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ORIGINAL ARTICLE

# Towards Safer Bus Transport in Developing Countries: Geospatial Analysis of Bus Crashes on an Intercity Highway in Ghana

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**Abstract**
In low- and middle-income countries, approximately 70% of inter-city trips are by buses but are characterised by rampant crashes. So far, there is scarce research on the spatial characteristics of bus crashes on specific highways. This paper contributes a geospatial analysis of bus crashes along the Accra-Kumasi highway in Ghana, where 53% of crashes involved buses (2236 bus crashes in 363 crash locations along the 243 km highway). Crash locations, trends, and geospatial relationships were geolocated and analysed using descriptive statistics and heatmaps. Bus crashes occurred mainly in the catchment areas of Accra and Kumasi. Along the highway, crashes were predominant: (1) at straight road sections and curves, (2) near dense settlements, (3) around vehicle service stations such as mechanic shops and fuel filling stations, and (4) in the afternoon under clear weather conditions. The major causes of bus crashes are driver inattention, excess speeding, lane-changing, and car-following behaviour. The minor causes are driver inexperience, poor road signage, improper turning, and fatigue. Most crashes result from rear-ended and head-on collisions. Possible countermeasures include the expansion of the road lanes, installing bus surveillance technologies, specialised warning signs near crash-prone locations, and increased police monitoring and regulatory enforcement. Findings and proposed countermeasures are helpful to all low- and middle-income countries having rampant intercity and highway bus crashes.

**Keywords** Geospatial analysis · Bus crashes · Highway crashes · Crash-prone locations · Crash countermeasures

## Introduction

Although bus transport is safer in developed economies [1–3], it is replete with crashes in low and middle-income countries [4–7]. In the ensuing discussion, this study adopted a bus definition as any commercial vehicle with a capacity of at least 25 passengers [8]. Buses are the main road transport for long-distance journeys beyond 100 km, occupy about 30% of road width, and transport around 70% of person trips in many low- and middle-income countries [9]. There are dire consequences of bus crashes on economic growth globally. In Ghana, over US$160 million (1.6% of the gross domestic product) is lost annually to road traffic crashes [10] and bus crashes take a large share of these losses.

Due to the low crash involvement of buses in developed countries, bus crashes have attracted few research contributions; hence the knowledge of bus crashes is comparably lower than other passenger vehicles [11]. Deplorable road infrastructure has been found to contribute to bus crashes [1]. The location of bus stops, motorists' driving attitude towards lane changing, lane width, presence of on-street shoulder parking, posted speed limit, median width, number of lanes per direction, and number of vehicles per lane have heterogeneous effects on bus crashes. Sarkar et al. [12] found that road sections with no signal control and poor signage posed a higher risk of bus crashes [3, 13]. Samerei et al. [2] analysed crash data in Victoria and found that road visibility, lighting conditions, and speeds influence highway bus crashes. Dai et al. [14] found that

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narrower lane widths recorded more crashes than wider lanes; therefore, their study proposed a standard lane width of 11–12 ft for bus routes.

Dharmaratne and Stevenson [15] found increased risk related to travel on privately owned buses compared to government public buses in Sri Lanka. They hinted that crash rate discrepancies involving the two categories of bus ownership were partly due to rarer safety necessities imposed on the deregulated public transit system. Sam et al. [5] analysed bus/minibus crashes in Ghana and found the absence of road medians, bad road terrain, and drunk driving as leading causes of bus and related crashes. Damsere-Derry et al. [4] used random parameters multinomial logit to analyse intercity bus crashes in Ghana. They found that the form of vehicles affects collision severity. Thus, intercity bus transportation crashes relating to large buses and minibuses had a higher probability of fatal injury than others buses. Some studies found that transgressive driving behaviours, including speeding, inexperienced drivers, wrong overtaking, careless driving, and other driver violation forms, were linked to fatal crashes [4, 5, 16–18].

However, the above-mentioned studies did not give insights into the geolocation of bus crashes [4, 5]. This research gap makes it difficult to find sustainable countermeasures. Therefore, this current study provides a new direction toward the crash locations and bus–bus crashes. In recent years, geospatial analyses have been used in the road safety literature to help decision-making [19–22]. They provide pictorial explanations that make understanding land use and spatial characteristics easy before applying statistical models.

Therefore, this study analysed (1) the geospatial characteristics of bus crash locations on the Accra-Kumasi highway, (2) reported leading causes and severities based on police crash reports in Ghana, and (3) proposed possible countermeasures. The findings and proposed countermeasures are helpful to all low- and middle-income countries faced with rampant intercity bus crashes.

## Methodology

### Case Study Highway

Accra and Kumasi are the two largest cities in Ghana [4]. The 243 km Accra-Kumasi highway (N6) is a two-lane single-carriageway with a width of 7.3 m, as shown in Fig. 1. Police crash reports show that bus crashes constituted 53% of crashes on this highway. It serves the Northern, Central, Western, and Southern parts of Ghana, making vehicle volume higher than other highways in Ghana.

### Data Collection

This study employed secondary data for the descriptive statistics and geospatial analysis. The bus crash data on the N6 covering 2005 to 2019 were obtained from the Building and Road Research Institute (BRRI) of the Council for Scientific and Industrial Research, Kumasi, Ghana. The BRRI manages the national road crash database of Ghana. In countries and case studies where there are regular changes to road infrastructure and safety engineering, studies crash sample sizes have been limited to between 3 and 5 years [23, 24]. However, in the analysis of different sample sizes from four countries, it was found that the prediction accuracy of longer sample sizes (15 years and above) varied based on the socioeconomic, traffic safety programs, and development conditions prevailing in study areas [25]. Notably, where there were no significant changes to the road infrastructure and policies, the prediction accuracy of more extended sample sizes still had good capabilities. Consequently, several studies have used sample sizes between 8 and 18 years for spatial crash analysis and prediction depending on the local conditions [25–28] Therefore, this study selected a fifteen-year sample size to give a detailed overview of the crash-prone locations based and proposed plausible changes. What informed this consideration was that there had not been significant changes on the case study road regarding the number of road lanes, pavement, road signage, and other safety conditions.

The database comprises road crashes compiled by the Ghana Police Service using a standard road crash report form from various crash locations. This report contains information on surviving traffic crash casualties, witnesses, detailed accident sketches, hospital post-mortem reports in the event of fatal crashes, and detailed reports from crash investigators and vehicle examiners. The database provides information on the driver, traffic elements, and road environment conditions at the time of the accidents. The driver information includes the name, gender, age, injury sustained, license number and status, a declaration of whether drunk driving was involved, and the driver errors associated with the accident. Information related to the traffic elements and road environment includes the vehicle types involved, vehicle manoeuvre, vehicle ownership, and usage, the extent of damage, vehicle defects suspected, and the direction of travel at the time of the incident. In addition, the road type and description, surface type, shoulder type, weather and light conditions, the presence of road separation, surface condition, accident location, traffic control, collision type, and surface repair are specified. Furthermore, the data indicate the day and time of the crash, the number of vehicles involved, the number

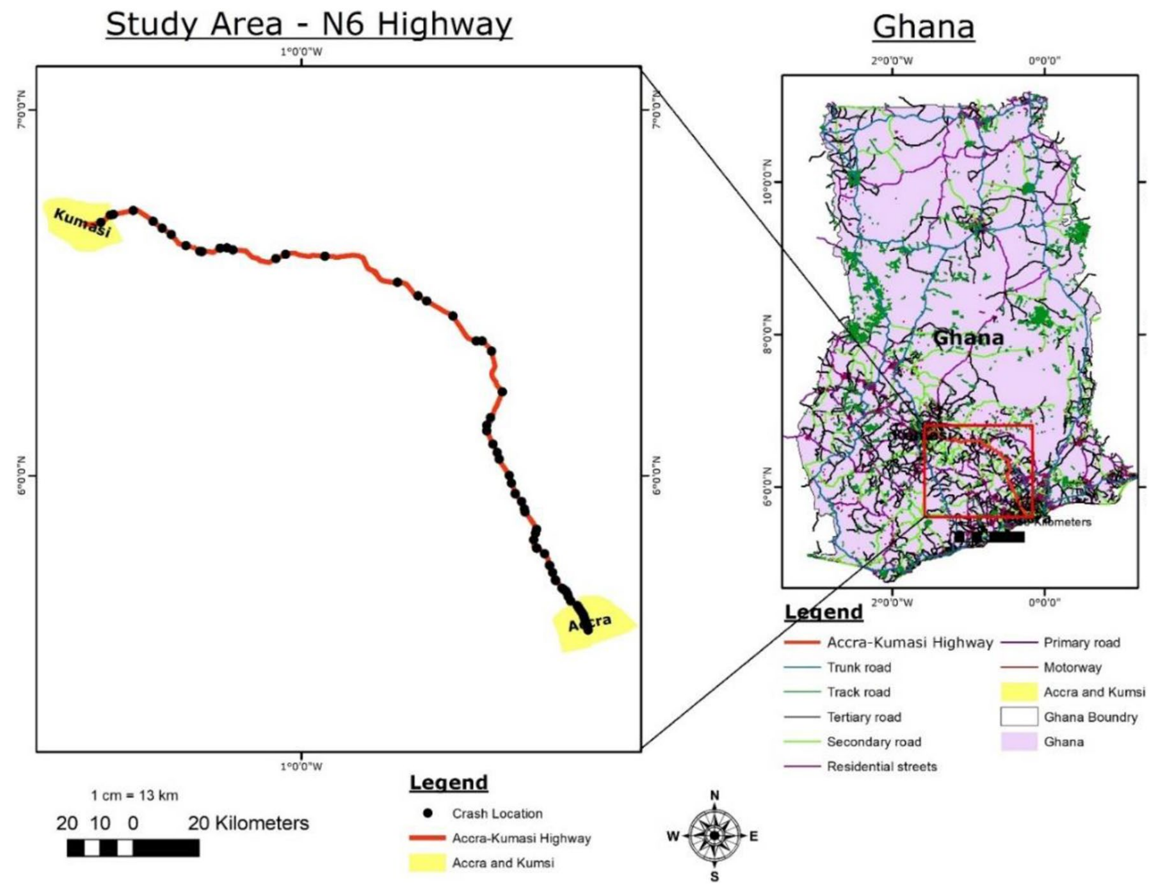



**Fig. 1** Road network of Ghana showing the Accra-Kumasi highway

of casualties killed and injured, and the accident severity, measured on a four-point scale. The data also have the name of the crash location, distance, and crash severity.

### Analysis

The authors first analysed the secondary data using descriptive statistics (percentage distributions) to understand the crash history of the highway, including crash proportions based on time of day, weather conditions, days of the week, type of road section, types of crashes, and driving errors. These analyses are relevant for engineering and designing traffic calming measures.

Then, the authors conducted a geospatial analysis using the crash severities covering 363 crash locations and data, such as the distance between crash locations and names of crash locations. These datasets helped to geolocate (getting *x* and *y* coordinates) all crash locations on the highway using Google Maps. Finally, the coordinates were imported to ArcGIS version 10.8 for mapping. Under the symbology, the heatmap function was used to identify corresponding crash and crash-prone locations, similar to a previous study [29]. Geospatial information, such as road network density, buildings, access points, transport services, etc., was also extracted and visualised.

## Results and Discussion

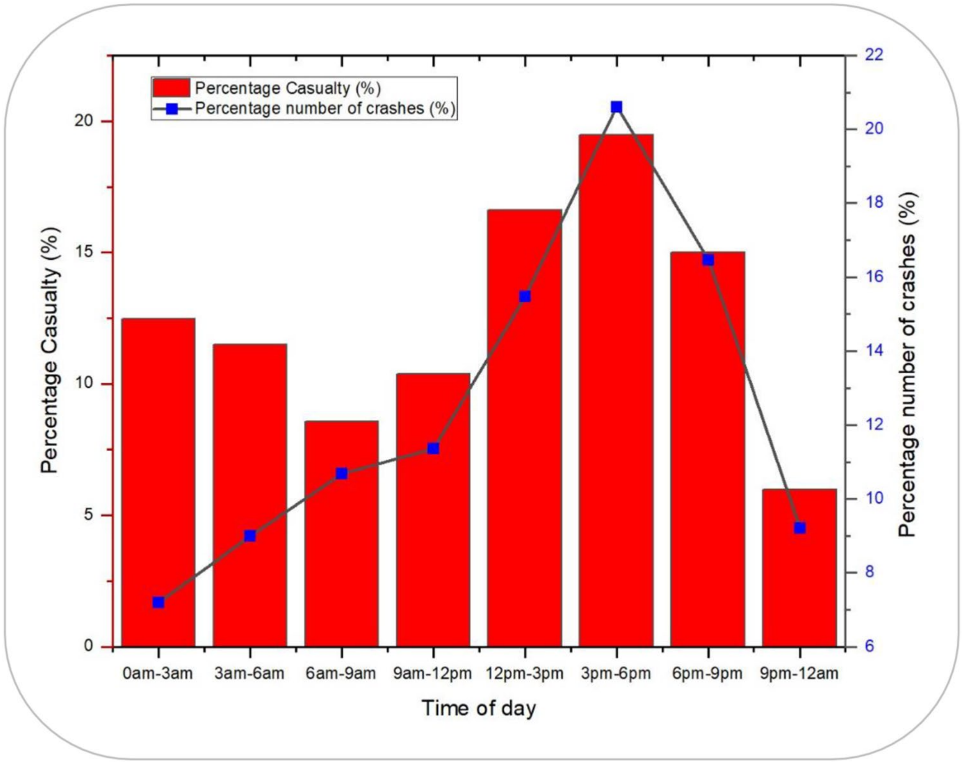
### General Crash Trends for the Studied Highway

#### Bus Crash Trends by Time of Day and Day of Week

There were 2236 bus crashes on the studied highway between 2005 and 2019, and 16% were fatal. To understand these crashes, the authors analysed the time of day patterns. The results in Fig. 2 show that most crashes and casualties occurred between 12 p.m. and 9 p.m.; however, mornings had far lower crashes.

Several studies have found that the time of day significantly affects road crashes [26, 30–32]. For example, in the USA, it was found that free-flow speeding and lane-changing behaviours contributed to large truck-involved crashes from mid-morning to afternoon [32]. Thus, bus crashes may increase in the afternoon because of drivers' speeding and lane-changing attitude that arises due to higher traffic

**Fig. 2** Crash trends by time of day



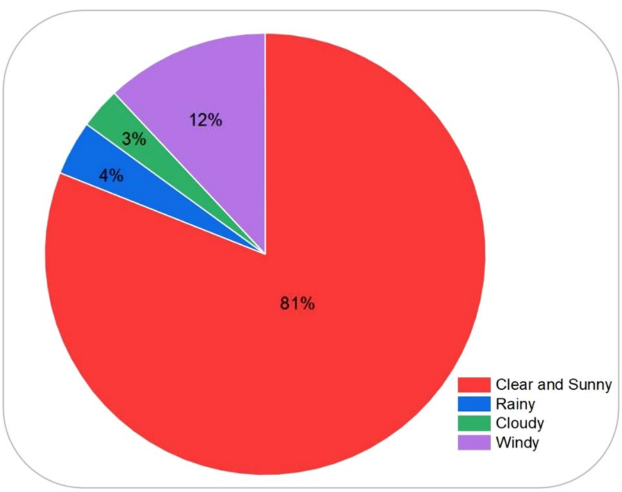




**Fig. 3** Crash trends under different weather conditions

demand and congestion. The traffic delays in Accra and Kumasi can cause driver anxiety [33, 34]. This result also corroborates the high incidence of crashes (81%) under clear weather conditions (clear and sunny, rainy, cloudy, and windy), as shown in Fig. 3. Another remote cause of afternoon crashes is driver fatigue. Commercial bus drivers travel long journeys, and fatigue can lead to driving errors [35]. Bus driver fatigue detection is gaining more research attention recently because it impacts drivers and contributes meaningfully to many road crashes [36–39]. Hopefully, there could be more future studies in Ghana to improve bus safety.

Figure 4 gives details about crash trends by day of the week. Although there were more bus crashes on weekends than on weekdays, Sundays had one of the lowest. This high occurrence could be explained by social activities that generate intercity trips, such as weddings, recreations and funerals, on Saturdays. A past study found that reckless driving occurred most on Saturdays [40]. The collisions can be alleviated by increased police enforcement along highways on Saturdays and public awareness, as expounded in some road safety studies [5, 41–43]. However, systemic police corruption and bus station overcrowding may contribute more to transgressive driver behaviours and the causation of bus crashes during these periods [44]. Nevertheless, it is notable that the crash casualty average for Tuesday and Wednesday is less but other days are comparable with weekend crashes. Lower intercity traffic demand on Tuesdays and Wednesdays (mid-week) could be plausible explanations, but this phenomenon would require more empirical observations.

## Crash Events at Different Road Sections

The type of road section is a significant factor regarding crash severity [45]. The results in Fig. 5 show that non-junction segments of the road, such as straight sections and curves, were associated with approximately 87% and 78% of casualties and crash events, respectively. This finding

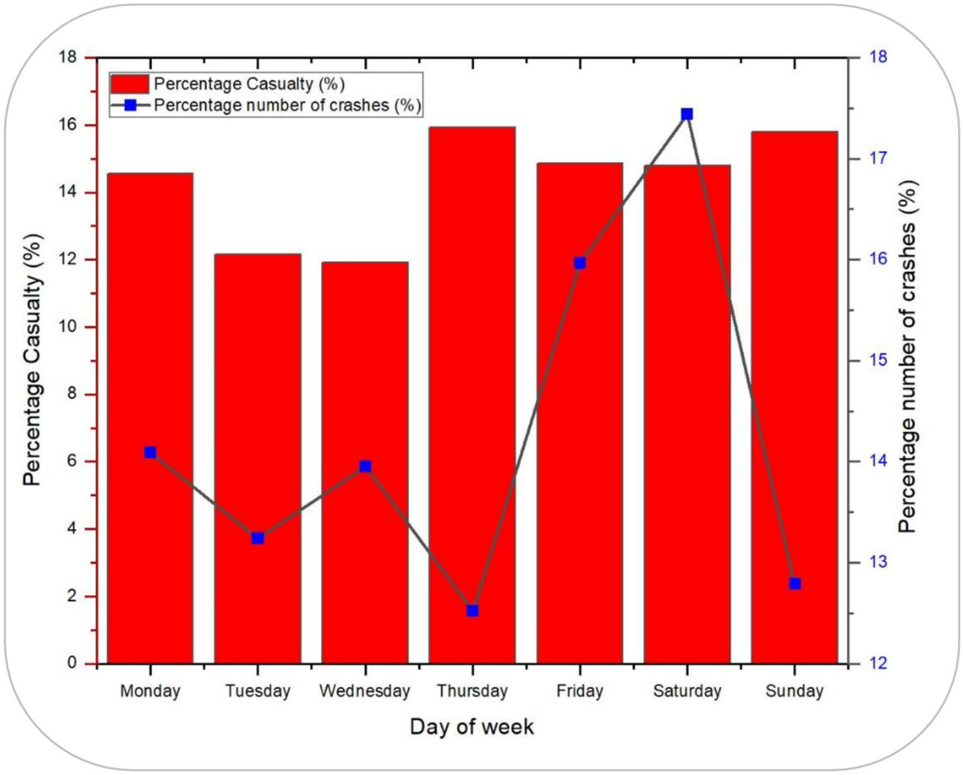



Fig. 4 Crash trends by day of week

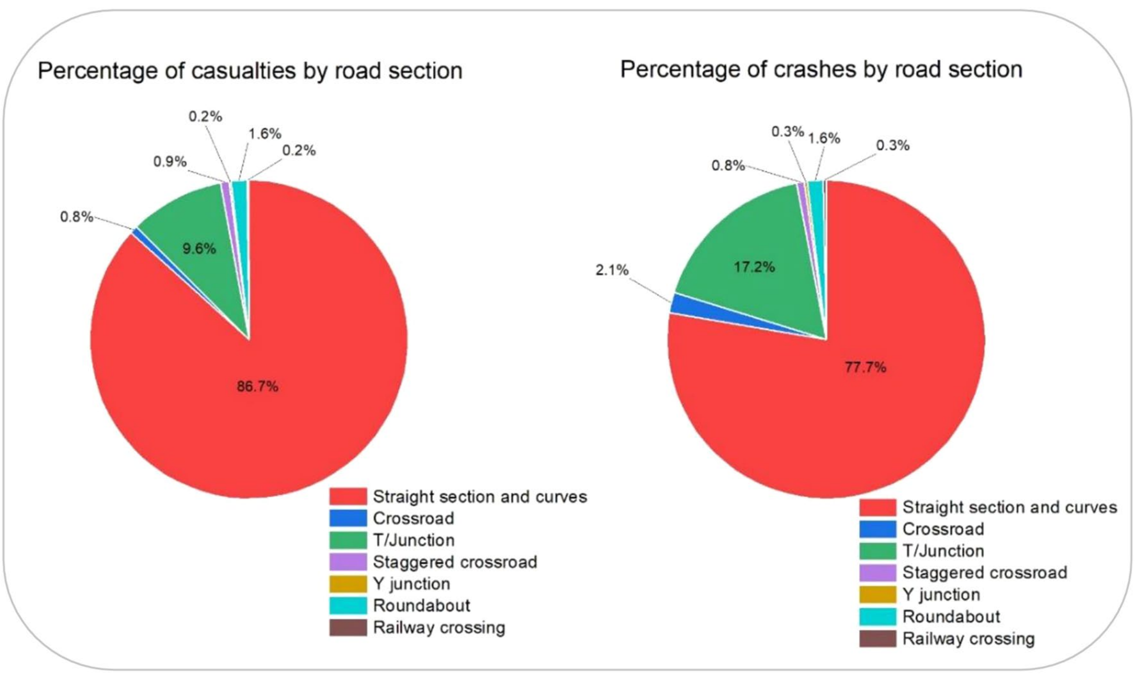



Fig. 5 Crash trends by road section

suggests that straight and curvy segments are crash-risk and require more attention. The road has a total of 118 curves and the straight section is 167.3 km constituting approximately 69% of the road length.

Factors such as sight distance, pavement condition, road signage, inattention, and excess speeding have been identified as crash-contributing factors in road curves in Ghana and abroad [46–48]. T-junction's casualties followed as the next highest number of bus crashes. Perhaps this is due to bus-motorcycle interactions in T-Junctions. The literature has shown that crashes in T-junctions often involve motorcycles drivers' failure to give way to other motor vehicles [49–51].

## Major and Minor Causes of Crashes

Figure 6 can explain the aggregate crash contributing factors by analysing crash types and driving errors. Rear-end, head-on, sideswipe, and run-off road collisions are major crash types in descending order. Except for run-off road, which usually occurs in curves, the other three major crash types usually occur on straight road sections.

The major causes of bus crashes are transgressive and aggressive driving behaviours such as inattention (46.0%), excess speeding (31.7%), lane-changing (8.1%), and car-following (8.1%). Inattention remains a discretion of traffic police based on the post-crash verbal accounts of drivers and passengers. The driver's eyes are monitored in experiments to understand their visual attention [52]. Perhaps future research can explain this phenomenon based on interviews with traffic police and simulation experiments in Ghana. The other major causes are common in traffic literature. For example, a previous study on the same highway showed that 95% of vehicles travelled above the posted speed limit (50 km/h) [53]. The minor causes of crashes are inexperience, poor road signage, improper turning, and fatigue.

To reduce high-speed-related crashes, Ackaah and Salifu [54] recommended speed monitoring programs for the highway. Lately, traffic calming measures have been employed on some major highways in Ghana [55]. The use of intelligent speed bumps can improve the safety of buses [56]. Therefore, expanding the roadway to supply extra lanes with road medians can reduce crashes [1, 5, 57, 58]. Also, past studies proposed surcharging drivers for errors [5] and installing CCTV surveillance at designated segments on the highway and buses [59, 60].

## Locations of the Crashes and Neighbourhood Characteristics

The geospatial analysis of the crash profile of the highway showed 363 crash locations (Fig. 7). The upper part (profile) shows the number of crashes at different locations along the highway, and the lower part (the map) visualises the crash severity at these locations using different colours. The map shows the fatal, hospitalised, injured not hospitalised, vehicle damage, and total crashes. Generally, it is found that the denser the settlement, the more crashes there were. For instance, the total number of collisions within the first 20 km from Accra is higher than in other 20 km locations (e.g.,

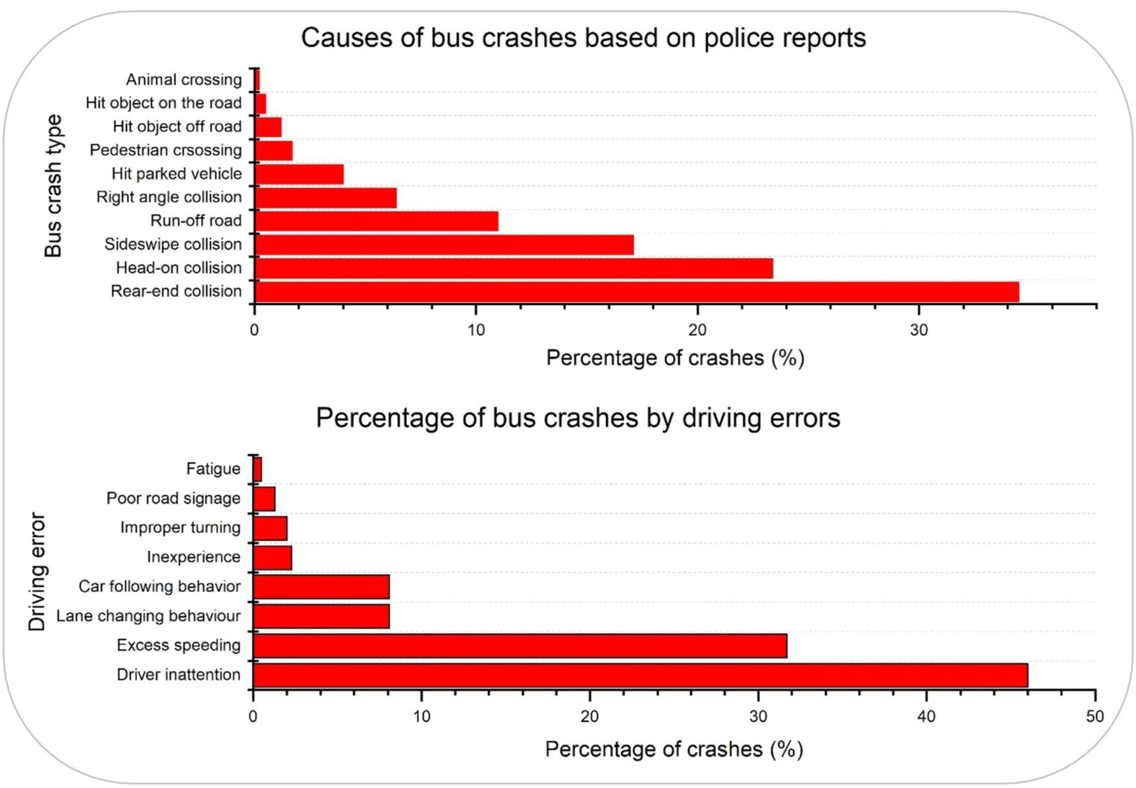



**Fig. 6** Distribution of crash types and drivers' errors

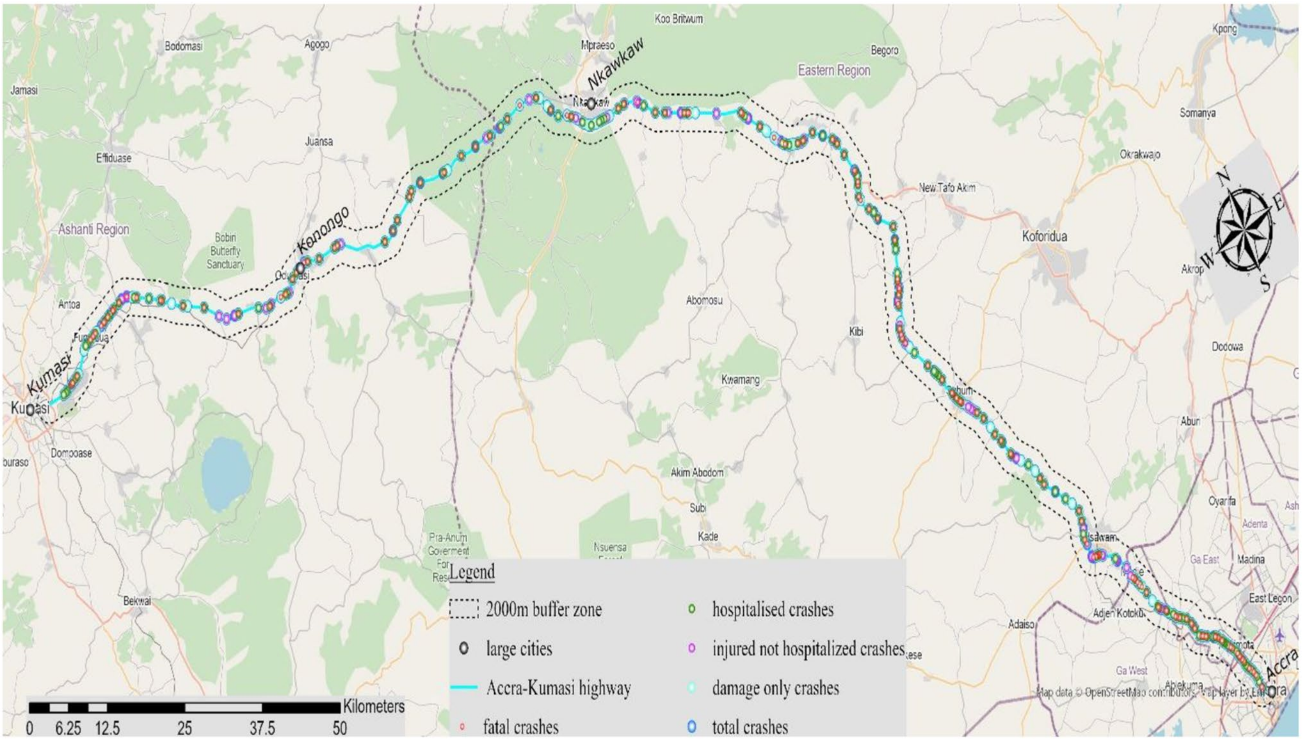



**Fig. 7** Crash profile of the studied highway

20–40 km, 40–60 km, 220–240 km, etc.). Also, the results show that fatal crashes mostly happen in road curves.

Figure 8 provides visualisations of the crash severities from Accra Kwame Nkrumah Circle (chainage + 00) towards Kumasi. It is evident in Fig. 8a that the fatal crash occurrences dominate in the first 25 km, and the highest ($n = 20$) is 191 km away from Accra towards Kumasi. Similarly, the first 40 km has the most damage-only crashes, as shown in Fig. 8b. Crashes resulting in hospitalised and non-hospitalised injuries appear evenly distributed along the highway (Fig. 8c, d). The location 12.1 km away (Ofankor Barrier) from the origin (Kwame Nkrumah Circle) had the highest number of crashes (34 crashes). Other notable locations within the first 200 km, such as Achimota, John Teye Memorial School, Teacher Mante, Asuboi, and Asaman Tamfoe Township, also had many crashes.

This study identified the high bus and low crash spots by linking crash data with transport facilities and geographical features (Fig. 9). The red colour represents locations with increased crashes; however, the yellow one represents locations with fewer crashes.

The map shows other geographical features such as road networks (residential streets, trunk roads, service roads, tertiary and secondary roads) and transport facilities (street lamps, bus stops, stop signs, traffic signals, road crossings, and bus stations) along the highway. In the present study, dense road networks characterised locations with high crash densities. For example, the crash densities are high from the two zoomed portions of the map on the upper part of the map. The upper left is near Kumasi, and the upper right is near Accra. As many research results have already found, the density of adjoining road networks can contribute to crashes on a highway [1, 3, 13]. Moreover, most locations with high crashes have a junction linking tertiary, secondary, and service roads. Access to these road types is also a potential reason for the high number of collisions at these locations.

Settlements along highways characterised by high population densities significantly influence the crash frequency and severity levels, as shown in Fig. 10. This can be ascribed to unduly reckless crossing behaviours of other road users, increased roadside activities, and more access points with fewer crossing structures. Findings indicated that the settlement densities in Accra and Kumasi are higher than in other highway locations. As shown in the map's upper right and left parts, Ewing et al. [61] similarly found that urban sprawl is significantly associated with fatal road crashes. Although their study was not exclusive to bus crashes, perhaps the high traffic densities in the catchment areas of Accra and Kumasi might account for this finding. These areas not only have more road users but also have many access points, as aforementioned.

As reported, the quality of road infrastructures and pedestrian environments, such as signal control and signage, affects the rate of bus crashes [1, 12]. It is imperative

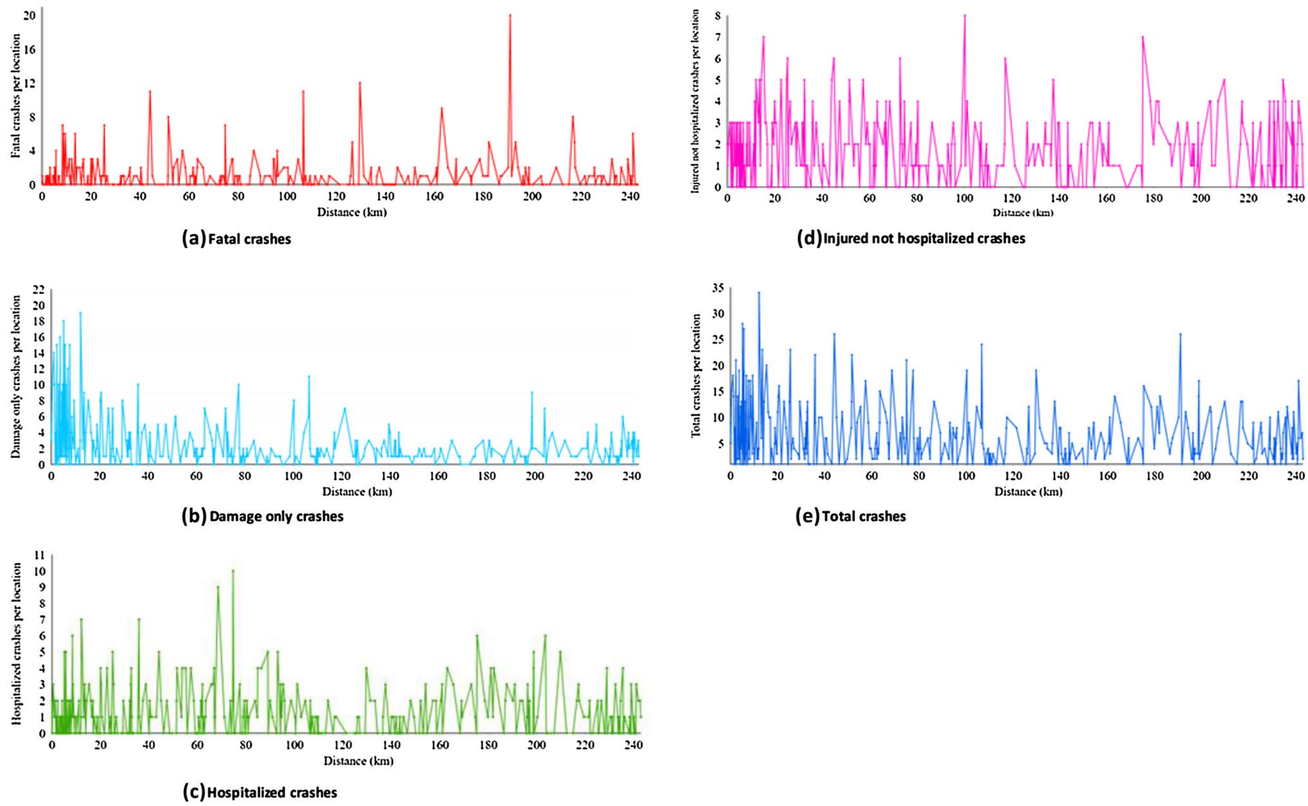



**Fig. 8** Crash severities per location

to have road inspections to check visibility, lighting conditions, and speed compliance on highways [2]. Although most crashes occurred in the afternoon, the percentage of night crashes (16.2%; 0:0 a.m.–6:00 a.m.) cannot be overlooked. The absence of road medians and bad road terrains on most of the roads in Ghana, including the Accra-Kumasi highway, remains a significant infrastructural deficit, as found by Sam et al. [5]. Other study results identified bus stops have a relationship with crash-prone locations. The location of bus stops, the lane width, and the road median are essential in promoting highway bus safety [3, 13, 14]. These factors emphasised the persistent call for low- and middle-income countries to invest in road infrastructures and mitigate bus crashes.

Road safety regulations require strict enforcement across the country's arterial or trunk roads. This study finds several driving errors accounting for the alarming number of bus crashes. Interestingly, past studies also found similar factors, such as drunk driving, excessive speeding, wrong overtaking, careless driving, and inexperienced driving, as contributors to fatal bus crashes [4, 5]. Some researchers argued that these issues persist because about 95% of bus transport services in Ghana are provided by private service providers who do not give enough training as state-owned transport companies do [4, 62]. This is consistent with previous findings in other developing countries, such as Sri Lanka, about the differential crash levels between public and private vehicle ownership employed for public transport [15]. This was squarely blamed on disparities in the deregulated public transportation system. Therefore, Road Traffic Regulations [63] should be fully enforced. Blantari et al. [64] found that televised road safety messages and awareness reduce road crashes effectively. Thus, they are good complements to traffic enforcement. However, they emphasised the need for different dialects in radio and television announcements and adverts.

## Conclusion

This study analysed bus crash trends and spatial characteristics along the Accra-Kumasi highway, Ghana using secondary crash data collected between 2005 and 2019. The findings and proposed countermeasures are helpful to all low- and middle-income countries faced with rampant intercity bus crashes.

This study found that bus crashes on the highway take place: (1) at road sections and curves other than junctions, (2) near dense settlements, (3) around vehicle service stations such as mechanic shops and fuel filling stations, and

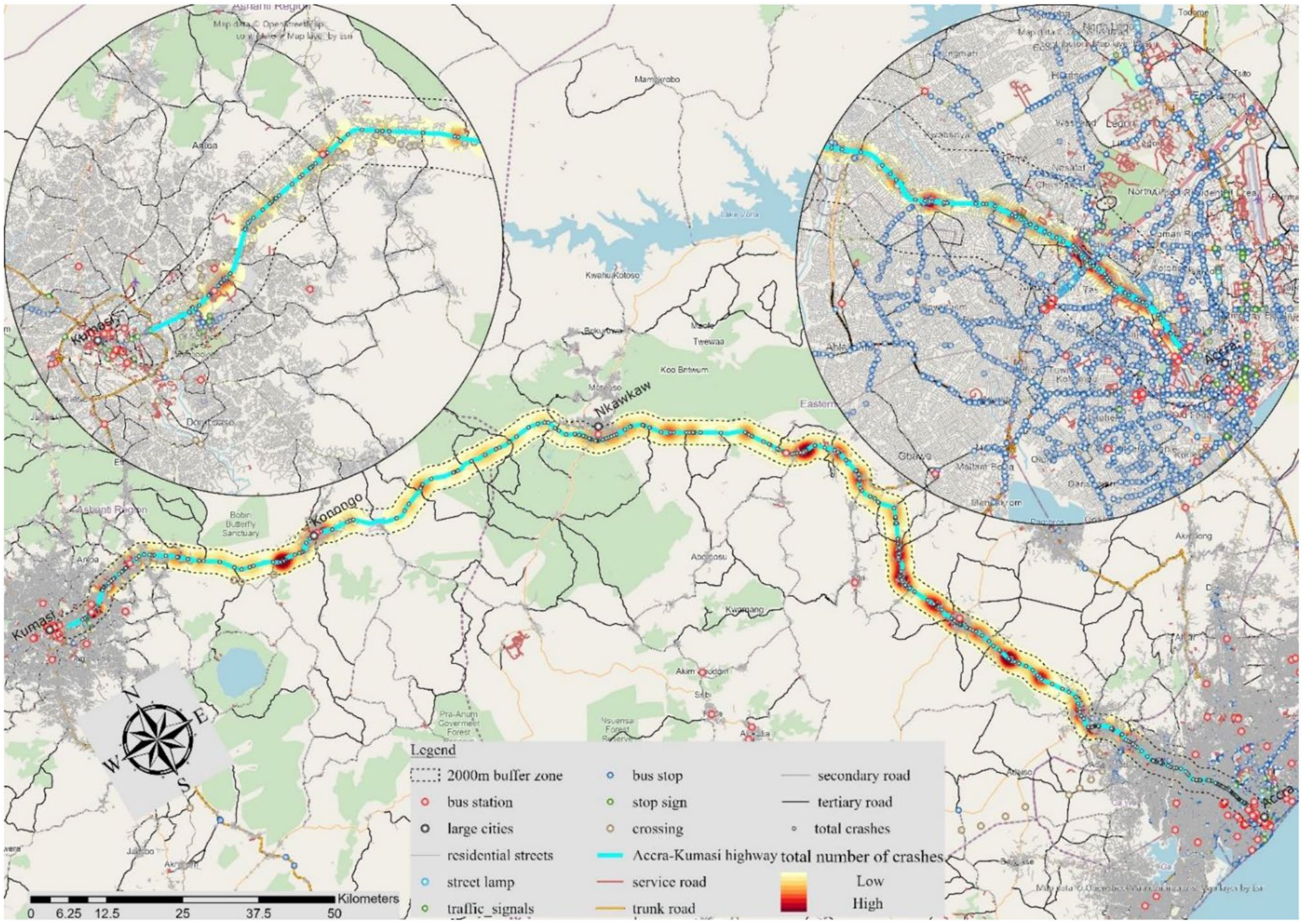



**Fig. 9** Linking crashes to geographical features and transport facilities

(4) in the afternoon and 81% occur under clear weather conditions. Crashes are primarily rear-ended and head-on collisions, mainly during weekends and holidays. The major causes of bus crashes are driver inattention, excess speeding, lane-changing, and car-following behaviour. The minor causes are driver inexperience, poor road signage, improper turning, and fatigue. From the heatmaps, most of the crashes happened in the catchment areas of Accra and Kumasi, where the street network, access points, and buildings are very dense.

## Recommendations for Bus Safety in Ghana and Developing Economies

This study proposed expanding lanes with surveillance cameras and intelligent speed bumps to reduce rear-end and head-on collisions. Beyond the posted speed limit, specialised warning signs can be positioned within 1 km of approaching settlement communities. This would require regular engagements between road safety agencies, bus operators, and driver's unions to sensitise themselves to safety measures. On weekends and holidays (festive seasons), increased police enforcement along the highway, especially near crash-prone locations, would be helpful. General issues related to driver licensure and traffic regulations require rigorous periodic reviews and post-implementation studies. Hence, Ghana's digitalisation revolution in other sectors of the economy must be extended by government and road agencies to road safety as well.

The findings emphasised the increasing need for developing economies to improve highway safety and road infrastructure. The following are recommended for countries with a high incidence of highway bus crashes:

- Traffic calming measures and intelligent transportation systems

  Traffic calming measures are required for settlement areas along highways and to reduce road traffic infractions. Speed bumps have been used over the years as traffic control measures, but this also sometimes causes cracks in the pavement. Therefore, it would be prudent to have smart speed bumps which can adapt to varying

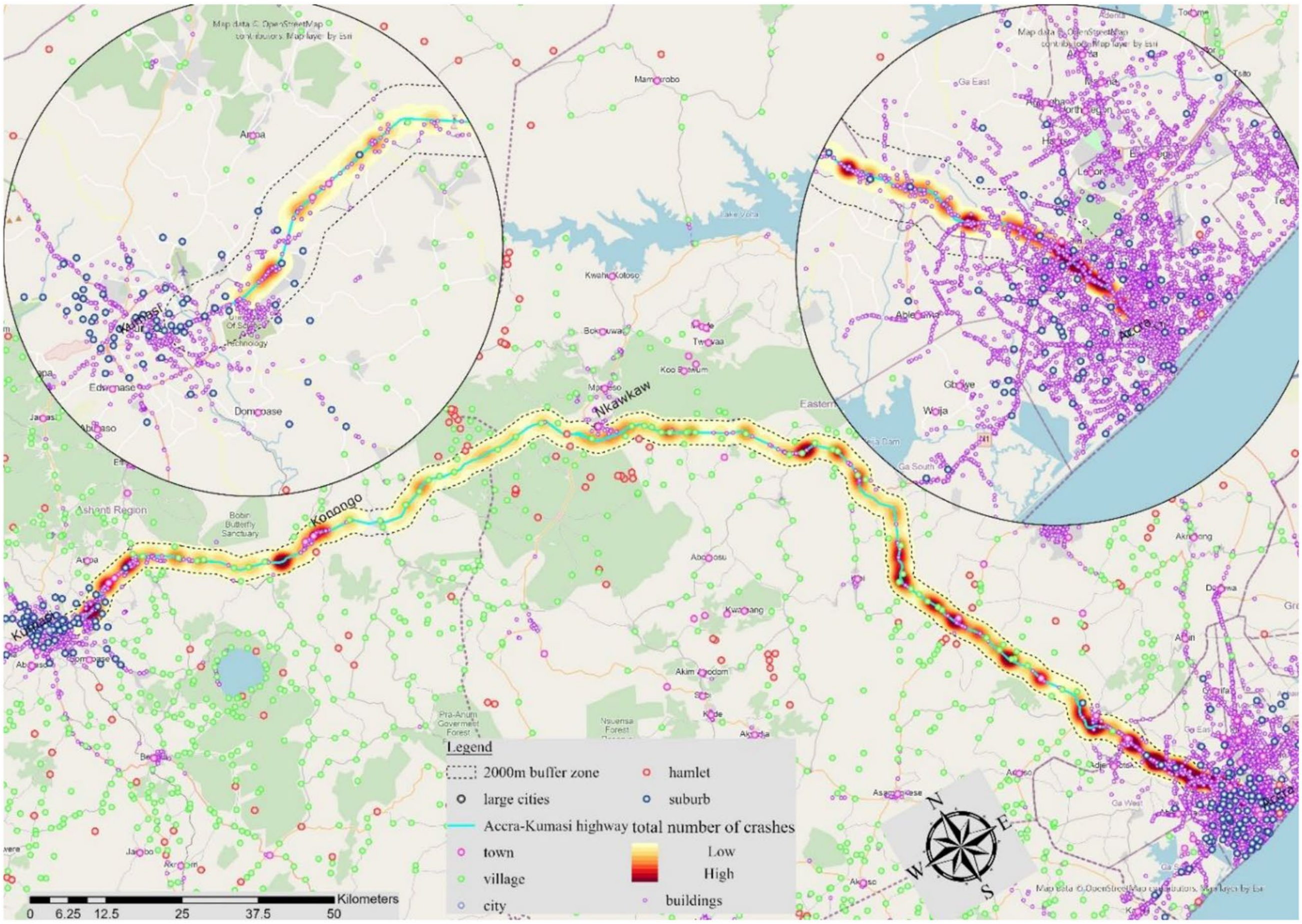



**Fig. 10** Linking crashes to settlement types

speeds of vehicles to reduce pavement effects. Additionally, intelligent transport systems and driving aids can be incorporated into the transport policy of developing countries, especially in Africa, to regulate bus transport.

- Road safety awareness, strict enforcement of traffic regulations, and engagement of bus operating companies

  Given that bus is preferred for inter-city transport, it is imperative to ensure bus operating companies have the best safety training and bus maintenance to help promote traffic safety. Quality assurance tests are required together with regular safety education to ensure that bus drivers are well equipped. In countries like Ghana, where private individuals and enterprises own the largest fleet of buses, regular road braking tests and inspections are required of traffic police to enhance traffic safety.

- Expansion of road width and infrastructure

  The quality of road infrastructure plays a key role in road safety. Therefore, to reduce bus crashes, road maintenance should be a priority in developing countries. This includes expanding the road width, constructing town overpasses where possible, posting speed limits, and increasing the number of road lanes. Though these engineering interventions can make bus trips safer in developed economies, they are capitally expensive.

## Limitations and Future Research

This study has some limitations. It did not include hotspot identification techniques due to the lack of traffic volume data. Thus, future case studies must identify crash hotspots using new techniques such as the Bayesian Poisson-lognormal CAR model and the Potential for Safety Improvement methods. These novel techniques would depend on the availability of crash data, average daily traffic, or average annual daily traffic. Additionally, crashes at non-junction sections were aggregated in the dataset. This gave a limitation in terms of the exclusive number of crashes in curves as against the straight road sections. Although the heatmaps showed plenty of fatal crashes in curves, it was difficult to quantify the percentage. Besides, the data covered an extended period, hence, several changes may have occurred in the trunk road infrastructure. However, the analyses give a general understanding of the road conditions and blackspot areas that would guide future engineering and planning.

**Author contributions** PKA: conceptualization, data curation; formal analysis; investigation; methodology; writing—original draft; editing; final draft preparation. AA: data curation; formal analysis; investigation; methodology; final draft preparation. SA: investigation; methodology; final draft preparation. GLartey-Y: editing; final draft preparation. All authors approved the final manuscript.

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**Data availability** The dataset is available upon request to the first author.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

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