Influence of Road Feature Variables on Accident Rate in Cameroun. Case study: The road triangle Yaounde-Douala-Bafoussam-Yaounde Highway.

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ABSTRACT

The objective of this work was to identify the road features variables that impact the crash rate on the road triangle, establish the relationship between these variables and the crash rate through descriptive analysis and correlation analysis using SPSS Software then propose solutions to improve on the safety of its users. To accomplish this, accident reports from the State Defense Secretariat (SED) for the years 2021 and 2022 were analyzed based on the safety performance indicators to identify accident-prone locations. Was obtained as risk locations, 13 risk segments and 7 risk intersections, then a site visit conducted to gather road feature data influencing the crash rate. Some key road parameters that emerged as responsible for crashes included inadequate number of lanes and width, insufficient shoulder width, poor road conditions (especially on the National Road 5), access points without access controls, absence of clear zones, and inappropriate intersection layout. Results from the correlation analysis revealed that the one-way lane width, number of lanes, median width and state of guardrails showed a good correlation with the crash rate suggesting that modifying these features positively could mitigate the crash rate. To enhance road safety several countermeasures including increasing the number of lanes particularly at sections like Douala-Yassa and Yaoundé-Obala, adopting a single speed limit of 80km/h expect at specific points, installing rumble strips, widening shoulder widths to 2.5 m so could serve as clear zones, regular road and environmental maintenance, and implementing proper signage. These measures aim to improve infrastructure and foster a safer road environment for all users.

Keyword: *Road safety, Road accidents, Accident-prone locations, Road feature variables, National Roads.*

1. INTRODUCTION

Road transport is the mode of transportation people prefer the most due to its accessibility and affordability. Most kinds of cargo, goods packed, goods containers, etcetera, which are scheduled for sea or air transportation have to be transported to and from the site via road transport [1], as a consequence it should be safe for its users. The World Bank and World Health Organization estimates reveal that about 1.2 million people die each year and as many as 50 million sustain injuries as a result of road traffic accidents [2-3]. Shockingly, road traffic accidents account for about

25% of all injury-related deaths globally. The situation is even more dire in developing countries where up to 93% of all road traffic fatalities occur [4]. Road crash now represent the eighth leading cause of death globally for all age groups surpassing HIV/AIDS, tuberculosis and diarrheal. The WHO predicts this trend will be tripled in 2030 if nothing is done. In Cameroon, according to the latest WHO data published in 2020, Road traffic accidents deaths reached 7,810 representing 4.36% of the total deaths. The aged adjusted death is 40.18 per 100,000 of population and ranks Cameroon 24th in the world. The material damage of these accidents is valued at over 100 billion CFA francs per year, equivalent to 1 % of the gross domestic product [5]

The most accident-prone axes as reported by the Ministry of Transport (MINT), with 70 % of all accidents, are the Yaounde-Douala, Yaounde-Bafoussam and Bafoussam-Douala axes, commonly called “Triangle de la mort” [6]. It is referred to as the “Death Triangle”, not only because of its triangular shape but also because of the countless deaths that occur on this axis every year. The National Road 3 links Yaounde, the political capital to Douala, the economic capital, the National Road 4 links the Yaounde to the Bafoussam and the National Road 5 links Douala to Bafoussam.

The three factors affecting road crashes include the human, the vehicle and road/environment factor. From these factors, the human factor is predominant with several studies demonstrating that excess speed is one of the major human causes of road crashes [7}. Though the human factor is predominant, the other factors when combined to it increases the occurrence and severity of the crash. Roadway/environment factors are the scope of civil engineering professionals, thus it is within this framework that the failure in considering road safety in the design of our roads is raised as a problem. Being very conscious of this, the purpose of this study is to identify the road feature variables affecting the crash rate on these roads, analyze the relationship that exist between these road feature variables and the crash rate, then propose countermeasures in order to improve on the road safety on this road triangle.

2. METHODOLOGY

2.1. Choice of the study area

The choice of the National roads 3, 4 and 5 constituting the " Death triangle” was based on the results obtained at the SED. The selection criteria, was the total number of crashes recorded, the severity of these crashes, the traffic volume and crash rate on these roads.

2.2. Study area

The study focuses on the portion of the National road 3 linking Yaounde (exactly at Mvan’s 2nd interchange) to Douala (exactly at the Dibamba bridge) with precisely 215 km, the National road 4 linking Yaounde to Bafoussam passing through Obala, Ebebda, Bafia, Ndikiniméki, Bangangte and Bandjoun having a total length of 259 km and National road 5 linking Douala to Bafoussam having a total length of 219km. The portions chosen for our study was based on the accidents recorded.

2.3. Data collection

Two types of data were obtained namely the accident data and road geometric data

2.3.1. Road accident data

Accident data reports spanning from January 2021 to December 2022 were obtained from the SED. These reports included general information on accidents such as, accident location, the day of the week, time of the day, crash severity, road type, type of collision, lightning condition, weather conditions, infrastructure defaults, mechanical defects, etecera. The information from these reports were gathered and transferred into an Excel sheet to determine the relationship between these features and the accident, then was identified the accident-prone locations on these roads using the safety performance indicators

2.3.2. Road data

The road data was obtained from a site visit of these risk locations. The road data consist of road geometric, road side and environment elements which vary with respect of the road segments and the road intersection. The road segment parameters adopted in this study were road segment length, surface width, shoulder width, median type, median width, median height, number of lanes, road alignment (number of horizontal curves and vertical grades count), number of access points, number of access control, illegal functions like street vendors, waste accumulation. guardrails, clear zones, drainage, rest zones, traffic signs and their legibility, presence of road lightening.

2.4 Data analysis method

2.4.1. Road traffic accident data analysis method

To ensure the consistency and homogeneity in our analysis, we divided the road network into equal segments of 8km as we went for the constant segmentation, approach. To analyze the accident data, two methods were used: crash frequency (CF) and injury severity density index (ISD) criteria. The CF method involves counting the number of crashes that occurred within a specified timeframe at a particular location (road section or intersection). Eq (1) was used to evaluate the CF, then compared to the critical CF. For road sections, the critical value is determined by Eq (2), while for road intersections, it is the average number of recorded accidents.

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

Where:

A = Total number of accidents

L = Length of section studied

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

The Injury Severity Density (ISD) method is a more detailed version of the CF. it involves categorizing crash data according to different severity levels. The ISD represents the average accident severity and is calculated by assigning different weights to the accidents based on the severity. Eq (3) was used to evaluate the ISD for road sections while Eq (4) was used for road intersections. Eq (5) was used to determine the threshold value. The weightage points assigned to accidents were modified from those used in Malaysia to account for the fact that the police reports collected did not distinguish between severe and slight injury accidents [8]

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

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

Where:

FA = Fatal Accident

IA = Injury Accident

PDO = Property Damage Only

L = Length of section studied

6,3,1 are weightage points

$$\text{Threshold}=(X,M) \quad (5)$$

Where :

X = Average of ISD values

M = Median of ISD values

2.4.2. Road data analysis method

The roadway element data from the accident-prone sites of these national roads under our study was collected, organized and presented in summarized tabular format in Excel for analysis. A descriptive analysis of the geometric, road side and equipment data was done with the aim of bringing out the influence of these road feature variables on the crash occurrence rate. An association analysis (correlation analysis) was equally carried out with the help of the SPSS software to determine which road feature has a strong correlation with the crash rate.

3. Data analysis, Results and Interpretation

From January 2021 to December 2022, 584 accidents were officially registered on the road triangle at the SED. After the study of close to 91 road sections and 20 intersections on the road triangle with the CF and ISD indicators, it was obtained as accident-prone locations, 13 road sections and 7 intersections as presented in Table 1.

Table 1. Result of risk segments and intersections determination with safety performance indicators (CF and ISD)

Segment or intersection code	Segment or intersection name	PDO	Injury accidents	Fatal accidents	Total number	Segment length	Crash rate	ISD for segment	ISD for intersection
T21	Sombo	6	5	10	21	8,018	2,619107	10,10226	
C4	Sombo intersection	3	2	2	7		7		25
T22	Mahole-Boga	7	6	9	22	8,007	2,747595	10,61571	
T23	Descente Mbanga - Boumyebel-Njok-Nkong	10	9	7	26	8,071	3,221409	12,51393	
C5	Boumyebel intersection	3	2	2	7		7		25
T24	Omog-Mamb	8	6	7	21	8,086	2,59708	9,646302	
T26	Makoda - Matomb	13	10	12	35	8,016	4,36626	16,34231	

T62	Nkoledouma-Efok	2	2	2	6	8,012	0,7488	2.995507	
T67	Bilik-Bindik-Ebebda	2	3	3	8	8,016	0.9980	4.366268	
C8	Ebebda intersection	3	2	1	6		6		21
T69	Ebebda II-Botatango	2	2	1	5	8,12	0.6157	2.463054	
T72	Edané-Boalong-Nguessogo-Ombessa	4	2	1	7	7,957	0,8797	2,764861	
C9	Ndikinimeki intersection	2	1	2	5		5		17
T84	Bantoum	2	3	1	6	7,948	0.7549	3.397081	
T34	Bekoko-Bomono Gare	5	4	2	11	8,292	1,326579	4,94452	
C11	Bomono exchange	4	2	1	7		7		22
T38	Kombe-Mouyouka-Mbanga	7	4	4	15	8,021	1,870091	6,3583	
C14	Mbanga intersection	3	2	1	6		6		21
T48	Nkongsamba	5	3	2	10	8,02	1,246882	4,2394	
C18	Nkongsamba intersection	3	2	1	6		6		21

05 road segments and 02 intersections on the N3 and N4 road, and 03 road segments and 03 intersections on the N5 road. The accident data analyzed with the CF and ISD revealed a critical crash rate value of 0.92, 0,37 and 0.38 for the road segments and a critical value of 6.2, 4.75 and 4.33 for the intersections on the N°3 road, N°4 road and N°5 road respectively.

Recently, research was conducted on the N°4 road, and it was found that the critical crash rate at segments recorded was 0.38 [9]. This value is slightly greater than the value we obtained, which can be attributed to the recent rehabilitation works that was carried out on this road. Similarly, on the N°3 road, another research was conducted, and it revealed a critical crash rate of 0.88 [10]. This value is lower than the one we obtained and could be due to the lack of proper maintenance on the road. As a result, some infrastructure components may have been deteriorated leading to a decrease in their effectiveness. The ISD was further used to obtain the exact risk locations as shown in Table 1.

3.1. Geometric, roadside and equipment factors of crashes at road segments.

These are parameters that constitute the road and its environment and must ensure it meets all the necessary requirements to assure the safety and comfort of road users. They are road lane width and number of lanes, median type and width, shoulder width and clear zone presence, access points and access controls, mixed vertical grade and horizontal curve, presence and state of guardrails, state of road surface, type of road deterioration, presence and state of side drains, presence, type and state of traffic signs, rest zone availability, presence of visual clutter and presence of street vendors as illustrated in Table 2, 3 and 4.

3.1.1. Road width and number of lanes

On these roads, the width of the road is quite uniform and depends on the number of lanes. The 2-lane road segments have an average width of 7.3 m, the 3-lane road segment an average of 11.2 m and the 4-lane road an average of 12.8 m at Bekoko interchange (the branch leading to Bafoussam) and 14.2 m at Bafoussam entrance. Considering the traffic composition on these roads with the majority being characterized by 2-lanes, the number of lanes can be an explanatory parameter for road crashes.

3.1.2. Median width and type

On these roads we noticed the presence of mostly painted white lines as median type either continuous or discontinuous. Both the continuous and discontinuous have a width of either 0.1 m or 0.15 m when single and a width of 0.3 m when double. We noticed different types of discontinuous lines. The T1, T2, and T3 category having a common length of 3 m. The T1 category is separated from the next by a distance of 10 m. The T2 category is separated from the next by 3.5 m and finally the T3 separated by a distance of 1.33 m.

At bendings, we typically encounter continuous lines and T3 lines shortly after completing the bend. These lines serve as warning to drivers, indicating that overtaking is unsafe in these areas due to reduced sight distance. While these lines act as deterrents, they do not physically separate the lanes, resulting in a higher risk of head-on collisions.

3.1.3. Shoulder width and absence of clear zone

The shoulder widths where present on the N°3, N°4 and N°5 roads are reported to be an average of 1.75 m, 1.2 m, 1 m respectively. However, considering the size of the articulated trucks that have a width of approximately 2.5 m, these shoulder widths are considered very insufficient as most vehicles when they encounter a breakdown, are forced to occupy a part of the lane width thus visibility hindered and risk of head-on collision.

At some segments of the N°5 road (precisely at Nkongsamba) the shoulder width was occupied by dirt which turned to equally occupy a portion of the lane width thereby reducing the available space and presenting risk for side-swap collision.

3.1.4. State of road surface and type of degradation

Globally, the state of the road surface on the N°5 road is catastrophic. This can be considered a contributing factor to the road accidents occurring on this road since a great part of the road is cracked, some areas delaminated, some with very deep pot holes, others experiencing ruth and depression and shoulder drop off. This is due to the fact that with time, traffic, weather conditions and ground conditions expose the road surfaces to wear and tear. Ruts, cracks and unevenness in the road surface reduce driving comfort and can be a traffic hazard. Ruts and cracks in the road surface may make it more difficult to keep a motor vehicle on a steady course. Large pot holes in the road surface can damage vehicles and lead to the driver losing control of the vehicle. To avoid this, some drivers perform maneuvers to avoid areas where the road surface is not convenient by moving to the lane reserved for the opposing traffic which might be a cause of head-on collisions. All these call for high rehabilitation works on the N°5 road.

On the N°3 road, the overall condition of the road surface is good. However, there are certain sections where the road condition is not satisfactory. Some areas exhibit cracks, while others show signs of delamination.

In contrast, the N°4 road has an overall very good condition, particularly in the Ebebda -Bafoussam section. This can be attributed to the rehabilitation work that was carried out in this specific portion. However, on the Ebebda-Yaoundé section, we have observed some cracks, delamination, and some potholes, particularly around Obala. This could strongly account for the high number of crashes registered on this section compared to the Ebeda – Bafoussam .

3.1.5. Number of horizontal curves

It was noticed that on the N°3 road, we had some segments where the straight alignment exceeded a maximum value of 2 km. This is considered as dangerous since according to the Setra, (2000) after 2km maximum, there is an absolutely need of a bend [11]. This is to:

- Prevent glare from the headlights of the vehicles coming in the opposite direction
- Avoid the monotonicity in driving that can create drowsiness.

3.1.6. Presence of guardrails

In certain areas along the road segments, guardrails are installed as safety measures. However, the general observation indicates that these guardrails have several issues. They are often broken, dirty, and covered with vegetation, which can significantly reduce their effectiveness in providing protection. Additionally, it is observed that in many instances, the guardrails are not continuous. Furthermore, there are sections where the ends of the guardrails are protruding. This is a concerning issue as it can greatly increase the severity of the crash if a vehicle collides with these protruding ends after an impact occurs. At the location of Nkometou on the N°4 road along the Bafoussam-Yaounde direction, it has been observed there is no guardrail present. This absence of a guardrail is particularly concerning due to the presence of houses located downslope from the road. This situation poses significant danger and risk to both the road users and the residents of these houses

3.1.7. Number of access points and access controls

A significant number of access points exist along these national roads, with very few of them being controlled that a good number of access points are present on these national roads with very few controlled. This turns to be a potential danger as access points naturally become conflicts points on the road. This is disadvantageous for both the driver on the minor road, as they may not have clear instructions or guidance, and for drivers on the main road segment, especially if there are no traffic signs indicating an intersection ahead.

At the location of Nkolguem 2, specifically at the access point of Carrefour Sa'a, it has been observed that there is no access control in place. The lack of access control is particularly concerning due to the presence of the bending road in the vicinity

3.1.8. Rest zones availability

There exist vague terrains by the roadside of these national roads serving as rest zones to some of the road users. Recalling the facilities which ought to be present on a rest zone such as toilets, food points etcetera, these terrains can be qualified as rest zones. Also, no traffic sign is placed on the road to announce them. The absence of these features leads to the conclusion that there are no rest zones available on the N°3 and N°5 road.

On the other hand, there is a progress being made on the N°4 road regarding rest zones. Two rest zones are under construction; one at Ndikinimeki and the other near the Bafia interchange. These efforts indicate a recognition of the importance of providing designated rest areas for road users, offering them a convenient place to take breaks during their travels.

3.1.9. Presence and state of side drains

Along these roads, it has been observed that the number of drains is limited, and in many areas, ditches are simply dug to serve as drainage channels. Regardless of the type of drain, it is noted that vegetations tends to invade these drainage systems. This vegetation growth tends to obstruct the proper flow of water off the pavement.

3.1.10. Presence and state of traffic signs

The N°3 road, is averagely well furnished with traffic signs. Though a wide variety of the signs present are not in good state. They are generally very dirty and hidden in the vegetation. On the N°4 raod, the traffic signs are quite in a very good state especially at the Ebebda- Bafoussam section. On the Ebeda – Yaounde portion, the traffic signs though present are very dirty and hidden in grasses.

In contrast, the furnishing in terms of traffic road signs on the N°5 road is very poor. There are very few present, and even those that exist are in a bad state. This situation presents a significant danger for road user, as traffic signs play a crucial role in warning them about the condition of the road ahead and providing necessary information for safe driving. Without this vital information, the risk of accidents and potential hazards are significantly increased.

3.2. Geometric, roadside and equipment factor of crashes at road intersections

3.2.1. Intersection description

On the N°3 road and N°4 road, there are a total of 02 critical intersections, and on the N°5 road, there are 03 critical intersections. The two critical intersections on the N°3 road, namely Sombo and Boumyebel, are both 4 leg intersections. These inteersectns are controlled by priority rules and lack channelization measures to guide and manage traffic flow. This can lead to confusion and conflict between vehicles.

At the Boumyebel intersection, there is a notable absence of road signalizatios. Considering the high population density and activity level at this point, the risk of collision between vehicles and pedestrians is significantly increased

Moving on the N°4 and N°5 roads, the critical interscetions at Ebebda, Ndikinimeki, Mbanga and Nkongsamba (Carrefou piste) are T-type intersections. Similar to the intersections on the N°3 road, these intersections are controlled by priority rules and lack channelization measures. This makes the decision-making process for drivers at these intersections solely dependent on their instinct and judgment, which can be risky and lead to potential accidents.

The Bekoko interchange being the meeting point between the N°3 road and N°5 road, is a critical location that requires proper signalization and infrastructure to minimize traffic conflicts and ensure safe traffic flow. However, it has been observed that the Bekoko interchange lacks adequate furnishings in terms of signalization, which is concerning. The absence of proper channelization and instructions for road drivers at this interchange can create confusion and increase the risk of accidents. Without clear guidance, drivers may not know which lanes to use or how to navigate the interchange correctly. This lack of clarity and direction can lead to conflicts between vehicles ad contribute to unsafe conditions.

3.2.2. Presence and state of lightning

At these critical intersections, it is observed that lighting is present in a good number of them but the condition of the lightening is not satisfactory. At intersections like Sombo, Mbanga, Ebebda, all the lightings fixtures are not operational. This is concerning because lightning plays a crucial role in improving visibility and helping drivers appreciate each other's maneuvers at intersections. Furthermore, the insufficient number of lightning fixtures at these intersections result in reduced visibility. Insufficient lightning can make it challenging for drivers to adequately asses their surroundings, recognize road signage and anticipate the action of the other road users. This can lead to confusion, misjudgment, and an increased risk of accidents.

3.2.3. Waste accumulation

Waste accumulation alongside the road has detrimental effects, including narrowing the road width and hindering proper water runoff. This can lead to increased road deterioration and contribute to accidents

3.3. Correlation analysis between road feature variables and crash rate

The analysis of road data was conducted using SPPSS Software. The road data collected from the onsite survey was transferred to an Excel file, coded and then imported into the SPSS Software for further analysis.

The correlation analysis carried out to examine the relationship between the road feature variables and the crash rate, revealed that some road features demonstrate a strong correlation with the crash rate. Table 5 illustrates that the road variables; Single Lane width, number of lanes, median width and state of guardrails have a significant influence on the crash rate.

3.3.1. One-way lane width

The road features single lane width and number of lanes correlates with the crash rate at a point, of value -0.628 and +0.647 respectively. The one-way width correlates negatively with the crash rate, implying that an increase in the one-way lane width will cause a decrease in the crash rate and vice versa. It should be noted that from several research, this is true to a certain value of the one-way width of not more than 3.7 m [12].

The correlation analysis equally revealed that the number of lanes showed a positive correlation with the crash rate. However, this observation needs to be considered in conjunction with the speed parameter. An increase in the number of lanes may contribute to an increase in crashes if the speed limit on the expanded road lanes has not been properly defined. Generally, increasing the number of lanes tends to reduce the overall crash rate, but it may elevate the fatality rate of those crashes that do occur. The obtained result in this study should be interpreted with caution due to certain limitations. The sample size for the 4-lane road was small. Thus, the analysis conducted with this segment may potentially distort the overall results, particularly as it appeared as an outlier in the scatter plot depicted in Figure 1. Additionally, this single 4-lane road segment had the highest crash rate observed. Upon physical examination, it was found that the road segment featured numerous tight curves with smaller radius which could explain the high crash rate. Both road features (One-way Lane width and number of lanes) are statistically significant at a confidence interval of 95% ($p < 0.05$).

3.3.2. Median width

It is observed that the median width demonstrates a significant negative correlation with the crash rate. This suggests that increasing the median width, specifically transitioning from painted medians to raised medians contributes to improve safety. Raised medians are commonly implemented on roads with four or more lanes. The fact that an increase in median width is associated with a decrease in crash rates aligns with the notion that moving from a two-lane road to a four-lane road reduces the crash rate. This observation also justifies the positive correlation between median width and number of lanes. The median width is statistically significant with the crash rate at a high confidence interval of 99% ($p < 0.01$).

3.3.1. State of guardrails

The state of guardrails shows a strong positive correlation with the crash rate. The road feature, state of the guardrails affects mostly the severity of the crash. When the state of the guardrail is bad, the severity of the crash is fatal meanwhile, when the state of the guardrail is good, the severity of the crash is much reduced. The state of the guardrails is statistically significant at a high confidence interval of 99% ($p < 0.01$)

4. Recommendations and proposed solutions

Solutions were proposed to ameliorate the safety of the road user. Among these solutions were the adoption of a unique speed limit except at singular points(intersections and agglomerations) where it has to be reduced; increase the number of lanes to a 4-lane road particularly at sections like Douala-Yassa and Yaoundé-Obala; regular road monitoring and maintenance such as resurfacing to maintain a good serviceability level; increase of shoulder width which could serve as clear zones ensuring traffic is maintained in case of a vehicle breakdown by the roadside; installation of rumble strips; monitoring and maintenance of guardrails; provision facilities at rest zones to provide a proper rest to drivers who have been on the road for long hours; and proper signage, channelization and lighting at intersections, adoption of the forgiving road concept. Also, to guarantee more exact results, a better accident data collection and management process was suggested

5. Conclusion

This thesis work was aimed at evaluating the influence of road feature variables on accident rates in Cameroon, with case study the road triangle Yaounde-Douala-Bafoussam-Yaounde highway commonly known referred as the "Death Triangle" and consequently propose measures to improve on the safety of the road users. To achieve this, accident data was collected from 584 accident reports at the State Defense Secretariat spanning from 2021 till 2022.

The accident data was analyzed using the safety performance indicators (crash frequency and the injury severity density) to determine the accident-prone locations and a map of these locations generated on ArcGIS. We obtained overall, 13 risk segments and 07 risk intersections on the road triangle, with precisely 05 risk segments and 02 risk intersections on the N°3 and N°4 road, 03 risk segments and 03 risk intersection on the N°5 road.

A site visit was carried out on these risk locations to obtain the road feature variables responsible for the crashes on these roads. A descriptive analysis of the collected road parameters was done in order to determine the influence of these ones on the crash rate. Results indicated that, reduction of road surface width, insufficient shoulder width, absence of median markings, poor road geometric alignment, lack of access control at access points, lack of rest zones facilities, worn out and inadequate traffic signs, poor road condition especially on the N°5 road where the degradation is advanced, poor condition of the guardrails, lack of channelization and lightning intersections, presence of street vendors and waste accumulation have a great impact on crash occurrence. These road parameters were further analyzed with the SPSS software to evaluate from statistical point of view which road parameters shows a strong correlation with the crash rate and which is statistically significant. From this analysis we found that, the single lane width, number of lanes, median width, and state of guardrails demonstrated a good correlation with the crash rate. Targeting the modification of these parameters to ensure safe standards will greatly reduce the crash rate on this road triangle especially on the N°5 road where the demand is high. In addition, given that road crashes occur due to the combination of two or more factors, interventions should be equally focused on the other factors with appropriate design to optimize road safety. Also, to guarantee more exact results, a better accident data collection and management process was suggested

Some of the major difficulties encountered during this study were the lack of information on traffic characteristics (traffic volume and traffic composition), operational speeds of vehicle when accident occurred, road radius and steepness at risk zones, high level of under reporting, inaccurate accident localization and information on road geometry in the accident reports. This limited the choice for the accident data analysis making it difficult to determine the exact accident-prone location and identify the factors related to the road that contributed to the accidents.

For future works, it could be interesting to consider other parameters like traffic characteristics, operational speeds, sight distances, horizontal degree of curvature, vertical grade steepness, set back distances and land uses. Also, a more detailed evaluation of road safety at intersections is recommended with parameters like angle between approaching roads, perception-reaction distance, maneuver distance.

Author Contributions:

WOUNBA Jean Francois and NKENG George ELAMBO contributed in design of the study

NGIKEM NGEMOH Pretty contributed in data collection, statistical analysis and writing of the manuscript

FONDZENYUY KOME Stephen did the proofreading and revision of the analysis.

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6. Appendix A

Table 2. Road data at risk segments on the N3 road

	Road Segment	Sombo	Mahole- Boga	Descente Mbanga - Boumyebel	Omog-Mamb	Makoda-Matomb
	Segment code	T21	T22	T23	T24	T26
No	**Geometric parameters**					
1	Segment length (m)	8018	8007	8071	8086	8016
2	Road width (m)	7,3	7,3	7,3	7,23	12,8
3	No of lanes	2	2	2	2	4
4	Median width (m)	0,15	0,15	0,15	0,15	0,15
5	Median type	Painted line: continuous	Painted line: continuous	Painted line: continuous	Painted line: continuous	Painted line: continuous and discontinous line
6	Shoulder width	2,1	1,5	2,1	1,7	1,3

7	Road condition	Medium	Medium	Medium	Medium	Medium
8	Type of degradation	Cracking, Edge subsistence, Shoulder drop off, Delamination	Cracking, Edge subsistence, Shoulder drop off, Delamination	Cracking, Edge subsistence, Shoulder drop off, Delamination	Cracking, Shoulder drop off, Delamination	Cracking, Shoulder drop off, Delamination
9	Number of Horizontal curvature	3	2	3	5	7
10	Numberv of Vertical gradation	1	1	1	2	0
No	**Road side parameters**					
1	Presence of guardrails	Yes	Yes	Yes	Yes	Yes
1	State of guardrail	Broken	Broken / Dirty	Broken	Bad /Dirty /Broken	Bad / Broken / Hidden
3	Presence of clear zones	No	No	No	No	No
4	Number of access points	2	2	2	5	1
5	Number of access control	0	0	0	1	0
6	State of road surface	Sandy, Filled with herbs	Sandy	Sandy	Sandy/ Covered with herbs	Sandy
7	Type of deterioration	Loss of material	Loss of material	Pot holes/ Loss of material	Loss of material	Loss of material
8	Rest zone availability	No	Yes	Yes	No	No
No	**Equipment parameters**					
1	Presence of side drains	Yes	Yes	No	Yes	No
2	State of side drains	Blocked	Blocked	Don't exist	Blocked	Don't exist
3	No of traffic sign	3	2	3	3	2
4	Traffic sign legibility	Good	Dirty	Good	Hidden / Dirty	Good

5	Type of traffic sign	Speed limit, Curve, Speed bumb	Speed limit, Curve,	Speed limit, Curve, Intersection, Speed bump	Speed limit, Curve, Speed bump,	Speed limit, Curve, Overtaking prohibited,
6	Presence of visual clutter	No	No	No	No	No
7	Street vendors	No	No	Yes	No	No

Table 3. Road data at risk segments on the N4 road

	Road Segment	Nkoledouma -Efok	Bilik-Bindik-Ebeda	Ebeda II-Botatango	Ndikinimeki	Bantoum
	Segment code	T62	T67	T69	T82	T87
No	**Geometric parameters**					
1	Segment length (m)	8012	8016	8120	8057	7948
2	Road width (m)	7,2	7,1	7,5	7,3	7
3	No of lanes	2	2	2	2	2
4	Median width (m)	0	0,1	0	0,15	0,15
5	Median type	Don't exist	Painted line: continuous	Don't exist	Painted line: continuous and discontinous line	Painted line: continuous and discontinous line
6	Shoulder width	0,7	1,1	1,3	1,2	1,3
7	Road condition	Medium	Medium	Medium	Good	Good
8	Type of degradation	Cracking, Rut and depression, Shoulder drop off	Cracking, Edge subsistence, Shoulder drop off	Cracking, Rut and depression, Delamination	None	Shoulder drop off,
9	Number of Horizontal curvature	4	9	4	5	5
10	Number of Vertical	0	0	0	2	4

	gradation					
No	**Road side parameters**					
1	Presence of guardrails	No	No	No	Yes	Yes
1	State of guardrail	Don't exist	Don't exist	Don't exist	Good	Bad / Broken / Hidden
3	Presence of clear zones	Yes	No	No	Yes	No
4	Number of access points	7	3	4	1	1
5	Number of access control	1	0	0	2	0
6	State of road surface	Sandy, Filled with herbs	Sandy, Filled with herbs	Paved , filled with herbs	Sandy/ Covered with herbs	Sandy
7	Type of deterioratio n	Loss of material	Loss of material	Loss of material	Loss of material	Loss of material
8	Rest zone availability	No	No	Yes	No	No
No	**Equipment parameter**					
1	Presence of side drains	Yes	No	No	Yes	No
2	State of side drains	Blocked	Don't exist	Don't exist	Blocked	Don't exist
3	No of traffic sign	2	2	3	8	9
4	Traffic sign legibility	Dirty	Hidden	Good	Good	Good
5	Type of traffic sign	Speed limit, Speed bumb	Speed limit, Speed bumb	Speed limit, Curve, Speed bump	Speed limit, Curve, Speed bump, Intersection,Overtakin g prohibited,Road narrowing	Speed limit, Curve, Speed bump, Intersection,Overtakin g prohibited,Road narrowing

6	Presence of visual clutter	No	No	No	No	No
7	Street vendors	Yes	Yes	Yes	No	No

Table 4. Road data at risk segments on the N5 road

	Road Segment	Bekoko- Bomono gare	Kombe- Mouyouka-Mbanga	Nkongsamba
	Segment code	T34	T38	T48
No	**Geometric parameters**			
1	Segment length (m)	8292	8021	8020
2	Road width (m)	7,28	7,1	7
3	No of lanes	2	2	2
4	Median width (m)	0	0	0
5	Median type	Don't exist	Don't exist	Don't exist
6	Shoulder width	1	0,9	0,7
7	Road condition	Bad	Bad	Bad
8	Type of degradation	Cracking, Deformation, Delamination, Edge subsisdence, Rut and depression, Shoulder drop off	Cracking, Deformation, Delamination, Edge subsisdence, Rut and depression, Shoulder drop off	Cracking, Deformation, Delamination, Edge subsisdence, Rut and depression, Shoulder drop off
9	Number of Horizontal curvature	4	15	6
10	Number of Vertical gradation	0	3	4
No	**Road side parameters**			
1	Presence of guardrails	No	No	Yes
1	State of guardrail	Don't exist	Don't exist	Bad, Broken, Hidden

3	Presence of clear zones	No	No	No
4	Number of access points	7	7	12
5	Number of access control	1	2	2
6	State of road surface	Sandy	Sandy, Filled with herbs	Sandy, filled with herbs
7	Type of deterioration	¨Pot holes, loss of material	Potholes/ Loss of material	Loss of material
8	Rest zone availability	No	No	No
No	**Equipment parameter**			
1	Presence of side drains	Yes	No	No
2	State of side drains	Blocked	Don't exist	Don't exist
3	No of traffic sign	0	2	3
4	Traffic sign legibility	Don't exist	Dirty	Hidden, Dirty
5	Type of traffic sign	/	Speed limit, Speed bumb	Speed limit, Curve, Speed bump
6	Presence of visual clutter	No	No	No
7	Street vendors	Yes	Yes	Yes

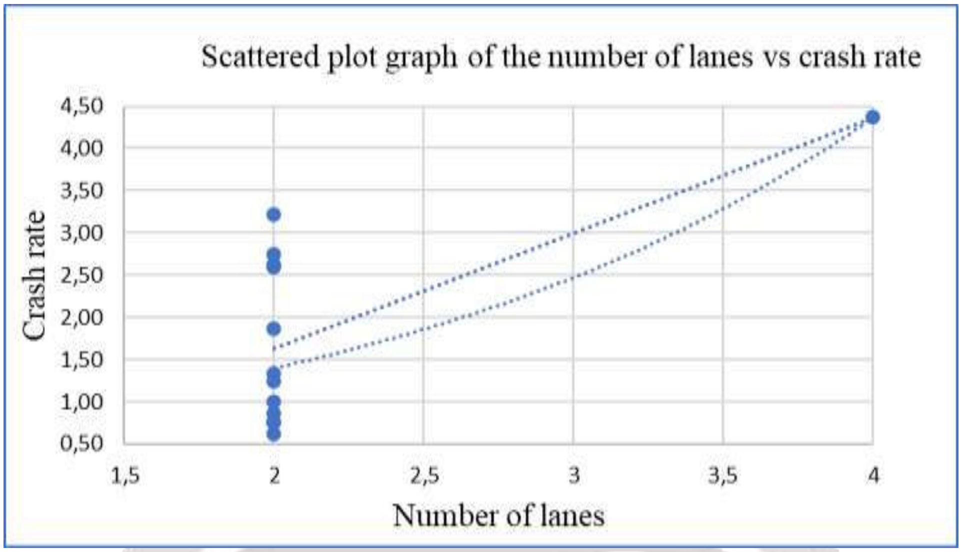
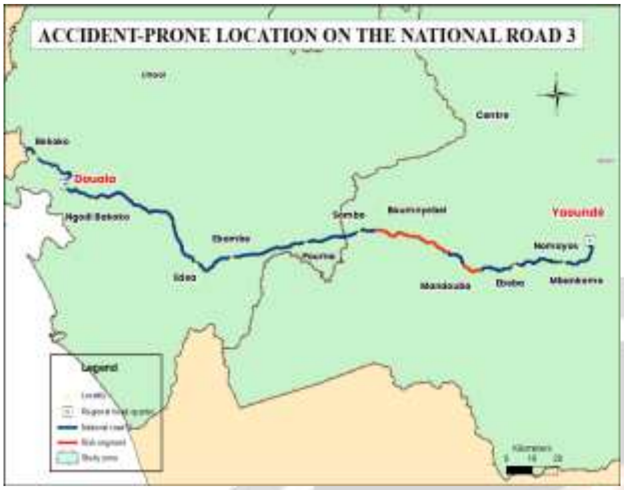


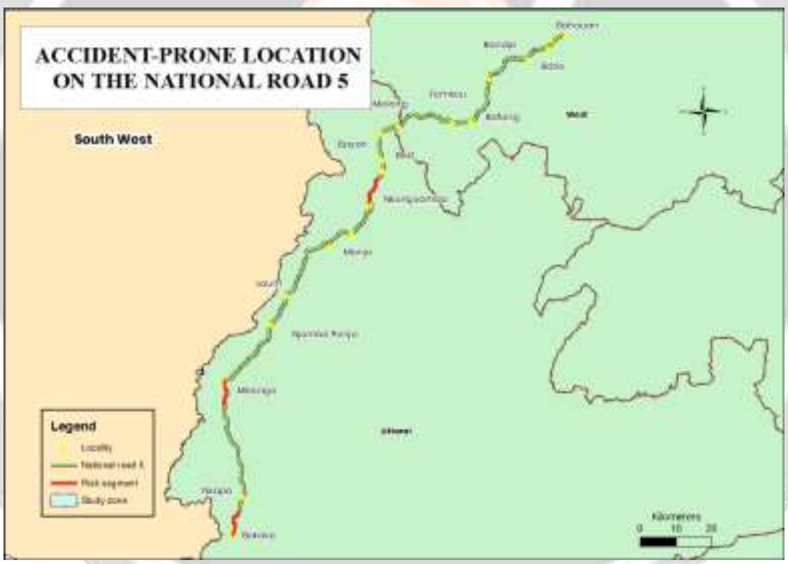
Figure 1. Scattered plot gragh of the number of lanes vs crash rate

Tableau 5. Results of correlation analysis between road feature and crash rate

		Injury accidents	Fatal accidents	Crash rate
one-way lane width	Pearson Correlation	-,614*	-,574*	-,628*
	Sig. (2-tailed)	0,026	0,040	0,021
	N	13	13	13
Number of lanes	Pearson Correlation	,631*	,577*	,647*
	Sig. (2-tailed)	0,021	0,039	0,017
	N	13	13	13
Median width	Pearson Correlation	-,665*	-,644*	-,684**
	Sig. (2-tailed)	0,013	0,017	0,010
	N	13	13	13
State of the guardrails	Pearson Correlation	,690**	,742**	,743**
	Sig. (2-tailed)	0,009	0,004	0,004
	N	13	13	13
**. Correlation is significant at the 0.01 level (2-tailed).				
*. Correlation is significant at the 0.05 level (2-tailed).				

Maps of the accident-prone locations on the N3, N4 and N5 road





7. Appendix B

Figure 2. Delaminated and cracked road filled with potholes at Bomono

Figure 3. Rut and depression with worn out guradrails extending to the road lane at Mbanga entrance

(a)

(b)

Figure 4. (a) Shoulder lane filled with dirts around Nkongsamba entrance, (b) insufficient shoulder width

(a) (b)

Figure 5. (a) Road lane occupied by a parked bus around Sombo, (b) Boumyebel intersection absence of signalisation and very poor channelization