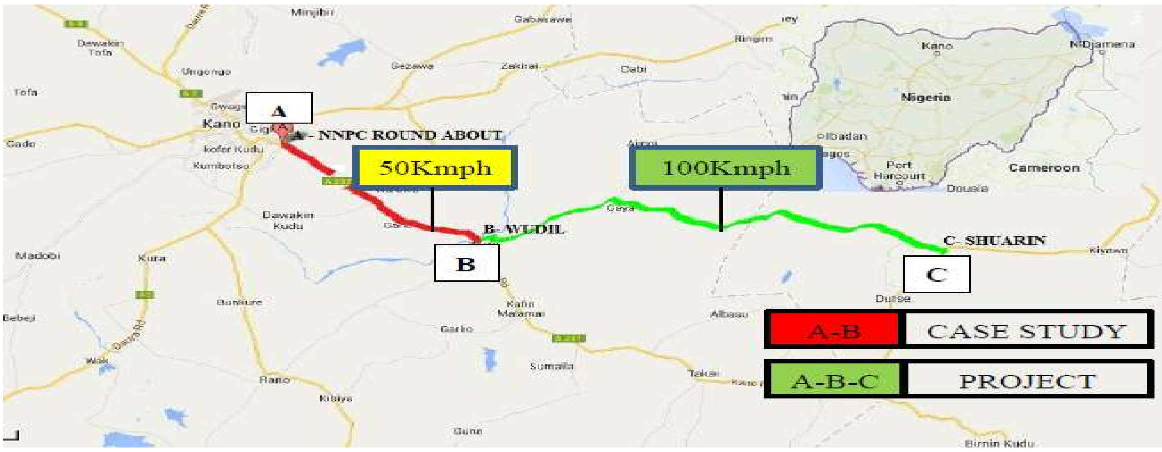

Figure 1. Map Showing Kano Maiduguri Road

Gadon- Kaya Junction is a signalised 4-leg intersection along Bayero University, Kano (BUK) road by Aminu Kano way of Kano metropolis as shown in Figure 2. The work zone is 800m in length. The junction has been reconstructed and changed from at-grade intersection to a grade separated intersection. Due to the fact that most of the higher institutions in the state are along the road, even the 6-lane do create some hold off especially during working days at peak hours, when students and workers are busy using the road. Due to this fact and some other reasons, the Kano state government decided to upgrade the road section by constructing an underpass at the Gadon Kaya cross junction, so that vehicles moving along BUK Road uses the down section of the underpass, while the traffic along Yahaya Gusau - Aminu Kano road uses the upper section of the underpass. This development will significantly enhance mobility and capacity of the junction. The project has a duration of 6 months and the average daily traffic through the work zone is 30,000 veh/day. A temporary roadway was provided to divert the traffic on BUK road to enable the excavation work to proceed along the road and traffic from Aminu Kano way were blocked.

Figure 2. Map Showing Gadon Kaya Junction

Site Inspection

During the site inspection, the actual condition of the work zone was visualised. Driving was experienced four times through each of the work zones during the peak hour, off-peak hour, day and night in both directions. Traffic condition, work zone configuration, behaviours of drivers and pedestrians, queue length, delay time, actual travel speed, feasibility of enforcement, effectiveness of signs, lighting, marking, and delineations, guard rails and crash cushions were all observed. Adequacy of the temporary traffic control devices was also noticed. Photographs and video recordings were taken during the inspection for later referencing. The potential hazards were observed and recorded base on the contributing factors, also their frequency in the work zone. Hazard in each section (advance warning area, transition area, activity area and termination area) of the work zone were also recorded. The severity level was obtained using a risk matrix in Table 1.

Table 1. Risk Matrix

Risk Level		**Severity**				
		5	**4**	**3**	**2**	**1**
Frequency	**5**	25	20	15	10	5
	4	20	16	12	8	4
	3	15	12	9	6	3
	2	10	8	6	4	2
	1	5	4	3	2	1

Risk Level	20-25	10-16	05-09	01-04
Meaning	Very high	High	Medium	low

Results and Discussion

Hazards identification, risk assessment and counter measures of potential hazards 23 potential hazards were identified from the 2-work zones and each was given an identification number of H1-H23. The hazards were classified into 4 main categories. i) 10- Temporary traffic control devices

(TTCD) related ii) 6- construction activity area related iii) 4-road user's behavior related v) 3-Road side related. The expected crash to be caused by each hazard was identified. The frequency of the crash was determined by multiplying the probability of crash occurrence and the frequency of that hazard from the two sites on scale of 1-5. The severity level, 1-5 (1=trivial, 2=minor injury, 3=injury requiring hospitalisation, 4=permanent disability, 5=fatality) to be caused by a potential hazard was estimated by qualitative method (experience and engineering judgements). The resulting risk level was then identified using risk matrix in Table 1, and corresponding definition was used to translate the risk levels. A countermeasure was then proposed to mitigate the perceived risk. Table 2 gives the list of the hazards, expected crashes, frequency, severity risk level, and the resulting countermeasure for the potential hazard.

Table 2**.** Risk Level and Countermeasures of Potential Hazards

	Safety Hazards	**Expected crash**				**Recommended counter measures**
		Type	**Frequency**	**Severity**	**Risk level**	
Temporary traffic control devices	H1-Improper sign placement.	All types of swipe	3	3	Medium	Maintenance to ensure all signs was placed in accordance with standards.
	H2-Improper maintenance of signs.	Swipe	4	4	High	Regular maintenance
	H3-Confusing signs.	All types of swipe	4	5	Very high	Make signs legible and clear
	H4-Missing TTCD	All types of swipe	4	4	High	TTCD be provided as required by specifications
	H5-Poor access design	head-on collision	3	4	High	Access should be designed as specified by AASHTO
	H6-Use of dangerous object for closure	All types of swipe	4	5	Very high	Objects used for closure must conform with MUTCD
	H7-Missing buffer	All types	4	5	Very high	Provide buffer spaces
	H8-Missing taper.	Sideswipe, head on collisions	5	4	Very high	Provide and ensure minimum taper length is provided.
	H9- Use of non- retro-reflective signs	Collision with dangerous object	4	5	Very high	Change all devices that lost their retro-reflective property.
	H10-Signs close to the travel lane.	Sideswipe	4	4	High	Provide required minimum lateral length

Construction activity area	H11-Workers' exposure to traffic	Sideswipe and same direction	3	5	High	Provide both lateral and longitudinal buffer spaces.
	H12-Unprotected work area	Sideswipe, rear end	4	5	Very high	Provide buffers
	H13-Improper work zone design	All types of swipe	3	5	High	Refer to the MUTCD for proper configuration.
	H14-Dangerous flagging	Sideswipe same direction	4	5	Very high	Flaggers should be trained and provided with proper flagging equipment.
	H15- missing safety alarms for heavy trucks	Worker hit by a working vehicle	5	5	Very high	Check all machineries without alarms and repair.
	H23- safety attires	Worker hit by a vehicle	3	5	High	Workers should be equipped with safety attires
Road Users	H16-Non-compliance with signs	Sideswipe opposite direction	3	5	High	Provide enforcements.
	H17-Misuse of traffic devices	Sideswipe same direction	3	5	High	Provide enforcements.
	H18-Speeding and aggressive driving.	All	5	5	Very high	Employ the use of speed calming measures like use of speed bumps.
	H19-On street parking	All types of swipe	3	4	High	Enforcement and provide an alternative parking area for visitors.
Roadside area	H20-Dangerous object within clear zone	Sideswipe	4	4	High	Provide minimum clear zone width.
	H21-Slippery road edge	Sideswipe	3	5	Medium	Provide lateral protection.
	H22-Improper pedestrian crossing	Vehicle-pedestrian crash	4	5	Very high	Pedestrian overhead bridges should be constructed

It can be seen clearly from Figure 3 that the risk level for all the identified hazards ranges from High to very high with only 2 having a medium risk level. 10 of the hazards have a "very high" risk level, 11 "have high" risk level. This is an indication of extent of safety problem with the work zones. Half of all the hazards with "very high" risk level are TTCD hazards followed by hazards in the Construction activities as shown in Figure 1. Improving the condition of TTCD will improve safety of the work zones by almost 50%. Proper configuration, provision of safety alarms and worker training as well as provision of all necessary attires for workers will immensely increase safety of the work zone.

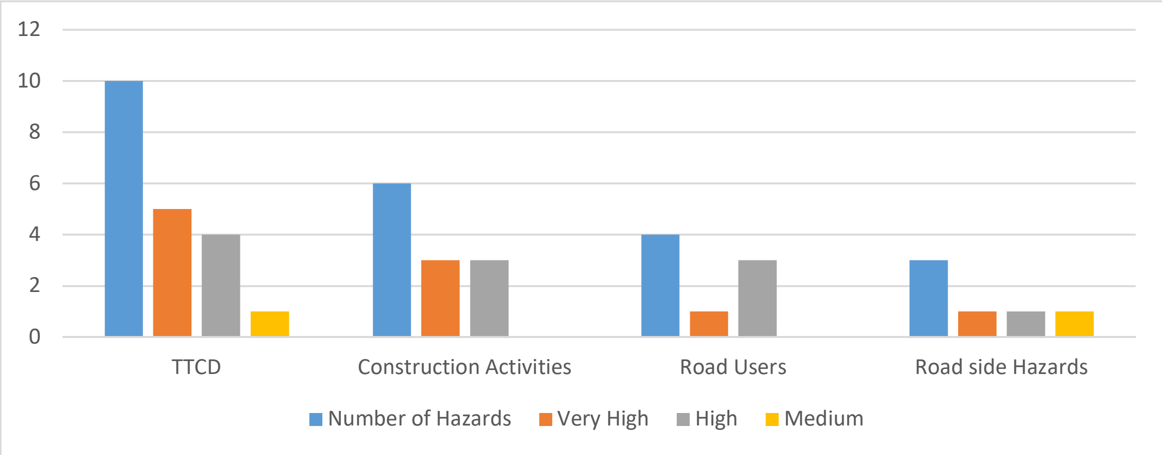

Figure 3. Hazards distribution.

Evaluation of Safety of the Work Zone Areas

To evaluate the danger in the work zone areas, the hazards observed in advance warning area, transition area, working area and termination areas were recorded and the corresponding risk concentration level (summation of risk level in the area) was used to access the danger level (0-49=low, 50-99=medium, 100-150=high, above 150=very high) of each area as presented in Table 3. Countermeasures were also provided to enhance safety of the work zone areas. Six different types of hazards were observed in the advance warning area, ten were observed in transition area, nine in activity area and four in the termination area.

Table 3. Risk level and countermeasures of Potential hazards

Work Zone Location	Hazards	Risk Level	Risk Concentration	Countermeasures
Advance Warning Area	H1	Medium	93	Install adequate warning signs to inform the road users with the extent of the hazards they are approaching. Signs installations should be strictly as provided in work zone safety manuals. All the signs should be regularly maintained.
	H2	High		
	H4	High		
	H9	Very High		
	H10	High		
	H20	High		
Transition Area	H1	Medium	169	Transition tapers should be provided to safely guide traffic through the working area. The radius of the transition needs to be increased to adequately accommodate trailers.
	H2	high		
	H3	Very high		
	H5	High		
	H8	Very high		
	H9	Very high		
	H14	Very high		
	H16	High		
	H18	Very high		
	H19	High		

Working Area (Activity Area)	H4	High	138	All machineries especially rollers, excavator, graders and tippers should have a safety alarm to help workers know that a machine is approaching. All works should be properly delineated and lateral buffers and longitudinal buffers should be provided.
	H6	Very high		
	H7	Very high		
	H11	High		
	H12	Very high		
	H15	Very high		
	H19	High		
	H21	High		
	H22	High		
Termination Area	H4	High	59	The termination area should have a proper sign indicating that the drivers can return to their normal operation.
	H5	High		
	H17	High		
	H20	High		

The transition area has highest number of potential hazards and hazards with "very high" risk level followed by the working area as shown in Figure 4. This is due to higher vehicular interaction and intensity of work activities in the transition area and activity area respectively. The transition area has very high risk concentration, followed by a working area with a high load concentration. The advance warning area and the termination area are characterised with medium risk concentration.

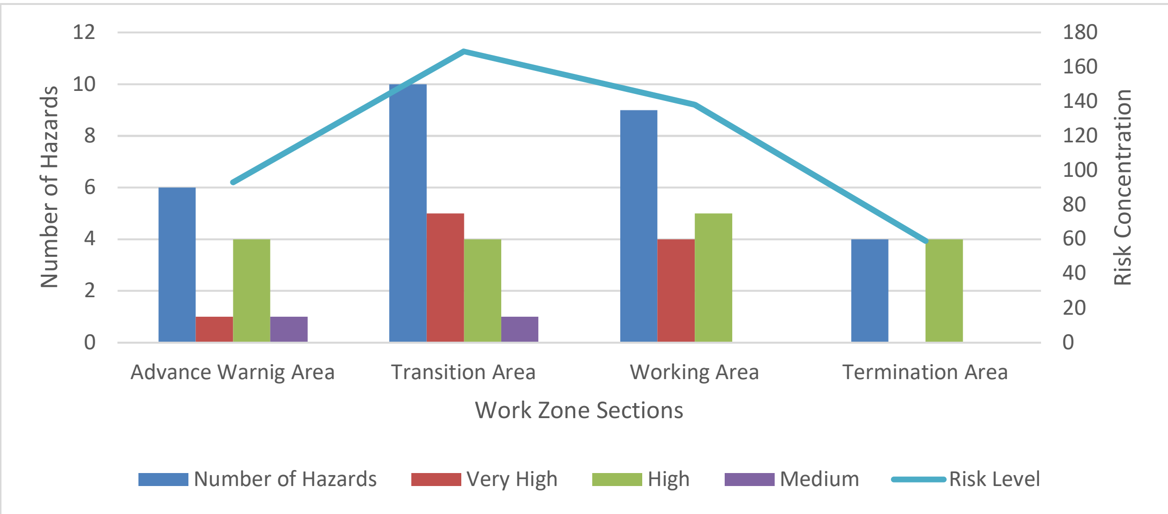

Figure 4. Hazards risk level in work zone areas.

Twenty-three potential hazards were identified in the two work zones studied. Eleven of the identified hazards have "very high" risk level, ten have "high" risk level and only two have medium risk level. This shows clearly that work zones are danger areas with much required to improve safety of both workers and the road users.

Confusing signs, use of dangerous devices for road closure, missing buffer, missing tapers, use of non-retro reflective devices, unprotected work area, dangerous flagging, missing safety alarms for heavy machineries, speed, aggressive driving and improper pedestrian access are the most dangerous hazards in work zone having a “very high” risk level.

The number of hazards associated with temporary traffic control devices outnumbered all hazards, followed by hazards in construction activity area, road users and finally hazards from road sides. Transition area was found to be the most dangerous area of the work zone with a “very high” risk concentration level followed by working area with a “high” risk concentration level, then advance warning area “medium” risk concentration level and finally termination area also with “medium” risk concentration level.

Proper installation and maintenance of TTCD, use of safety attires by workers, fitting and repair of all moving machineries with safety alarms, use of retro reflective devices, proper delineation of work activities, providing buffers for workers, and enforcement will surely improve safety of the work zones.

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