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INFRASTRUCTURE CAUSES OF ROAD ACCIDENTS ON THE YAOUNDE – DOUALA HIGHWAY, CAMEROON

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ABSTRACT

The overall goal of this study was to determine the causes of road crashes related to road infrastructure parameters on the National Road No. 3 (N3) and provide measures to improve the safety of all road users. To achieve this, 225 accident reports for the years 2017 and 2018 were collected from the State Defense Secretariat. This accident data was analyzed using the crash frequency and the injury severity density criteria to obtain the accident-prone locations (7 critical sections and 2 critical intersections) and a map presenting these locations produced with ArcGis 10.4.1. A site visit of these locations was then performed to obtain the road infrastructure and environment data necessary to get which parameters are responsible for road crashes. Ten parameters that affect the safety of road users were obtained, namely inappropriate number of lanes and median width, inadequate shoulder width and absence of clear zone, unsatisfactory access control, poor state of guardrails, mediocre state of road surface, poor state of side drains, unequipped rest zones, presence of street vendors, inadequate intersection layout, and absence of lighting at intersections. To provide a convenient safety level, amongst other measures proposed are the establishment of a unique speed limit except at singular points, the conversion to a 2x2 lane road with raised median, the setup of a monitoring and maintenance schedule for roads, the increase of shoulder width and creation of clear zones, and proper signage, channelization and lighting at intersections.

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INTRODUCTION

The democratization of road transport came with the invention of the motor vehicle in the 20th century. Over the years, the number of motor vehicles has kept on increasing on a road network which has changed very little leading to its inefficiency and an increase in the number of road crashes. In 2004 road crashes were ranked as the 9th cause of death worldwide and if nothing is done, it will move to the 5th place by 2030 (WHO, 2010). Road crashes kill approximately 1.3 million people around the world each year, and seriously injure as many as 20 to 50 million people (WHO, 2018). Over 93% of these deaths occur in low- and middle-income countries, where there is only 60% of the global vehicle fleet (WHO, 2020) with close to half of the victims being vulnerable road users (pedestrians, bicyclists, users of two-wheeled or three-wheeled motorized vehicles) (WHO, 2009). In Cameroon, over 16500 accidents are recorded every year with an average of 1200 deaths and 4000 to 5000 injuries, including dozens disabled for life each year. The material damage of these accidents is valued at over 100 billion CFA francs per year, equivalent to 1 % of the gross domestic product (UNECE, 2018). This high proportion of accidents is explained by a low level of education of all road users on safe road behaviors and a low level of enforcement. The most accident-prone axes as reported by the ministry of transport, with 70 % of all accidents, are the Douala-Yaounde, Yaounde-Bafoussam and Bafoussam-Douala axes(NGHEMKAP, 2010). Cameroon's national road No. 3 which connects Yaounde, the political capital to Douala, the economic capital is a major transport road since it is part of the road network linking the Douala seaport to other parts of the country and neighboring countries which do not have access to the sea. This gives rise to a dense traffic composed mainly of heavy vehicles and to road users who are in a rush, leading to crashes. The main causes of these crashes are excess speed, inattention and other human causes. Though the human factor plays a predominant role in road crashes, there exist also vehicle and infrastructure factors which when combined to human factors increase the risk of accidents and worsen the accident consequences. The state of the road infrastructure on the national road No. 3 is often denounced as an explanatory variable for the high number of crashes registered on this road. The main complaint is with regards to the poor state of the road surface which is not regularly taken care of(Andzongo, 2017). Conscious that this is not the only problem present, the question of which road infrastructure parameters have an influence on road crashes on the national road No. 3, and how they can be ameliorated is asked. The general objective of this work is consequently to find the road infrastructure parameters which increase the risk of road crashes on the national road No.3 or increase their gravity, and propose measures that could be applied to improve safety.

METHODOLOGY

This study is carried out on Cameroon's national road No. 3 (N3), precisely on the 215 km long road section linking Yaounde (exactly at Mvan's 2^{nd} interchange) to Douala (exactly at the Dibamba bridge). setting-up a map of accident-prone locations, visiting these locations to collect data and finally grouping this data to understand which infrastructure parameters play a role in the occurrence of road crashes on the N3.

Police reports: Police reports centralized at the State Defense Secretariat in Yaounde were collected in paper format and digitized using a pre-established Excel form. These reports spanned from January 2017 to December 2018. Table 1 presents the information relevant for this study extracted from the police reports and grouped on road sections and road intersections.

Criteria for identification of accident-prone locations: The accident data was analyzed using two crash data analysis methods, the crash frequency (CF) and the injury severity index (ISD). The CF method counts the number of crashes that have occurred at a given location (along a roadway section or at an intersection) over a specific period of time. The CF was evaluated using Eq. (1) and compared to a critical value. For road sections, the critical value is given by Eq. (2) and for road intersections, the critical value is the average number of accidents recorded on all intersections.

$$CF = \frac{A}{L} \qquad (1)$$

Where A = Total number of accidents
L = Length of section studied

Table 1. Accident data by location

Road sections	Code (T: Road section, C: Road intersection)	Road or intersection	Length (m)	Fatal accidents	Injury accidents	PDO	Total accidents
Yaounde (2^{nd} interchange Mvan) - Ndoupe	T1		8047.20	2	0	1	3
	C1	Nomayos intersection		0	1	0	1
	T2		7928.52	1	4	2	7
	T3		8023.25	0	0	0	0
	T4		8023.25	1	0	1	2
	T5		8023.25	0	0	0	0
	T6		8023.25	0	1	1	2
	T7		5786.92	1	3	4	8
	C2	Mandoumba descend		0	0	1	1
	T8		5509.91	0	1	2	3
	T9		5509.91	2	5	2	9
	C3	Ngoung		0	1	0	1
	T10		7220.87	1	8	8	17
	T11		5485.62	0	5	3	8
	T12		5485.62	2	6	1	9
	C4	Boumnyebel intersection		0	1	5	6
	T13		7788.66	4	3	6	13
	T14		7788.66	2	3	2	7
	C5	Sombo chiefdom entrance		4	2	4	10
	T15		1170.64	0	0	3	3
	C6	Sombo intersection		1	0	1	2
	T16		3965.47	1	2	1	4
	C7	Ndoupe intersection		1	0	0	1
	T17		331.00	0	0	0	0
Ndoupe - Pouma	T18		9337.41	1	3	4	8
	T19		9337.41	4	5	3	12
Pouma - Edea	T20		7706.05	1	3	2	6
	T21		7706.05	0	3	3	6
	T22		7706.05	1	4	3	8
	T23		7706.05	0	2	1	3
	T24		7706.05	1	2	6	9
	T25		4767.57	1	3	1	5
	C8	Ntoumba intersection		1	1	0	2
	T26		2139.77	1	2	0	3
	C9	Edea weigh station		1	3	1	5
	T27		206.04	0	0	0	0
Edea - Douala (Pont Dibamba)	T28		698.46	0	1	0	1
	C10	Tradex petrol station		0	1	1	2
	T29		249.78	0	0	0	0
	C11	Party house		0	1	2	3
	T30		7204.30	3	1	1	5
	T31		7631.80	0	2	3	5
	T32		7631.80	1	4	1	6
	T33		7631.80	2	1	2	5
	T34		7631.80	5	0	4	9
	T35		7631.80	1	0	1	2

$$\text{Critical CF for road} = \frac{Total\ number\ of\ accidents}{Total\ length\ of\ road\ (km)} \quad (2)$$

The ISD method is a detailed variant of the CF; here the crash data is detailed into categories. Developed in Norway, the ISD represents the average accident severity. It is obtained by weighting accidents differently according to their severity (Elvik, 2007); the more serious the accidents, the higher their weight. The injury severity index was evaluated using Eq. (3) for road sections and Eq. (4) for road intersections, and the threshold value evaluated using Eq. (5). The weightage points used were obtained modifying those used in Malaysia (Rahim, Marjan, & Voon, 2013), which are valid for developing countries, to take into account the fact that the collected police reports do not distinguish between severe and slight injury accidents.

$$ISD = \frac{6*FA+3*IA+1*PDO}{L} \quad (3)$$

$$ISD = 6*FA+3*IA+1*PDO \quad (4)$$

Where FA = Fatal accident
IA = Injury accident
PDO = Property damage only
L = Length of section studied
6,3,1 are weightage points

$$Threshold = (X, M) \quad (5)$$

Where X = Average of ISD values
M = Median of ISD values

Set-up of crash black section map: The identification of the accident-prone locations and the set-up of a map was done as follows:

- The accident data was digitized in the Google Earth software. Each crash was represented by an icon detailing the type of crash that occurred. The file produced was transferred to ArcGis 10.4.1;
- The file format obtained from Google Earth (kmz type) since not supported by ArcGis 10.4.1 was converted using Qgis to the supported file format (shp type);
- The accident data in the correct file format was opened in ArcGis 10.4.1, as well as, a shape file of the study road;
- The road was sectioned paying attention to the Cameroon Geographic Road Referential (Mission d'assistance technique conjointe, 2011) and intersections into sections of 1-9 km where possible. Due to the proximity of certain intersections, sections of less than a km were encountered;
- The sections and intersections were named;
- The name of the sections and intersections, their corresponding number of accidents and gravity, and length (where applicable) were recorded using Microsoft Excel software;
- This data was analysed using the crash frequency and injury severity density criteria and the road sections or intersections categorized following the steps in the flow chart in Figure 1;
- The accident-prone locations were highlighted in the ArcGis 10.4.1 software and a map of the accident-prone locations produced.

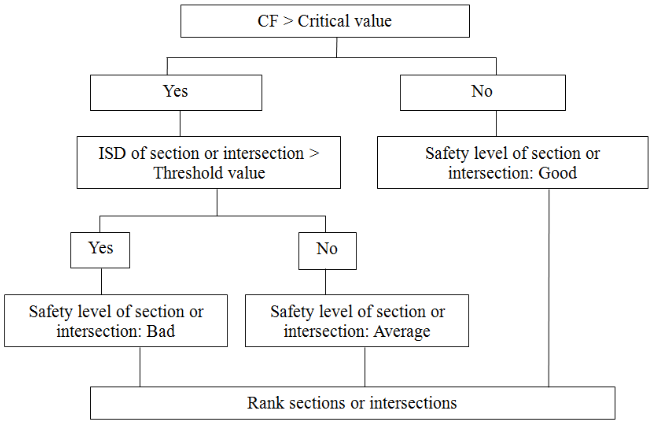

Figure 1. Flow chart for ranking of accident-prone locations

RESULTS AND DISCUSSIONS

After the study of 35 road sections and 11 intersections, it was obtained as accident-prone locations, 7 road sections and 2 intersections as presented in Figure 2.

Infrastructure causes of road accidents at road sections

The road data collected from the road sections are presented in Table 2. From this data, accident causes at road sections were obtained. A conflict example could be between, heavy vehicles which move slowly and automobiles which tend to move faster, thus, where 1x1 lanes are present (this is predominantly the case), automobiles tend to overtake even if the road marking is a continuous line, which is risky.

Number of access points and access controls: A high number of access points not always equipped with control mechanisms are recorded. An example is segment T34 which has the highest number of access points (16) but no access control is present, implying, the driver on the minor road has no instruction. Also, no traffic sign announcing an intersection is present on that segment, thus the driver on the main road too is not informed of a conflict point ahead.

Presence and state of guardrails: Along all road segments, guardrails are present only at curves, and all curves are not equipped. The general remark that can be made on the guardrails present is that they were broken dirty and not continuous.

Shoulder width and absence of clear zone: No clear zone is present and the shoulder width of 2.4 m is not convenient to accommodate breakdown vehicles such as trucks by the roadside (Figure 3).

State of road surface: The road surface is cracked, rutted and delaminated (Figure 4) which leads to hazards such as water collection on the road. This increases the risk of aquaplaning and leads to drivers performing manoeuvres to avoid damaged areas by moving to the lane reserved for the opposing traffic which might be a cause of head-on collisions.

Presence and state of side drains: Poor state of side drains which are predominantly non-cemented ditches dug to serve as evacuation. No matter the drain type, the general observation is they are invaded.

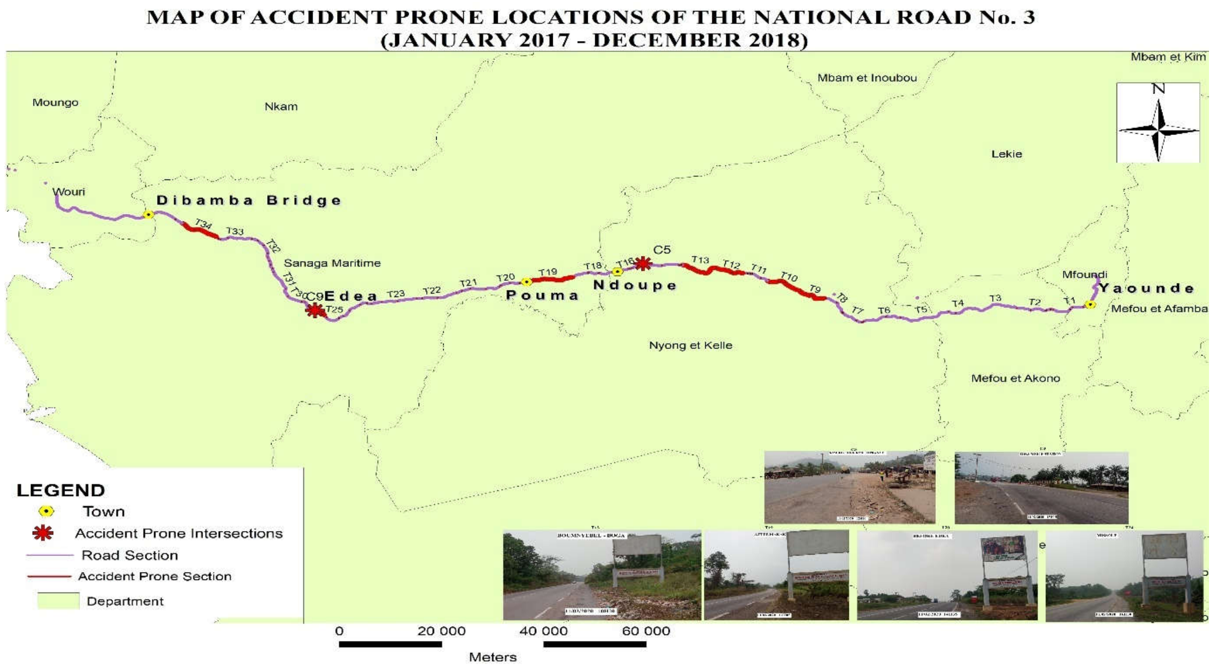

Figure 2. Map of accident-prone locations

Figure 3. Parked vehicle by the roadside occupying part of the vehicle lane since shoulder width is insufficient

Figure 4. Delaminated road surface

Rest zone availability: Absence of equipped rest zones although vague terrains are available along the road. This results in long driving hours with no rest, parking on shoulders at towns' entrances and hence a decrease in road safety.

Presence of street vendors

Presence of street vendors principally at toll stations and at all points where bus agencies usually slow down for passengers to buy local products.

Table 2. Road geometric and environment elements of road sections

	Road Segment	Before Matomb - After Matomb	After Matomb - After Mamb	After Omog - Boumnyebel	Boumnyebel - Boga	After Makak	Before Edea	Missole
	Segment code	T9	T10	T12	T13	T19	T26	T34
No	Geometric elements							
1	Segment length (m)	5509.91	7220.87	5485.62	7788.66	9337.41	2139.77	7631.80
2	Road width (m)	7.38	7.3	7.25	7.35	7.3	11	7.28
3	No of lanes	2	2	2	2	2	3	2
4.1	Median width (m)	0.15	0.15	0.15	0.15	0.15	0.3	0.15
4.2	Median type	Painted line: continuous	Painted line: continuous	Painted line: continuous	Painted line: continuous	Painted line: continuous	Painted line: single discontinuous and double continuous	Painted line: continuous
5	Shoulder width	2.45	2.42	2.45	2.43	2.42	2.43	2.44
6	Presence of clear zone	No	No	No	No	No	No	No
7.1	Number of access points	7	9	7	8	8	3	16
7.2	No of access controls	1	4	2	2	1	0	0
8	No of mixed vertical grade and horizontal curve	3	1	2	0	0	0	1
No	Environment elements							
1.1	Presence of guardrails	Yes	Yes	Yes	Yes	Yes	No	Yes
1.2	State of guardrail	Not continuous / Broken	Not continuous	Good	Not continuous	Not continuous / Broken		Not continuous
2.1	State of road surface	Medium	Good	Medium	Medium	Medium	Good	Good
2.2	Type of deterioration	Cracking	Cracking	Cracking / Delamination	Cracking	Cracking	\	\
3.1	Presence of side drains	Yes	No	No	No	No	No	Yes
No	Environment elements							
3.2	State of side drains	Blocked	\	\	\	\	\	Blocked
4.1	No of traffic sign	6	9	10	18	28	4	10
4.2	Traffic sign legibility	Good	Good	Good	Good / Hidden / Broken / Dirty	Good	Good	Good / Hidden / Broken / Dirty
4.3	Type of traffic sign	Speed limit, Curve	Speed limit, Curve, Intersection, Overtaking prohibited, Road beacon	Speed limit, Curve, Intersection, Toll	Curve, Overtaking prohibited, Road beacon, Lane attribution	Speed limit, Curve, Double curve Overtaking prohibited, Road narrowing, Road works	Speed bump, Give way, Weigh station, Unknown danger	Speed limit, Curve, Double curve, Overtaking prohibited
5.1	Rest zone availability	No	Yes	Yes	Yes	Yes	No	No
5.2	Rest zone equipment	\	Empty field	Empty field	Empty field	Empty field	\	\
6	Presence of visual clutter	No	No	No	No	No	No	No
7	Street vendors	Yes	Yes	Yes	No	No	No	No

Table 3. Geometric and environment elements of intersections

	Intersection name	Sombo chiefdom entrance	Edea weigh station
	Intersection code	C5	C9
No	Geometric and environment elements		
1	Intersection type	Four-leg	Four-leg
2	Intersection control	Priority	Priority
3	Channelization	No	No
4	Street vendors	Yes	No
5	Waste accumulation	Yes	No
6	Presence of lighting	Yes	No
7	State of lighting	Bad	\

This has a great influence on vehicle to pedestrian crashes since the vendors do not hesitate to occupy the carriageway to sell their products.

Infrastructure causes of road accidents at road intersections

From the interpretation of the data in Table 3, an overview of the problems recorded at intersections were obtained.

Intersection type, layout and state: The 2 intersections visited were both 4-leg intersections with priority control and no channelization. The absence of strict guidelines leads to conflicts among road users.

Presence of street vendors: Street vendors are present at intersections located in rural centers. They occupy the shoulders and stand a risk being struck by a vehicle, thus increasing the probability of vehicle to pedestrian crashes.

Presence and state of lighting: Visibility at the intersections is hindered due to absence of streetlights or presence of damaged streetlights.

Proposed recommendations for improvements

Recommendations are proposed to increase the safety of road users based on what is present in the literature and adapting them to the Cameroonian context.

Speed consistency: The speed at the time of the collision being the main determinant of the kinetic energy that the human body sustains in a crash, this makes it the most important factor in determining the result of a collision and the most important factor to keep under control. On the N3 there exist 5 speed limits practiced 30 km/hr, 60 km/hr, 80 km/hr, 90 km/hr and 110 km/hr. The first thing to note is the great variability of speed which can be confusing for the road user. Also, mindful of the dimensions of the road and the poor maintenance frequency, having a section where it is possible to practice a speed of 110 km/hr is dangerous. Following the analysis of Racioppi *et al*., (2004) on the effects of speed, it is recommended a unique speed limit of 80 km/hr in order to strike a balance between safety and mobility.

Number of lanes and median: The conversion of the whole road to a 4-lane road with raised median will reduce the number of injury accidents (Elvik *et al*., 2009) since there exist a space for slow moving vehicles thus reducing the conflict between vehicle categories and the presence of a raised median separates opposing traffic flows, reducing the risk of head-on crashes.

Monitoring and maintenance of road surface: Regular road maintenance should be performed to guarantee safety of the road user. Also, maintenance costs and time increase with increased degree of defects. Efficiency of side drains has to be maintained by regular cleaning to ensure evacuation of rain water, thus road flooding avoided and aquaplaning risk reduced.

Shoulder width increase and clear zone creation: The provision of space by the road side for break down vehicles has to be assured in order to guarantee the concept of “forgiving road side design” which wants that, when a driver commits a mistake due to unavoidable circumstances, his or her mistakes will be forgiven by the design concept. This can be assured by the provision of clear zones and an increase in shoulder width (Elvik *et al*., 2009).

Maintenance of Guardrails: Considering the importance of guardrails in the safety of road users (Elvik *et al*., 2009), their rapid rehabilitation is recommended in the case where defects are noticed so their continuity is maintain.

Equipping of rest zones: Driving for long periods without a break reduces driver performance and may lead to an increase in the accident rate, as has been shown in a Norwegian study (Elvik *et al*., (2009)). On the N3 are present vague terrains which have to be furnished with all the required facilities in order to transform them into rest zones following the recommendations of SETRA, (2000) which state that, once a road is put in service, a rest area must be provided at least every 30 km and a service area every 60 km.

Provision and maintenance of traffic signs: One of the most common factors associated with road accidents is the failure of road users involved to see each other in time, or at all. By putting up “give way” or “slow down” signs, road users will reduce their speed before driving pass an intersection. This aims to increase the reaction time before reaching an intersection. Access roads on the N3 can be considered as minor three-leg intersections though not designed as such. These access roads are generally announced on the main road using the intersection traffic sign but not all access (minor) roads are equipped with a stop sign which represents a major hazard. It has been demonstrated by Elvik *et al*., (2009) that, putting up stop signs reduces the number of injury accidents by about 20% in three-leg junctions and by about 35% in four-leg junctions. Placing and regularly maintaining these signs would increase the safety level at these intersections.

Provision and maintenance of lighting: Providing street lighting at intersection locations can reduce night time crashes by making the intersection features visible to both vehicles and pedestrians. Lighting intersections can also aid navigation and helps drivers to see the intersecting road, turning vehicles, traffic queues and any other road users. Installing and maintaining lighting at all intersections (especially C5 and C9) would go a long way to making the road safer for all users

Channelization type: The provision of the appropriate channelization type will assure safe and efficient operations at intersections by managing the conflicts that are inherent to intersections.

Appropriate data collection and management process: The delay in data analysis and the loss of data with time are some of the reasons why the safety of users is not regularly monitored. Thus, it is recommended.

- A unique data collection sheet prepared by qualified personnel should be put in place over the whole territory. This will facilitate data interpretation and ensure all necessary data is always collected on the field;

- The officers in charge of data collection should be trained in data collection and data processing. This will make them conscious of the importance of each data they are collecting;
- Regular digitization of the collected accident data should be performed. Also, regular accident statistics have to be evaluated so as to monitor and ensure appropriate measures are taken in time to solve issues which arise;
- Regular road survey has to be conducted to collect data on the state of the road and measures taken to guarantee the safety of the road users.

Conclusion

Road crashes in Cameroon represent one of the major death causes which is still not very much addressed. The objective of this study was to find out which road infrastructure parameters have an impact on road crashes on the national road No. 3 and propose solutions to improve road safety. To achieve this, a procedure was established that consisted of data collection and analysis which showed that some infrastructure parameters responsible for road crashes were the inadequate road layout, the poor state of some infrastructures like roads and lighting, and the lack of rest zones and clear zones. The road parameters obtained were studied based on what is recommended and some propositions made such as the adoption of a unique speed limit except at singular points, the regular monitoring and maintenance of infrastructures, the provision facilities at rest zones and proper signage, channelization and lighting at intersections. Though pertinent results were obtained, the results could be improved by the use of accident-prone identification criteria utilizing traffic data which was not possible in this study since the data was not available

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