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EVALUATION OF THE SAFETY PERFORMANCE OF INTERSECTIONS IN CALABAR, USING THE TRAFFIC CONFLICT TECHNIQUE.

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Abstract

Road traffic crashes and fatalities are major public health issues in developing countries, including Nigeria, where crash reduction measures have had limited effectiveness. The poor quality of crash data and empirical research methods contribute to the ineffectiveness of road safety interventions. Therefore, alternative safety measures that focus on traffic conflicts rather than crashes are necessary. This study employed the surrogate safety measures based on systematic observation of traffic behavior and conflicts to assess road user behavior and investigate factors determining traffic conflict severity at key intersections in Calabar Metropolis. Video camera data were collected at selected intersections and analyzed using Traffic Conflicts Techniques (TCT). The study examined the safety performance of intersections considering variables such as time of day, intersection type/number of arms, vehicle maneuvers, conflicting traffic streams, and traffic conditions. The applicability of TCT was highlighted, and recommendations for improving road safety were provided where necessary.

Keywords: Highway Intersection safety performance, Traffic conflicts Techniques, Unsignalized intersections.

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1.0 Introduction

Every year approximately 1.19 million people die globally (equivalent to over 3250 deaths every day), and an extra 20-50 million people suffering injuries with many incurring disabilities (WHO, 2023). According to the World Health Organization (2023), 92% of the world's fatalities on the roads occur in low- and middle-income countries, even though these countries have only around 60% of the world's vehicles. The African region is the worst hit with a fatality rate of 26.6% per 100,000 population (WHO, 2016).

Understanding the causes of roadway fatalities and injuries has remained a priority in most countries. Over the years considerable advances have been made in road safety analysis, especially in developing statistical methodologies to model the relationship between crash frequency/severity and their determining factors, gaining knowledge about the crash occurrence mechanism, and providing safety polices and countermeasures. Past studies in road safety have used the statistical analysis of crash data. While the success of these modeling efforts and the need for better understanding of crash data are important, there are also key limitations associated with the crash data and corresponding modeling methods, such as under-reporting, small sample size, high cost of data collection, longer data collection and collation time and biased reporting impairs its feasibility and often make its application very difficult (Zheng, 2021). Therefore, the need for a more comprehensive and robust understanding of the associations, various factors and events leading to a crash informed the development of the Traffic Conflict Technique (TCT).

1.1 Traffic Conflict Technique (TCT)

The Traffic Conflict Technique (TCT) is a proactive road safety analysis method that identifies and assesses potential collision scenarios before they occur. According to Hyden (1987), a traffic conflict could be defined as “an observable situation in which two or more road users approach each other in space and time to such an extent that there is risk of collision if their movements remain unchanged”. Conflict points are locations where the travel paths of road users intersect. If the paths and speeds of two road users lead to them reaching a specific conflict point simultaneously, at least one must adjust his/her speed or direction to avoid a collision (Uzondu et al., 2018). The TCT is based on the "Heinrich Triangle" theory (Heinrich, 1941), which posits a relationship where "no-injury accidents" precede "minor injuries." According to this theory, events at the base of the triangle (less severe incidents) occur more frequently and precede those nearer the top (more severe incidents). Applying this theory in TCT involves defining specific traffic conflict factors as indicators of near-crash events.

Literature on TCT highlights its advantages, such as the ability to evaluate safety without waiting for crashes to happen, generally less expensive than investigating actual crashes, provides insights into road user behaviors and interactions, contributing to a better understanding of traffic flow and conflict points, data from TCT can be used to design specific safety interventions, applicability to various traffic environments and TCT provides quantifiable metrics for near-crash events, allowing for clear assessment and comparison of safety conditions over time (Svensson & Carsten, 2007; Uzondu et al., 2018).

The Traffic Conflict Technique (TCT) has been widely investigated and applied in developed countries such as the United States, United Kingdom, Canada, Finland, Germany, France, Sweden, Austria, Denmark, and the Netherlands. In contrast, its practicality in a developing country like Nigeria is still limited. Given the prevalent issue of underreporting road crashes in Nigeria, employing TCT studies could be instrumental in identifying the primary factors contributing to road crashes. This could enable authorities to craft targeted safety measures. This study seeks to use Traffic Conflicts Technique (TCT), to assess the safety performance of key intersections in Calabar metropolis through the examination of traffic behaviour and conflicts of various road users.

2.0 Methodology

For this study, the Swedish Traffic conflict technique was used and based on two measures, namely:

(i) **Time to Accident (TA):** defined as the remaining time from when the evasive action is taken until a collision would have occurred if the road users did not change their speed and direction.

(ii) **Conflict:** an observable situation in which two or more road users approach each other in space and time to such an extent that there is risk of collision if their movements remain unchanged. Other variables assessed include;

(iii)**Traffic Volume:** The recorded data included the volumes of vehicles, tricycles, and pedestrians. Cyclist volumes were also recorded, as private cyclists are active in the city. All traffic passing through each location during the data collection period were counted through video recordings.

(iv) **Vehicle Speed**: To estimate the speed of at least 100 free-flowing vehicles and tricycles, a standard distance of 5 meters from the intersection was marked on each lane. Using basic physics, the time taken for each vehicle to travel this distance was recorded with a stopwatch, allowing for speed estimation during morning and evening peak hours. The observation period totaled eighteen hours per location. Additional data collected included road user characteristics (gender, estimated age), types of conflicts (same direction, crossing, opposite direction), and brief descriptions of events leading to conflicts.

2.1 Study location and data collection

The research was conducted at three chosen non-signalized intersections of high priority in Calabar, Cross River State, from 5th February 2024 to 19th February 2024. These intersections (Mount Zion by Uwanse, WAPI Junction and Mayne Avenue by Ekpo-Abasi) were selected due to their characteristic representation of urban and suburban road links, areas with high pedestrian traffic, and roads accommodating mixed traffic flows.

Data gathering was conducted in favorable weather conditions during peak hours in the morning (7:00 am to 9:00 am) and afternoon (3:30 pm to 5:00 pm) across all days of the week. The process included on-site video recordings and manual data collection through observation, carried out by a dedicated team of nine enumerators, with three assigned to each location.

During the observation period, data on traffic volume (e.g., vehicles, pedestrians, and cyclists), vehicle speed (velocities of a minimum of 100 vehicles and tricycles in free flow were measured using fundamental physics principles. A line was marked 5 meters before the intersection on each lane, which served as the reference distance for timing the vehicles as they approached the intersection. A stopwatch was employed to track the time it took for each vehicle to reach this line) and the nature of the conflicts (observations of interactions among various road users who appeared to be on a trajectory that could lead to a collision. This necessitated the presence of evasive maneuvers, such as braking, swerving, or accelerating to avoid an accident) were recorded.

Table 1: Characteristics of Study Locations

INTERSECTION NAME:	**MT. ZION BY UWANSE, (Location 1)**	**WAPI JUNCTION, (Location 2)**	**MAYNE AVENUE BY EKPO ABASI, (Location 3)**
General Description:	Single carriage way, No lane markings, mixed traffic, Poor Traffic condition.	Dual carriage way, with lane marking, mix traffic, good road condition.	Single carriage way, No lane markings, mixed traffic, Poor Traffic control/condition.
Speed Limit:	Not Specified	50km/hr.	Not Specified
Parking and Loading:	Not Specified	Restriction of street parking; No restriction on loading.	Not Specified
Pedestrian Crossing:	No	No	No
Pedestrian Path:	No	Yes, all sides	No
Traffic Lights:	None	None	None
Road Layout:	Cross Road 4-legged Un-signalised.	T-Junction; Three-legged un-signalised.	T-junction Three-legged Un-signalised.
Traffic Control/ Warden:	Yes, part of morning peak (2-3 hours)	Yes, part of morning peak till dusk	None
Presence of Road Divider:	No	Yes	No

Mount Zion by Uwanse (Location 1)

WAPI Junction (Location 2)

Mayne Avenue by Ekpo Abasi (Location 3)

Figure 1: Study locations

2. 2. Data Analysis

The Swedish TCT was used to evaluate the likelihood of near crashes in the study areas. Descriptive analysis provided simple summaries of behavioral observation data, focusing on frequency counts. This helped identify the percentage of road users who violated traffic rules and exhibited unsafe behavior, and the times of day these behaviors were most prevalent.

Since the study aimed to use surrogate safety measures for road safety assessment, further statistical analysis was conducted on the conflict data using various methods of discrete data analysis. This analysis investigated the influence of road user behavior on conflicts. Data for the analysis were extracted from the conflict observation form and recorded video, consisting of dichotomous or categorical variables.

2.3 Traffic volume count

Figure 2 presents the hourly traffic counts for all road users across various locations during the morning peak (7:30-9:00) and evening peak (3:30-9:00) periods.

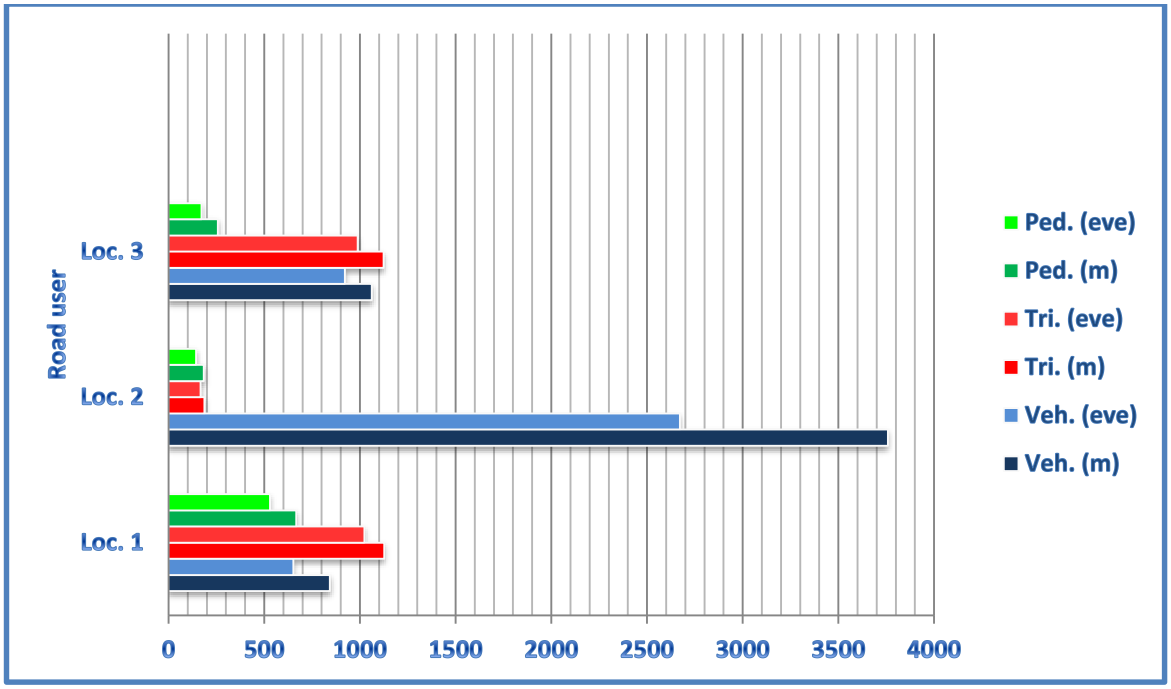

Figure 2: Traffic Volume per peak period

At Location 1, tricycle volumes were the highest in both peak periods, likely due to the presence of several arterial routes and the proximity to two major colleges, UNICAL and UNICROSS, facilitating student transportation. Vehicle and pedestrian volumes were also notably high.

At Location 2, traffic volumes were higher in the morning peak than in the evening. Pedestrian volumes were lower due to a distant pedestrian path, reducing their presence at the intersection. Tricycle volumes were also low, as they are restricted to the minor carriageway and rarely cross the intersection. Vehicle volumes were highest, attributed to the location being along a major highway leading to offices, schools, government secretariats, markets, and financial institutions.

Location 3 showed a prevalence of tricycles, dominating vehicle and pedestrian volumes in both peak periods. The high volume of tricycles and vehicles is due to nearby destinations such as the Atakpa market and the state university, UNICROSS.

2.4 Vehicle speed

The analysis revealed that mean speeds were significantly low across all study locations during both peak periods. Specifically, Location 1 recorded mean speeds below 20 km/hr, Location 2 recorded mean speeds below 30 km/hr (despite the speed limit being 50 km/hr), and Location 3 also recorded mean speeds below 30 km/hr. These findings indicate that speed violations were not prevalent in the studied locations.

Furthermore, the t-test results indicated a significant relationship between the presence of tricycles and mean speeds at Locations 1 and 3.

Table 2: Mean speed by location and road user type

Locations	Road-user Type	morning peak mean (SD)	Evening peak mean (SD)	df	T	P
Location 1	Vehicle	14.75 (10.33)	15.02 (11.66)	99	-0.172	0.436
	Tricycle	13.13 (8.6)	16.57 (11.16)	99	-2.365	0.009º
Location 2	Vehicle	27.07 (8.22)	27.26 (7.71)	99	-0.161	0.436
	Tricycle	18.32 (6.62)	17.96 (7.84)	99	-0.429	0.334
Location 3	Vehicle	27.41 (10.68)	275 (12.29)	99	-0.064	0.475
	Tricycle	20.49 (7.61)	24.27 (12.22)	99	-2.553	0.006º

2.5 Traffic conflict

At Location 1,280 traffic conflicts were observed, almost equally split between morning and evening peak periods. Speeding was not a significant issue; however, driver behavior violations caused vehicle clusters, leading to numerous near-crashes. Notable violations included failing to yield and disobeying traffic wardens, exacerbated by traffic volumes exceeding the intersection's capacity. Vehicle-tricycle interactions accounted for nearly 50% of conflicts, with 187 serious and 93 slight incidents recorded. The intersection's 4-arm crossroad design contributed to 65.7% of conflicts involving crossing maneuvers.

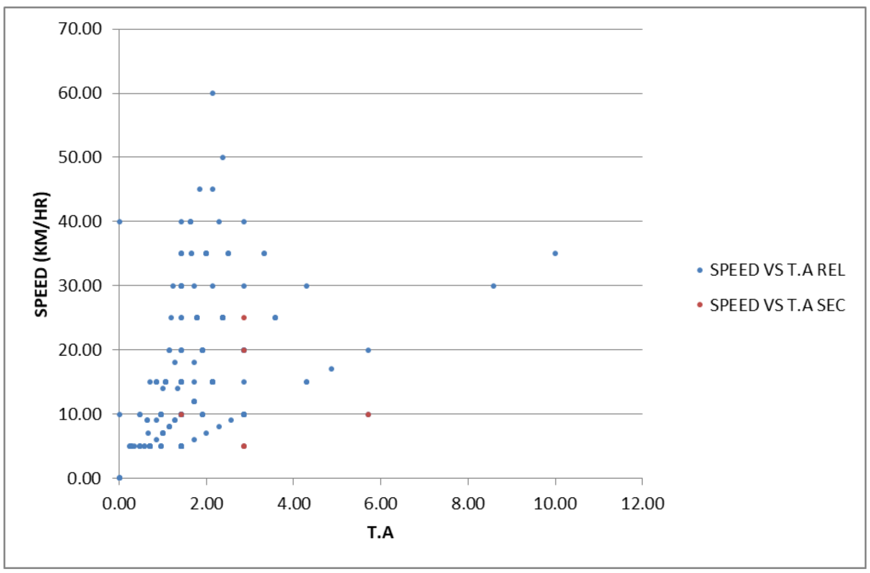

Figure 3: Conflict severity Levels at Location 1

Location 2 experienced 149 conflicts, with more occurring during the morning peak (55%) than the evening peak (45%). Vehicle-vehicle interactions were most common (40.3%), followed by vehicle-tricycle (30.2%), vehicle-pedestrian (12.1%), tricycle-tricycle (11.4%), and tricycle-pedestrian (6%). Slight conflicts (52.3%) outnumbered serious ones (47.7%), likely due to traffic wardens and good intersection layout. Crossing conflicts dominated at 47%, with same-direction (27.5%) and opposing interactions (25.5%) also noted. The conflict rate was 1.7 per hour.

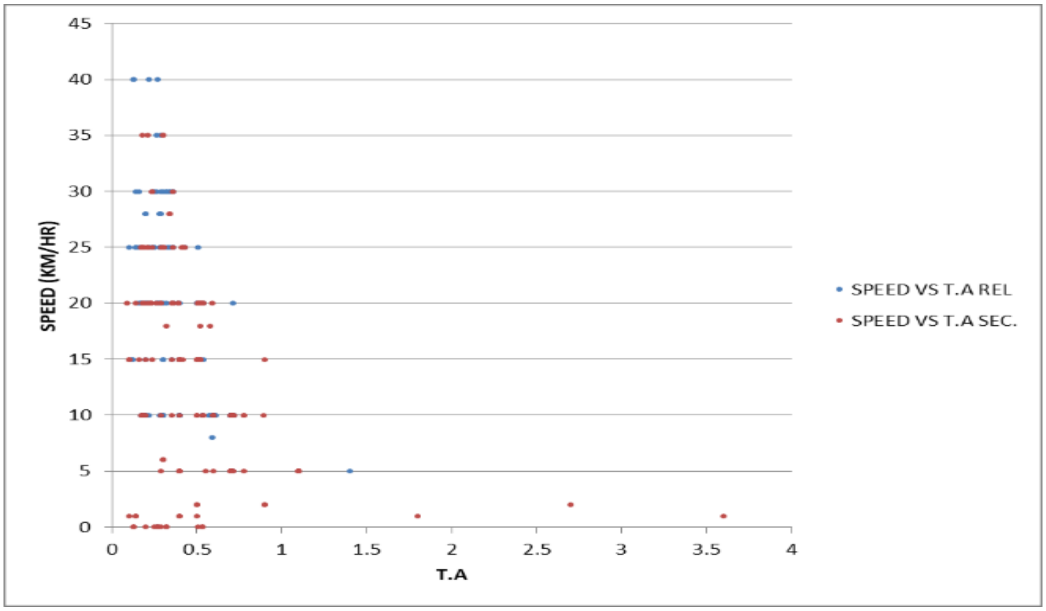

Figure 4: Conflict severity Levels at Location 2

Location 3 recorded 212 conflicts, with 53.8% in the morning and 46.2% in the evening peak periods. Serious conflicts (67.9%) were prevalent, influenced by driver behavior, traffic violations, and the lack of a traffic warden. Crossing interactions accounted for 49.1% of conflicts, with vehicle-vehicle (31.1%) and vehicle-tricycle (26.4%) interactions following.

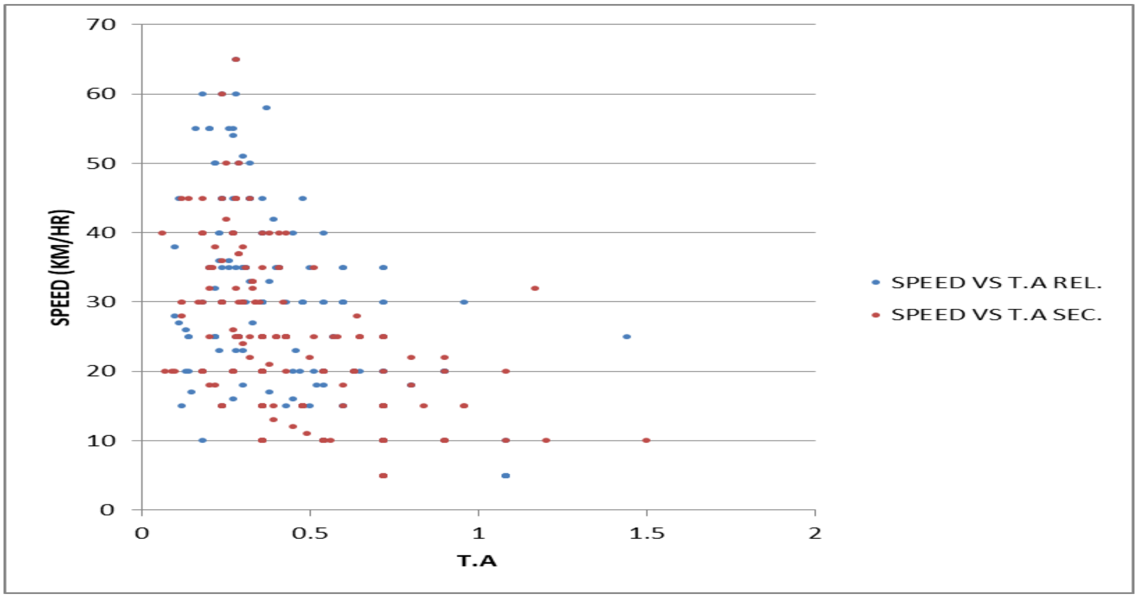

Figure 5: Conflict severity Levels at Location 3

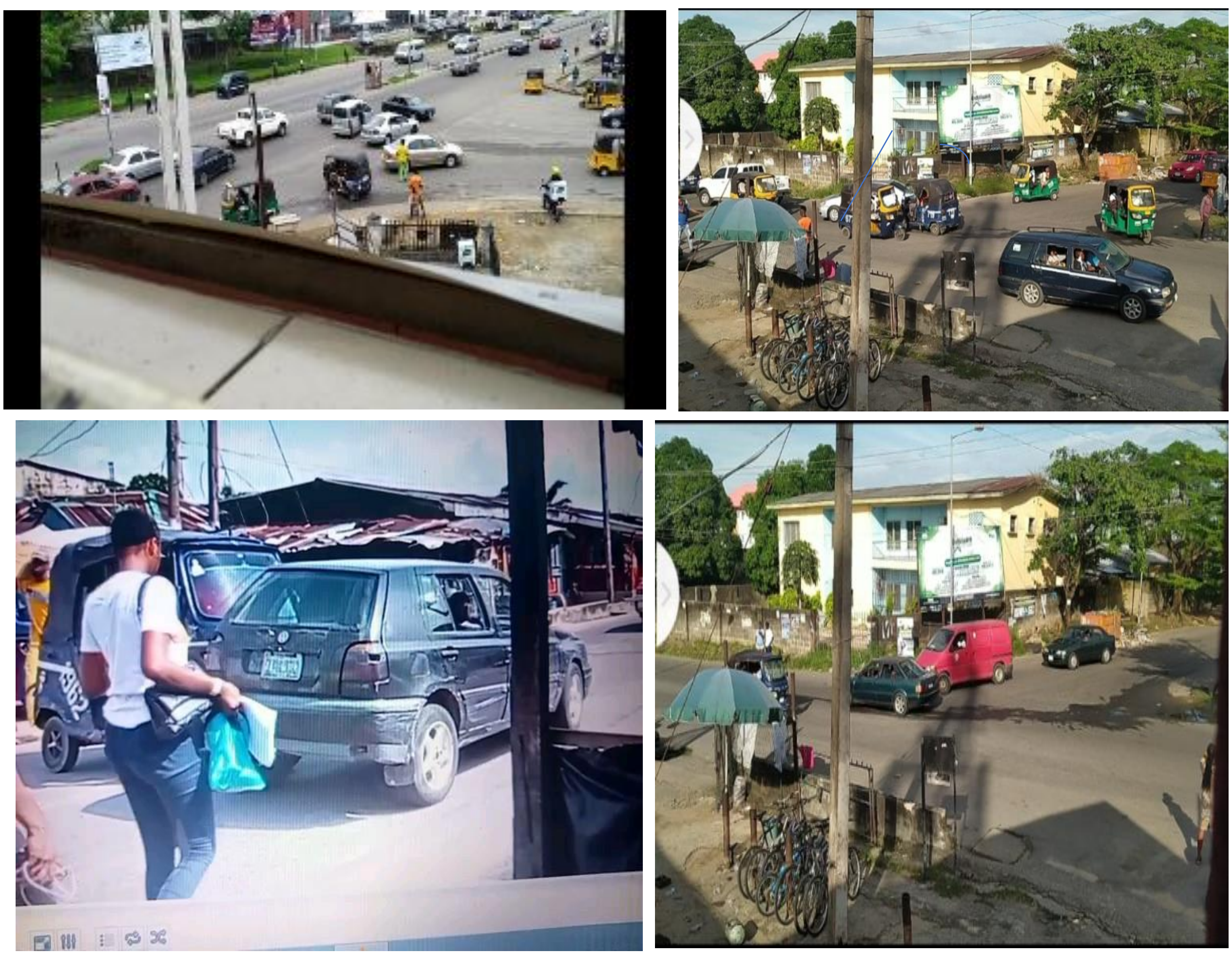

Figure 6: Examples of observed conflicts

2.6 Prediction of conflicts

Adopting the model used by Uzondu et al. (2018), we consider conflict severity as a dependent variable that is dichotomous (0 for serious and 1 for slight). This model predicts the likelihood that Y=1Y = 1Y=1 (slight conflict) instead of Y=0Y = 0Y=0 (serious conflict) based on the influence of a set of XXX values. If P is the probability of a road user being involved in a slight conflict (Y=1Y = 1Y=1), then the probability of being involved in a serious conflict (Y=0Y = 0Y=0) is 1−P1 - P1−P. The independent variables were derived from the conflict observation form and video recordings. Among the 641 interactions recorded at the three locations, there were 168 vehicle-vehicle interactions, 52 vehicle-pedestrian interactions, 239 vehicle-tricycle interactions, 131 tricycle-tricycle interactions, and 51 tricycle-pedestrian interactions.

Regarding gender distribution, a significantly higher number of observed conflicts involved male road users (565) compared to females (76). Additionally, conflicts during the morning hours slightly surpassed those in the evening, with counts of 330 and 311, respectively.

The predictive accuracy of the models—74.1%, 71.1%, and 68.9% for the three locations—indicates a satisfactory classification of conflict severity. For model validation, the Nagelkerke R-Square, which ranges from 0 to 1, shows that the new models can explain approximately 21%, 31%, and 24% of the variance at each location, respectively. Additionally, the p-value of the Hosmer and Lemeshow test suggests that the models fit the data well.

Table 3: Binary logistic model for conflict severity

	Reference Category	**Loc1**			**Loc2**			**Loc3**		
Variables		*B*	*P*	Exp.(B)	*B*	*p*	Exp. (B)	*B*	*p*	Exp. (B)
Direction of traffic same direction opp. direction	 crossing	 -0.26 -0.492	 0.950* 0.207*	 0.975 0.611	 -0.884 1.054	 0.079* 0.045º	 0.413 2.869	 -0.322 0.169	 0.443* 0.719*	 0.724 1.185
Age (rel.) 15-24 25-45 46-64	 ≤ 15	 -19.625 -20.605 -20.830	 1.000* 1.000* 1.000*	 0.000 0.000 0.000	 -0.662 -1.689 -2.108	 0.189* 0.016º 0.047º	 0.516 0.815 0.121	 1.002 -0.145 0.364	 0.547* 0.932* 0.835*	 2.723 0.865 1.439
Gender (rel.) male	 female	 -1.460	 0.002º	 0.232	 -0.883	 0.193*	 0.414	 0.717	 0.216*	 2.049
Evasive action										

braking swerving	others	1.219 -0.830	0.016º 0.161 *	3.383 0.436	-1.426 -2.130	0.105 * 0.025º	0.240 0.119	20.865 0.265	1.000 * 0.589 *	11E8 1.304
Age (sec.) 15-24 25-45 46-64	≤ 15	0.217 -0.999 -1.626	0.857 * 0.377 * 0.192 *	1.243 0.368 0.197	-0.665 -0.311 -1.137	0.592 * 0.809 * 0.035º	0.514 0.733 0.321	0.412 0.508 -0.736	0.728 * 0.572 * 0.491 *	1.510 1.662 0.479
Period Morning	Evening	0.450	0.134 *	2.116	1.023	0.017º	2.780	0.119	0.574 *	1.221
Constant		22.361	1.00	51E7	3.295	0.72	26.974	-2.174	0.238	0.114
Nagelkerke's R^2		0.210			0.310			0.247		
Correctly classified		71.4%			71.1%			68.9%		
Hosmer and Lemenshow			0.806			0.380			0.420	

2.6.1 Prediction based on direction of traffic

In the study, the direction of traffic refers to the direction in which road users were traveling during a conflict (Uzondu, et al., 2018). This was categorized into same direction, opposing direction, and crossing (reference category). Crossing conflicts were prevalent across all locations. At Location 2, the data showed that vehicles traveling in the opposite direction were 2.9 times more likely to be involved in a slight conflict compared to crossing. Conversely, the likelihood of a slight conflict when traveling in the same direction was low (odds ratio of 0.4). The negative beta coefficient indicated that traveling in the same direction decreased the probability of a slight conflict.

2.6.2 Prediction based age: Although the age of the relevant road user is an important predictor of conflict severity, Table 3 shows that not all age groups were consistently significant across all locations. Compared to road users aged under 15 (reference category), the odds of a road user aged 25-45 and 46-64 being involved in a slight conflict are 0.815 and 0.1 times, respectively. The age of the secondary road user had a minor contribution, particularly in Location 2, where the odds of a secondary road user being involved in a slight conflict are 0.3 times compared to a road user aged under 15.

2. 6. 3 Gender: Results showed a minimal relationship between the gender of the relevant road user and conflict severity, with the chances of a female road user being involved in a slight conflict being 0.2 times compared to male road users.

2.6.4 Evasive action: This was a significant contributor to conflict severity, particularly in Locations 1 and 2. In Location 1, the odds of a braking action leading to a slight conflict are 3.4 times higher compared to other evasive actions like acceleration. In

Location 2, the likelihood was much lower, at 0.2 times.

2.6.5 Period (time of day when conflict was observed): Results from Location 2 showed that the chances of a slight conflict occurring during evening peak hours are 2.8 times higher compared to morning peak hours.

3.0 Discussions

The study observed that Location 1 had the highest number of conflicts among the three locations, primarily due to the higher volume of road users. However, this does not necessarily indicate that Location 1 was more hazardous. Rather, it highlighted the importance of considering the rate of conflicts per interaction. Notably, Location 3 had a higher conflict rate per interaction, especially for vehicle-vehicle interactions, consistent with literature that suggests non-signalized intersections pose more hazards than signalized ones (Neuman, 2003).

The following unsafe behaviors where identified across the locations; **Picking/Dropping Passengers** (Tricycle drivers often stop abruptly to pick up or drop off passengers without pulling over completely, causing chaos and conflicts)**, Tailgating (**Many road users followed vehicles or tricycles too closely, leading to same-direction conflicts), **Right of Way Violations** (Failing to yield or give way to other road users was a common cause of conflicts) and **Speeding** (Many drivers exceeded speed limits and did not slow down near intersections or other vehicles).

The time of day also influenced conflict severity, with evening peak periods resulting in more serious conflicts compared to morning peaks.

The study compared conflict severity across the three locations, finding that road environment and intersection layout significantly influence road user behavior and conflict likelihood. Location 1 and Location 3, situated in southern Calabar and characterized by dense traffic and poor road layouts, recorded more serious conflicts. In contrast, Location 2, a modern highway with better infrastructure, had fewer and less severe conflicts. Locations 1 and 3 experienced more serious conflicts due to factors such as: dense traffic from schools, markets, and banks and high prevalence of tricycles with erratic driving behavior. Location 2's modern layout and moderate traffic conditions contributed to safer driving conditions.

4. 0 Conclusion

Crash data collection and analysis remain one of the most effective methods for evaluating and studying traffic conflicts at intersections. Crash data helps assess traffic conflicts in relation to road user behaviors, peak and off-peak periods, vehicle types and speeds, and the types of intersections or roads involved. However, issues such as ambivalence and inconsistency in traffic conflict frameworks, along with the lack of accurate and reliable crash data government bodies such as the Federal Road Safety Corps (FRSC), Ministry of Health and Police present significant challenges in developing countries like Nigeria.

This study highlights the current traffic conflict technique's strengths, particularly in using near-crash data to analyze and predict traffic conflicts, thus providing a means to minimize them at intersections. The application of Binary Logistic Regression in predicting conflict severity has proven successful, offering a surrogate measure of safety. The findings indicated that traffic conflict techniques (TCT) can be highly effective for road safety assessments in developing countries.

The study's outcomes support further decision-making regarding the safety assessment of various road users and necessary infrastructure improvements. To enhance traffic safety at intersections in Nigeria, the study recommends:

- Enhancing Road Infrastructure: Improve road layouts and conditions.
- Effective Regulations and Enforcement: Implement and enforce traffic laws more stringently.
- Comprehensive Road Safety Education: Educate Road users about safe driving practices.
- Expanding Road Widths and Deploying Traffic Signals: Especially in problematic areas like Location 1 and Location 3.

These measures aim to address identified unsafe behaviors and infrastructural deficiencies, ultimately reducing traffic conflicts and improving overall road safety.

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