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A Geographic Information System Mobile Application for Road Traffic Crash Data Collection, Management and Analysis

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ABSTRACT

The study addressed the issue of road traffic crashes in developing countries like Nigeria by developing a mobile app called Geographic Information System-Road Traffic Crash Data (GIS-RTCD). The app developed and tested in Southwest Nigeria is designed to transform the collection and management of real-time road traffic crash data by replacing the traditional paper-based method known for its imprecise, missing, contradictory, and disparate data. The app, accessible on Android and iPhone platforms, uses an Epicollect5-implemented mobile user interface, web server, PostgreSQL-based database, Apache Tomcat/Geoserver application/GIS server, and OpenLayers-implemented web service for map data visualization. The app provides precise crash location determination through GPS/geospatial mapping, digitally structures data collection, prevents data duplication, and eliminates labour-intensive tasks associated with manual data processing. The study recommends replacing manual crash data recording systems in Nigeria with the GIS-RTCD app to standardize crash data records and enhance comprehensive data collection for national analysis and research.

Keywords: Road Traffic Crashes, Data, RTCD, Mobile GIS, Mobile app, PostgreSQL, Geoserver, GPS, Geospatial

1. Introduction

The introduction of Information and Communication Technologies (ICTs) has revolutionized the way spatial data is collected, transmitted, and managed (Chen et al. 2023; Abdalla, 2016). Electronic surveillance systems powered by ICT, such as closed-circuit television (CCTV) cameras, facial recognition cameras, smartphone data-gathering apps, automated license plate readers (ALPR), and biometric systems, have been in use in developed countries since the early 20th century (Yau, 2019). However, their adoption in developing nations began in the early 21st century (Bonnet et al., 2017). These advanced technologies rely on a widespread wireless network and digital devices to provide sophisticated computational and communication capabilities from remote locations (Sacks et al., 2015). Through these technologies, which are more efficient than conventional paper-based methods, it has been possible to collect data in real-time, hold them in centralised web databases, analyse, monitor and map geo-referenced phenomena across time and space with the primary goal of aiding the formulation of critical solutions to socioeconomic problems (Cinnamon & Schuurman, 2010; Sacks et al., 2015; Bonnet et al., 2017). Among the phenomena that require accurate, timely, and spatially referenced electronic data collection are road traffic crashes (RTCs), which constitute a major public health, transportation, and socioeconomic challenge worldwide.

In Nigeria, data on RTCs are gathered from three main sources: the Nigeria Police Force (NPF), the Federal Road Safety Corps (FRSC), and the Federal Ministry of Health (Odinfono & Olawole, 2024; Niniola, 2022). The FRSC and the NPF collect RTC data at the crash scene, while the Federal Ministry of Health gathers information on accident victims from hospitals. These entities traditionally utilize different paper forms/templates for RTC data collection (Aderamo, 2012; International Transport Forum, 2018; Odinfono & Olawole, 2024), a method prone to inadequacies resulting from human error or insufficient personnel training, leading to missing or incomplete data. The missing or

incomplete data often pertains to the victims' demographics, road conditions, vehicles and drivers' pre-crash factors, types of injuries sustained, and seat positions of casualties. These factors are crucial for distinguishing between RTCs with similar characteristics. Therefore, there is a need for a unified digital system to effectively capture and report RTC data and enable comprehensive documentation of all relevant parameters associated with RTC occurrences.

Odinfono, Adesina and Adeoye (2020) also showed that the Nigerian RTC data sources lack precise spatial components due to the non-use of a geospatial approach. This deficiency results in ambiguous and subjective descriptions of crash locations, which are pivotal for the identification of hazardous road segments and the enhancement of traffic safety (Anderson, 2009; Saric et al., 2011; Jobin, 2015). Furthermore, precise RTC spatial referencing facilitates the integration of RTC databases with other databases containing information about the roadway environment, such as vehicular volume, highway geometry, and meteorological data (WHO, 2023; Imprialou & Quddus, 2019). Hence, there is a pressing need for an automated spatial referencing system to provide accurate and quantitative descriptions of crash locations in Nigeria.

The NPF, FRSC, and the Federal Ministry of Health in Nigeria each independently collect and maintain their records, leading to issues such as duplicate data, underreporting, and significant discrepancies between sources (Odinfono & Olawole, 2024, Niniola, 2022). Disparities exist between the documented RTC data by the FRSC and the NPF for specific areas over given periods (Shitta-Bey et al. 2020; Odinfono & Olawole, 2024; FRSC, 2024). According to WHO (2010), a minimum requirement for an RTC data system is to capture nearly all crashes, provide detailed information about vehicles, road users, and the road environment, include the precise crash location, and yield timely and reliable output for informed decision-making. Unfortunately, this is not the case in Nigeria. Therefore, there is a need for a unified electronic RTC data capturing and reporting system to enable automatic synchronization and harmonization of data from all agencies involved in RTC data collection in Nigeria.

One method of collecting and managing data for meaningful RTC analysis in the manner recommended by WHO is the use of Mobile Geographic Information Systems (GIS). Mobile GIS combines the communication capabilities of wireless/mobile devices and networks, the accurate spatial data acquisition capability of the Global Positioning System (GPS), and the analytical power of GIS (Tsou, 2004). It enables real-time collection of geo-referenced information using mobile devices, transmission to centralized databases, visualization, editing, and analysis in both field and office environments (Gao & Mai, 2018; Huang, 2019).

Mobile data collection systems have been successfully deployed globally in sectors such as public health surveillance, disaster management, environmental monitoring, and infrastructure asset management. Examples include Open Data Kit (ODK)-based health surveillance systems, mobile disease-reporting platforms, and GIS-based infrastructure inspection systems that support real-time data capture and centralized data management (Tomlinson et al., 2009; Hartung et al., 2010; McNeil et al., 2022; Moreno Castillo & Barcellos Neto, 2023; Cicek & Kantarci, 2023). Similarly, Mobile GIS applications have been developed in several countries to support transportation safety and crash management through field-based crash reporting, spatial analysis, and decision support (Miller & Shaw, 2015; ESRI, 2022). Despite these advancements, existing systems are either sector-specific or designed for transportation environments outside Nigeria and therefore do not adequately address the need for integrated and harmonized RTC data management in the country.

Furthermore, a review of the available literature revealed a paucity of empirical studies on the design and implementation of an integrated Mobile GIS architecture specifically developed for harmonized RTC data collection, management, and analysis in Nigeria. The GIS-RTCD Mobile Application developed in this study was therefore designed to address these gaps by integrating mobile data capture, GPS-enabled spatial referencing, centralized database management, real-time synchronization, and web-based visualization within a single framework tailored to the Nigerian road safety environment. Consequently, the objective of this study is to design and develop a Mobile GIS application for RTC data collection, analysis, and management in Nigeria, with emphasis on Oyo, Osun, and Ondo States in the Southwest geopolitical zone. These states were selected because previous studies have reported notable positive spatial clustering of RTCs, RTIs, and RTFs within the region (Osayomi & Areola, 2015; Olawole & Olapoju, 2018).

2. Literature Review

2.1. Mobile GIS Technology

Mobile GIS integrates Geographic Information Systems (GIS), Global Positioning Systems (GPS), wireless communication networks, and mobile computing devices to facilitate the real-time acquisition, transmission, visualization, and analysis of spatial data in the field (Tsou, 2004; Gao & Mai, 2018; Gharbi & Haddadi, 2020). Unlike conventional GIS, it enables geo-referenced data to be captured directly at the point of occurrence, thereby reducing delays, transcription errors, and positional inaccuracies associated with paper-based data collection methods.

The design of a Mobile GIS system requires careful consideration of factors such as portability, usability, communication infrastructure, database architecture, and the operational requirements of the intended application (Gharbi & Haddadi, 2020). Consequently, a typical Mobile GIS architecture comprises a mobile client for field data collection, a communication layer for data transmission, a centralized database for data storage and management, and web-based services for visualization and analysis (Mansourian et al., 2006; Markus, 2016; Gharbi & Haddadi, 2020).

The implementation of such architectures is supported by a range of hardware devices, software applications, and communication technologies designed for field-based spatial data collection and management. While digital field data collection dates back to the late 1980s with pioneering tools such as ArcPad, the widespread adoption of smartphones has accelerated the development of Mobile GIS applications. As a result, software solutions such as ODK Collect, Survey123 for ArcGIS, Collector for ArcGIS, FME Reporter, gvSIG Mobile, CartoPocket, CyberTracker, and IntraMaps Roam have emerged to support real-time spatial data acquisition, editing, and visualization (Gharbi & Haddadi, 2020). These technologies have largely replaced paper-based forms, resulting in more efficient, accurate, and streamlined field data collection processes.

A critical aspect of Mobile GIS development is the selection of appropriate software tools and platforms that align with project requirements and budgetary constraints. In this regard, Free and Open-Source Software (FOSS) offers a cost-effective and flexible alternative, with source code made publicly available under open-source licenses (Open Source Initiative, 2012; O'Donohue, 2023). Common open-source GIS tools include GeoServer, MapServer, PostgreSQL, QGIS, GeoDa, uDig, GRASS GIS, gvSIG, OpenJUMP, SAGA GIS, MapWindow, and OrbisGIS. These platforms provide robust capabilities for spatial data management, analysis, and application development, thereby supporting the rapid advancement of Mobile GIS technologies.

2.2. Development of Mobile Applications

Mobile applications may be developed using native, web-based, or cross-platform approaches. Native applications provide high performance and direct access to device hardware but are restricted to a specific operating system. Web applications are platform-independent but depend heavily on internet connectivity and generally provide limited access to device resources. Cross-platform development offers a balance between these approaches by enabling a single code base to operate across multiple operating systems while reducing development time and cost (Shah, Sinha & Mishra, 2019; Zohud & Zein, 2021).

Considering that Android and iOS collectively account for more than 99% of the global mobile operating system market, this study adopted a cross-platform solution to maximize accessibility and usability (StatCounter, 2024; Taylor, 2024). Epicollect5 was selected because it supports both Android and iOS devices and provides integrated GPS data capture, offline data collection, cloud-based synchronization, multimedia data collection, customizable electronic forms, and centralized project management with minimal programming requirements (Aanensen et al., 2009; Imperial College London, 2024). Furthermore, Epicollect5 offers a simplified deployment process, integrated cloud synchronization, and a graphical project management environment that reduces technical configuration requirements compared with platforms such as ODK and Formhub (Hartung et al., 2010; Brunette et al., 2013; Tomlinson et al., 2009). These characteristics make it suitable for road traffic crash data collection involving multiple agencies and field personnel.

2.3. Related Works

Several studies have demonstrated the applicability of Mobile GIS and web-based GIS technologies for transportation, disaster management, and road safety data collection. However, significant differences exist in their architectures, functionalities, scalability, and suitability for real-time crash data collection.

Mansourian et al. (2006) developed a web-based disaster management system within a Spatial Data Infrastructure (SDI) framework. Although the system facilitated data sharing and centralized management, it primarily focused on web-based data integration and lacked a dedicated mobile component for real-time field data collection. Similarly, Kresse and Danko (2012) proposed a client-

server architecture with a spatial database but did not address the challenges of mobile crash reporting, GPS-enabled location capture, or field usability.

Markus (2016) developed a Mobile GIS architecture for traffic accident management in Sweden using an Android application linked to PostgreSQL/PostGIS databases through web services. The system demonstrated the feasibility of mobile crash data collection and centralized storage. However, its dependence on a native Android application restricted accessibility for users operating other mobile platforms. In addition, the study focused primarily on data collection and storage architecture, with limited emphasis on multi-agency data harmonization and standardized crash reporting.

Montella et al. (2019) introduced ReGIS, a web-based platform for crash data collection and analysis based on the LAMP architecture. Unlike Markus (2016), ReGIS provided robust web-based analytical capabilities and cloud deployment features. Nevertheless, the platform relied largely on web technologies and was not specifically designed for real-time mobile field data collection using GPS-enabled smartphones. Consequently, challenges associated with on-scene crash reporting, offline data capture, and direct spatial data acquisition remained insufficiently addressed.

Zeng et al. (2019) developed a cross-platform emergency spatial data collection system capable of operating on Android, iOS, web applications, and mini-programs. While the study demonstrated the advantages of cross-platform development, its focus was emergency management rather than road traffic crash reporting, and it did not incorporate standardized crash-reporting parameters or mechanisms for harmonizing crash records across multiple agencies.

Gharbi and Haddadi (2020) developed a Mobile GIS solution for road network management in Algeria using IntraMaps Roam, PostgreSQL, PostGIS, QGIS, and QGIS Cloud. The system successfully improved field data collection and road asset management through mobile devices. However, the application focused on roadway inventory and road infrastructure management rather than comprehensive road traffic crash data capture, analysis, and inter-agency integration.

A critical review of the foregoing studies reveals that although Mobile GIS technologies have significantly improved spatial data collection and management, several limitations persist. These include platform dependency, inadequate support for real-time crash reporting, limited interoperability among agencies, insufficient integration of standardized crash-reporting parameters, and inadequate support for harmonized crash databases. Furthermore, most existing systems were developed in Europe, Asia, or North Africa, while empirical applications for road traffic crash data collection and management remain scarce in Sub-Saharan Africa and virtually non-existent in Nigeria.

The present study addresses these gaps by developing a GIS-based Road Traffic Crash Data Mobile Application (GIS-RTCD Mobile App) that integrates real-time GPS-enabled crash data capture, standardized reporting templates, centralized database management, cross-platform accessibility, and spatial analytical capabilities. The system is specifically designed to support harmonized crash data collection among road safety stakeholders in Nigeria while providing accurate spatial references required for crash analysis, blackspot identification, and evidence-based road safety interventions.

3. Material and Methods

3.1. System Design and Architecture of the GIS-RTCD Mobile App

The design and implementation of the GIS-based Road Traffic Crash Data (GIS-RTCD) Mobile Application followed a four-stage framework comprising:

1. Identification of project requirements,
2. Application design
3. System implementation,
4. Testing and validation.

The overall approach and development procedure were adapted from the Mobile GIS framework proposed by Gharbi and Haddadi (2020), with modifications to accommodate road traffic crash data collection, spatial analysis, and multi-agency data harmonization requirements in Nigeria.

3.2. Identification of Project Needs

The design requirements of the GIS-RTCD Mobile Application were derived from a review of existing RTC data collection forms used by the FRSC, NPF, and the Federal Ministry of Health, as well as recommendations contained in international road safety data standards (WHO, 2010; International Transport Forum, 2018). The objective was to develop a harmonized digital crash-reporting platform capable of capturing the minimum data elements required for comprehensive crash analysis and management.

The dataset designed for the application comprises seven major categories of information:

1. Crash overview information, including date, time, location, crash severity, and crash type
2. Vehicle information, including vehicle category, registration number, and ownership details
3. Driver/rider information, including demographic and licensing characteristics
4. Roadway information, including road type, surface condition, and traffic control characteristics
5. Information on persons involved, including casualties and injury characteristics
6. Items recovered at the crash scene
7. Hospital follow-up information for injured victims

These data elements were incorporated into the application to facilitate standardized and comprehensive crash reporting.

The functional requirements of the system included GPS-enabled location capture, multimedia data acquisition, online and offline data collection, automated synchronization with a centralized database, spatial and statistical querying, report generation, data editing and updating, and interoperability with desktop GIS environments.

3.3. Hardware and Software Selection

Open-source and cost-effective hardware and software components were selected to ensure accessibility, scalability, and ease of deployment. The hardware platform consisted of Android and iOS-compatible smartphones/tablets for field data collection and a personal computer for database administration, system configuration, and data analysis.

The software environment comprised Epicollect5 for mobile data collection and web-based administration, PostgreSQL 12 with PostGIS for spatial database management, Apache Tomcat 9 as the application server, GeoServer 2.24.1 as the GIS server, and OpenLayers 8.2.0 with Bootstrap and jQuery libraries for web-based visualization and spatial querying. These tools were selected because they are open-source, interoperable, and capable of supporting the requirements of a Mobile GIS architecture.

3.4. Design of the Application

The GIS-RTCD Mobile Application was designed using conceptual, logical, and physical data modelling approaches. The conceptual model was developed using the Entity-Relationship (ER) modelling technique to define data entities, their attributes, and relationships. The model comprised seven principal entities corresponding to the major categories of crash information collected by the application. Table 1 presents the identified entities and their attributes, while Table 2 summarizes the relationships and cardinality constraints among the entities. Figure 1 illustrates the resulting Entity-Relationship schema.

Table 1. Entity Types and their associated attributes for the study

Entity Types	Attributes
Accident	Accident_Id, Date, Time, FRSC Command, State, LGA, Municipality, Road_Name, X-Coord, Y-Coord, Land_Use, Severity_Type, Collision_Type, Non_Collision_Attributes, No_Injured, No_ Killed, No_Involved, No_Veh_Involved.
Vehicle	Veh_Id, Reg_No, Type, Make, Model, No_Of_Persons_Involved, Ownership, Fleet_Operators' Name, Insurance_Type, Insurance_No, Insurance_Company, Pre-Crash_Factors.
Drivers/Riders'	Victim_Id, Veh_Id, Name, Address, Mobile_No, Citizenship, Gender, Age, Martital_Status, Education, Driving_Status, Licence_No, Experience, Outcome, Injury, Protection, Pre-Crash_Factors
Information	Road_Name, Type, Surface_Type, Surface _Condition, Segment Speed, Alignment, Gradient, Road_Feature, Light_Condition, Weather, Road_Marking.
Road	Victim_Id, Veh_Id, Name, Address, Mobile_No, Road_User_Type, Pedestrian_Behaviour, Gender, Age, Marital_Status, Education, Occupation, Outcome, Injury, Protection, Seat Position
Persons Involved	Accident_Id, Perishable_items, personal_effects, vehicle, money
Items Recovered	Victims_Id, Name, Hospital_Name, Status_30th_Day, Date_of_death

The logical design translated the conceptual model into a relational database structure comprising multiple linked tables and primary–foreign key relationships. Detailed relational schema definitions are presented in Apendix Tables A1–A7.

For physical implementation, PostgreSQL with the PostGIS spatial extension was selected as the database management system because of its support for spatial data storage, indexing, querying, and

integration with open-source GIS applications. The resulting GIS-RTCD architecture consists of a mobile data collection application, a web server for data administration and synchronization, a PostgreSQL/PostGIS database server for storage and querying, a GeoServer-based GIS server for spatial data publication, and a web mapping service for visualization and analysis. Figure 2 illustrates the overall system architecture.

Table 2. Relationship Types and Cardinality constraints

Relationship Types	Cardinality Constraints
Vehicles are involved in an accident.	One or more vehicles are involved in an accident.
Persons are involved in an accident.	One or more persons are involved in an accident
Drivers are involved in an accident	One or more drivers are involved in an accident.
Accidents happened on the road.	An accident happened on one road.
Accidents contain recovered items.	An accident contains one or more recovered items.
Victims followed up in the hospital were injured in an accident.	An accident has one or more victims followed up in the hospital.

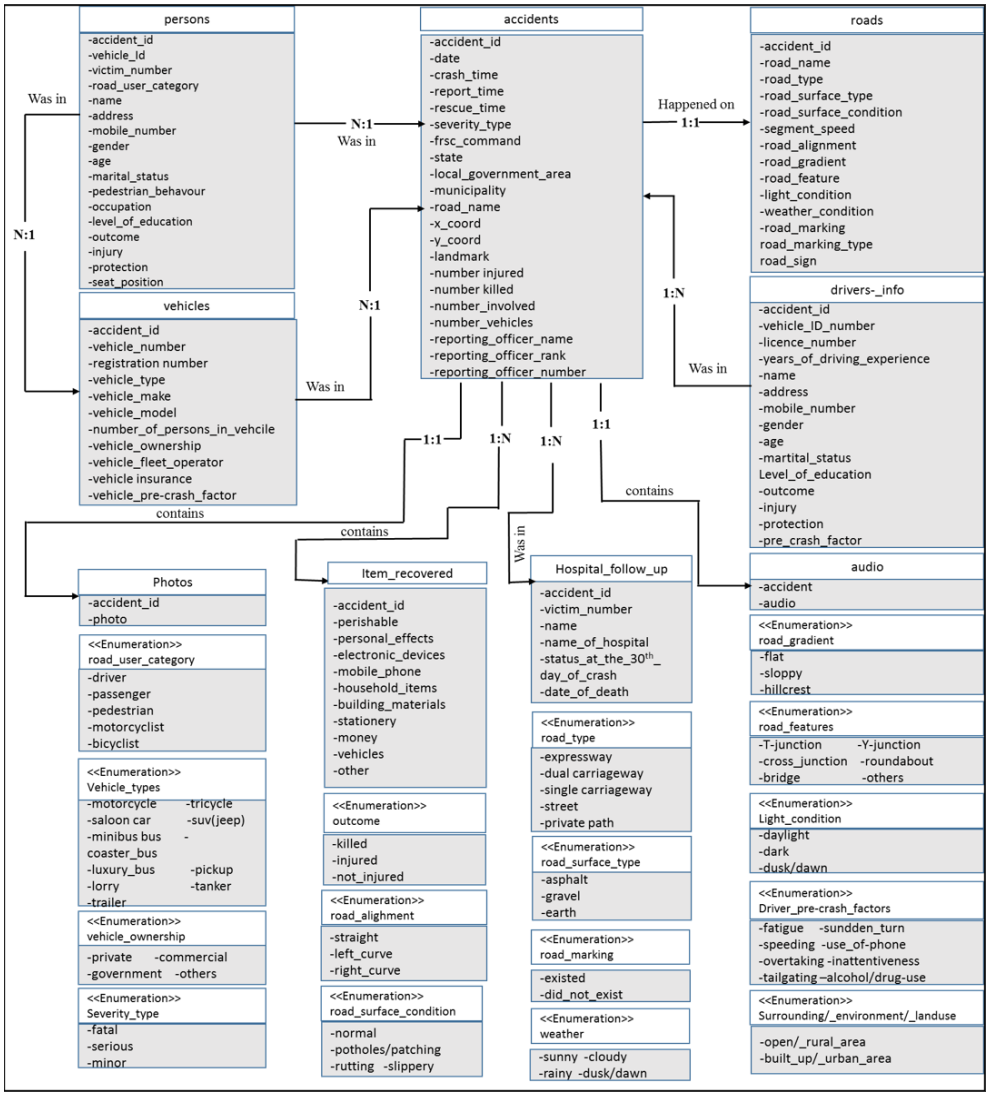

Figure 1. Conceptual Data Model for the GIS-RTCD mobile App.

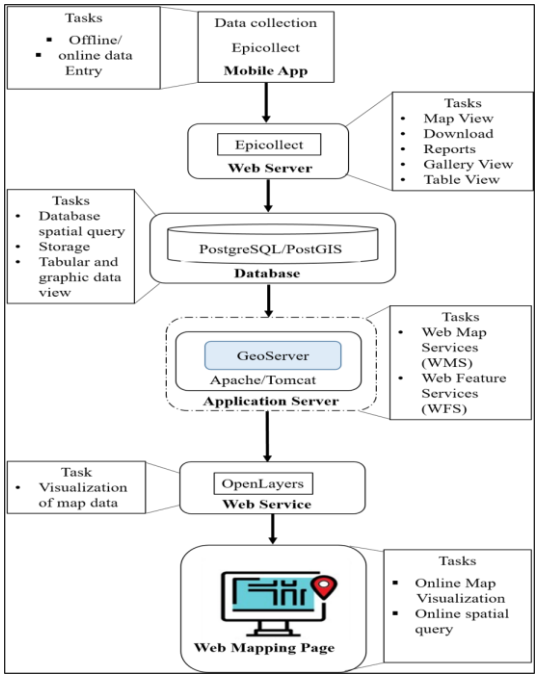

Figure 2. The Block Diagram of the GIS-RTCD Mobile App.

4. Result

4.1. Implementation

The GIS-RTCD Mobile Application was successfully implemented using a two-tier architecture comprising front-end and back-end components. The implementation integrated mobile data collection, centralized data management, spatial database technology, GIS web services, and interactive web mapping functionality.

4.2. The Front-end Component

The front end component is the mobile app that users utilize for online/off line data collection. It runs natively on mobile devices/ tablets using pre-designed digital form, GPS, and camera features. It was implemented using Epicollect5 open-source cross-platform resource. To get started, a user (front-end user), uses a smartphone or tablet to search, select, download, and install the Epicollect5 Mobile app from the Apple Store or Android Play Store. The app offers various front-end features.

a. User Authentication: Users access the system through the Epicollect5 mobile application installed on their smartphones or tablets. Authentication is performed using registered user credentials.
b. Road Traffic Crash Data Capture: After authentication, users download the “GIS Road Traffic Crash Data System” form and create a new record by selecting the “Add Entry” option. The application enables the collection of general crash information, GPS-based crash location coordinates, photographs, videos, and other relevant crash attributes. Additional modules capture information relating to vehicles, drivers, passengers, roadway characteristics, recovered items, and hospital follow-up records. Built-in validation rules help ensure data completeness and consistency before records are saved. Figures 3A and 3B present the application's home page and multimedia capture interface, respectively.
c. View Data Form: By selecting a saved entry from the list of project records and scrolling through the form, users can view a completed or saved road traffic crash data form on the mobile application.
d. Edit Data Form: By selecting a saved entry and clicking the edit button associated with the response to be modified, users can update information contained in the saved road traffic crash data form. Figure 4A shows a screenshot of the edit button on the “Overview Information of the Crash” section.
e. Delete Report: By selecting a saved entry and clicking the “DELETE” button located at the top-right corner of the form, users can permanently remove the saved road traffic crash report from the mobile application.

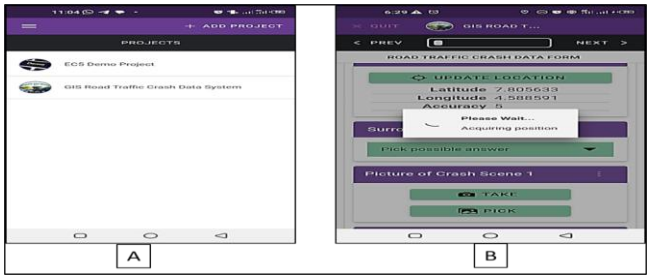

Figure 3. [A] showing the app home page and [B] showing the multimedia capture interface.

f. Data Synchronization: By clicking the cloud icon on the top-right corner of the home screen or the “Upload” button on the warning banner and selecting “Upload Data,” users can synchronize completed road traffic crash data forms with the web server when an internet connection is available (online mode). In the absence of internet connectivity, data are stored locally on the mobile device and automatically synchronized when connectivity is restored. Entries marked with a green checkmark on the cloud icon indicate successful synchronization. Users can also upload crash-related photographs, audio recordings, and videos to the web server using the corresponding upload buttons. Figure 4B presents a snapshot of the uploaded data, photos, audio, and video screen.

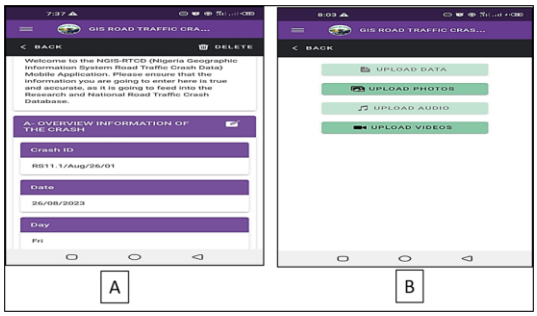

Figure 4. [A] The edit button on the overview Information of the Crash. [B] showing the upload.

4.3. The Back-end Component

The GIS-RTCD mobile application's back end comprises a web server, database server, Application/GIS server, and web service, accessible only to registered administrators.

a. The Web Server: The application's web server serves as a mediator between the mobile app component and the database. It was implemented using the Epicollect5 web server. It is typically used for data storage and administration. An administrator creates an account on https://five.epicollect.net and logs in to the "GIS Road traffic crash data system." Features include viewing and tracking reported crashes, updating and editing them, deleting them, viewing or deleting uploaded photos and videos, and downloading them.

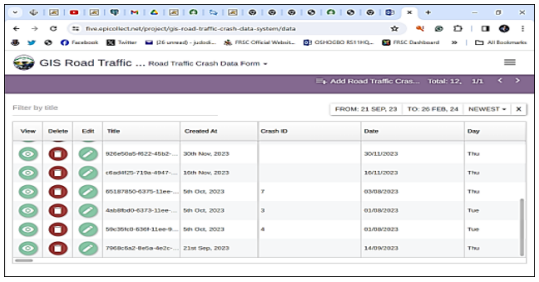

Figure 5. A snapshot of the web server showing the table view of submitted RTC data.

b. The Database Server: The database server was implemented using PostgreSQL 12 with the PostGIS extension. It was downloaded and installed using the stack builder. During the installation, the "spatial extension" option was checked, allowing the PostGIS extension to be downloaded via the stack builder. The database for the GIS-RTCD mobile app was then created on PostgreSQL using PgAdmin 4 v8.1. The RTC data was downloaded from the Epicollect5 web

server, converted into shape files, and imported into the PostgreSQL database using the PostGIS import/export manager.

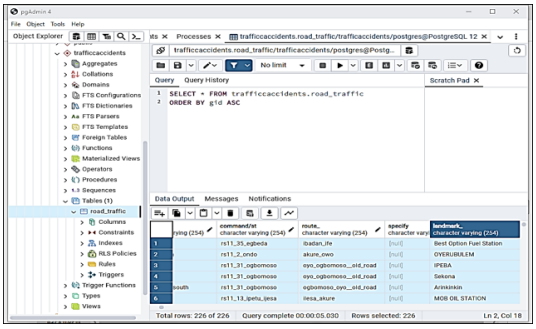

Figure 6. A snapshot of the loaded shape files on the PostgreSQL database.

c. Application server/GIS server: The application server was implemented using Apache Tomcat 9, with Geoserver version 2.24.1 as the GIS server. Apache Tomcat 9 was downloaded and installed alongside JRE 17, and hosted on localhost:08088 in Google Chrome. Figure 7 is a snapshot of the Google Chrome browser showing the launching of Apache Tomcat 9. Geoserver 2.24.1 was downloaded and deployed on Apache Tomcat. To publish the PostgreSQL database's shape files, Geoserver was configured by creating a new workspace,named "trafficaccidents," a new PostGIS store named "road-accident," and a new layer named "trafficaccident: road_traffic." The default publishing style was modified from polygon to point, and the GIS layer projection systems were set.

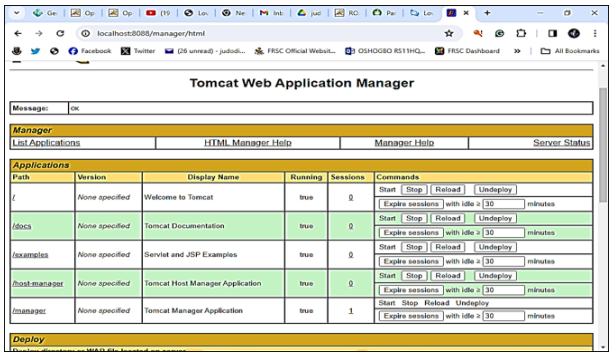

Figure 7. The launching of the Apache Tomcat on Google Chrome browser.

d. Web Service: The web service was developed using OpenLayers 8.2.0, Bootstrap version 5.0.2, jQuery version 1.13.2, and an OpenLayers switcher for style and base layer modifications. An Apache Tomcat web application's "Web mapping" subdirectory was created, and the application code was developed and added to an index.js file. The OpenLayers was loaded into the web browser using localhost08088/webgis/map_wms_wfs_query.html in Google Chrome. The OpenLayers' layout features control buttons for Local Query, Overlays, Legend, GetFeature, Measurement type, and Available WMS layers, allowing users to generate spatial data queries, analysis, and HTTP requests from the GeoServer. Figure 8 shows an example of a spatial query displaying crash records within Oyo State.

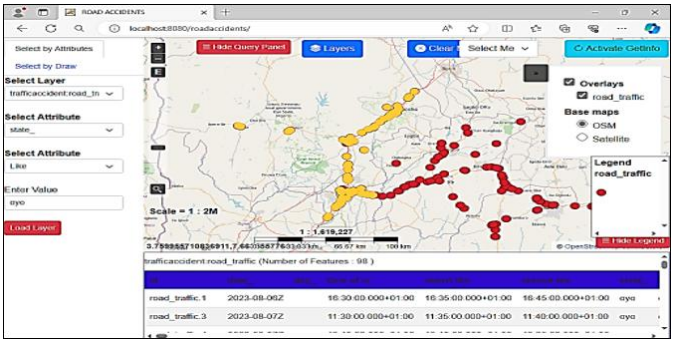

Figure 8. Result of the web service's spatial data query for the crashes in Oyo State.

4.4. Testing and Validation

The developed GIS-RTCD Mobile App was subjected to a pilot testing and validation exercise using sampled RTC field data collected over a two-week period in Ile-Ife, Osogbo, and Ibadan. The objective of the pilot study was to evaluate the operational functionality of the application, assess the reliability of data transmission and synchronization, validate the accuracy of GPS-enabled crash location capture, and identify any deficiencies in the crash data collection template before large-scale deployment.

During the pilot phase, crash records were successfully captured using both the online and offline modes of the application and subsequently synchronized with the central database through the web server. The test confirmed that the mobile user interface, database server, application server, GIS server, and web mapping components functioned as an integrated system. In addition, the GPS component successfully generated geo-referenced coordinates for crash locations, thereby eliminating the subjective location descriptions commonly associated with paper-based crash reporting systems.

The pilot exercise also provided an opportunity to evaluate the completeness of the crash-reporting template. Based on observations made during field deployment and feedback obtained from data collectors, several modifications were introduced to improve the comprehensiveness of the system. Specifically, new data elements including “day of the week”, “non-collision attributes”, additional “vehicle pre-crash factors”, and additional “driver pre-crash factors” were incorporated into the digital crash-reporting form. These additions improved the capability of the application to capture the temporal and behavioural characteristics of RTCs.

Qualitative feedback obtained from field users indicated that the application was easy to navigate and simplified the process of recording crash information compared with conventional paper forms. However, a few operational challenges were observed during the pilot phase. These included delays in obtaining GPS coordinates in areas with poor network coverage or difficult terrain and occasional reluctance of crash victims to provide socioeconomic information required in the digital form. These observations informed subsequent user training and system refinement prior to full deployment.

Following the successful completion of the pilot study and implementation of the identified improvements, the GIS-RTCD Mobile App was deployed for a five-month real-time RTC data collection exercise across the study area. The deployment resulted in the successful collection and synchronization of 507 RTCs, 1,497 RTIs, and 323 RTFs, demonstrating the operational reliability and scalability of the developed system for large-scale crash data collection and management.

5. Conclusion and Recommendations

RTCs remain a major public health and transportation challenge, particularly in developing countries such as Nigeria, where crash data collection is often characterized by incomplete records, inconsistencies, duplication, and limited spatial referencing. This study developed and implemented a GIS-based Road Traffic Crash Data (GIS-RTCD) Mobile Application to enhance the collection, management, and visualization of RTC data using a geospatial approach. The developed system integrates mobile data collection, GPS-enabled location capture, centralized database management, and web-based visualization tools to facilitate the acquisition and management of crash information in real time.

The pilot testing and subsequent deployment of the system demonstrated its capability to support digital crash reporting, capture accurate geographic coordinates of crash locations, reduce data duplication, and improve the efficiency of data synchronization and storage. During the five-month deployment period, the system successfully supported the collection and management of 507 RTCs, 1,497 RTIs, and 323 RTFs within the study area. These results demonstrate the practical applicability of the developed GIS-RTCD Mobile Application for RTC data collection and management.

Despite these achievements, the effectiveness of the system depends on institutional adoption, smartphone battery life in the field conditions, user training, and the availability of supporting information and communication technology infrastructure. Consequently, the long-term sustainability and scalability of the system require organizational commitment from agencies responsible for RTC data collection and management.

Based on the findings of this study, it is recommended that agencies involved in RTC data collection consider adopting digital geospatial data collection systems such as the GIS-RTCD Mobile Application to improve data quality, consistency, and accessibility. Efforts should also be directed toward

harmonizing crash data collection practices among relevant stakeholders to support the development of a unified crash database for planning, research, and decision-making.

Furthermore, future developments may focus on integrating crash databases with other transportation-related information systems, including driver licensing, vehicle registration, emergency response, and road infrastructure management systems. Additional studies should also explore advanced geospatial analytical techniques for emergency medical service optimization, and evidence-based road safety interventions. Such enhancements would further strengthen the role of geospatial technologies in supporting road safety management and transportation planning.

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7. Disclosure Statement

The authors report no conflict of interest.

8. Data Availability Statement

The study data and finding models are available from the corresponding author upon reasonable request.

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