Integrating GIS into Traffic Incident Management: A Web-Based System

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ABSTRACT

The increasing frequency and severity of road accidents in Malaysia, driven by a significant disparity between vehicle growth and infrastructure capacity, present a pressing need for advanced traffic management solutions. This study details the design, development, and evaluation of a Web-GIS Traffic Incident Management System (WGTIMS), an integrated platform designed to enhance incident reporting, spatial visualization, and multi-stakeholder coordination. The system was constructed using a structured methodology of planning, design, development, and implementation, with deliberate integrations for performance and security. Built on an open-source stack (PHP, MySQL, Leaflet.js), WGTIMS employs a role-based architecture to serve administrators, police officers, and public users. A rigorous evaluation strategy was employed, combining black-box testing with preliminary user feedback. The technical testing demonstrated that the system successfully met all specified functional requirements, with test cases for critical workflows—including user authentication, incident reporting, and spatial data visualization, yielding the expected outcomes and robust error handling. User sessions indicated that the interface was intuitive and the GIS visualization was particularly effective for situational awareness. These findings confirm that WGTIMS is a viable and robust platform for improving response times and analytical decision-making in traffic incident management. Future work will focus on large-scale field deployment, cloud integration, and incorporating AI models for predictive analytics to further elevate its operational impact.

Keywords— Web-GIS, Traffic Incident Management, Road Accidents, Geographic Information System, Database Life Cycle

INTRODUCTION

Traffic accidents remain a critical global issue, causing significant public safety risks and economic losses. In Malaysia, escalating vehicle ownership and insufficient monitoring infrastructure have led to high accident rates, especially during festive seasons and in urbanized states [1], [2]. Geographic Information Systems (GIS) have emerged as a powerful tool to address these challenges, enabling the mapping of spatial distributions, identification of accident hotspots, and analysis of temporal patterns [3],[4].

Recent research combines GIS with data mining and machine learning to improve incident prediction and detection. For instance, ElSahly & Abdelfatah (2024) developed a machine-learning-based Automatic Incident Detection (AID) system with a 95.6% detection rate [5]. Similarly, Alsahfi (2024) employed spatial-temporal analyses like DBSCAN and KDE to identify accident clusters in Californian cities [6]. In the Malaysian context, studies show clear seasonal accident patterns, underscoring the need for dynamic management tools [7].

Despite these advances, many existing systems lack real-time reporting capabilities and comprehensive GIS integration accessible to multiple stakeholders. This paper presents the design, implementation, and evaluation of the Web-GIS Traffic Incident Management System (WGTIMS), a unified platform that consolidates incident reporting, spatial visualization, and database management for police, administrators, and drivers. By building on

proven methodologies and modern technologies, WGTIMS aims to enhance decision-making and accelerate emergency response.

Background

Traffic management in Malaysia has increasingly adopted digital and geospatial technologies to improve congestion control, safety, and incident response. One notable initiative is the Smart Traffic Analytics and Recognition System (STARS), developed by TM One. The system uses real-time data from cameras and sensors to optimise traffic signal timings, reportedly reducing waiting time at intersections by up to 65%. Its enhanced version, STARS 2.0, integrates predictive analytics by considering external factors such as weather, public events, and holiday travel patterns [8].

Beyond signal optimisation, recent efforts have focused on real-time traffic intelligence through artificial intelligence (AI) platforms. For instance, CelcomDigi, in collaboration with MyDigital, Digital Nasional Berhad (DNB), and Majlis Bandaraya Petaling Jaya (MBPJ), launched Malaysia's first AI-driven traffic management platform. This system leverages AI and 5G to generate real-time traffic insights, aiming to improve congestion management, accident response, and road safety monitoring [9]. Similarly, the Malaysian Highway Authority is piloting the Automatic Road Incident Detection System (ARIDS), which seeks to detect accidents on expressways and federal routes in real time, thereby reducing emergency response delays [10].

Parallel to these national initiatives, research worldwide has demonstrated the effectiveness of combining GIS with predictive modelling techniques. Ulu, Kilic, and Türkan (2024) developed a geohash-based model integrated with machine learning algorithms to improve spatial accuracy in predicting traffic incident locations [11]. Likewise, Chen (2024) showed that integrating AI with GIS for real-time accident prediction in high-risk urban areas can achieve prediction accuracy of around 85% while reducing emergency response times by 20% [12].

These technological advances underscore a growing trend towards integrating GIS, AI, and real-time analytics for traffic incident management. However, most implementations remain either pilot projects or limited to large urban centres. A significant gap exists in providing a unified, Web-GIS based solution that can deliver real-time reporting, spatial visualization, and data analytics accessible to multiple stakeholders such as police, drivers, and administrators. Addressing this gap motivates the development of the proposed Web-GIS Traffic Incident Management System.

Related Works

GIS and spatial analysis have been widely adopted in traffic safety and accident management research. In Nigeria, Geospatial Probability Mapping of Road Incidents used GIS to compute the likelihood of road traffic accidents based on historical data, helping to prioritize road safety awareness and planning [13].

A study from China introduced a geo-parsing approach to extract geographic information from textual news articles about traffic crash incidents, enabling mapping and spatial analysis of incidents beyond official databases [14]. In Saudi Arabia, A GIS Approach for Analysis of Traffic Accident Hotspots studied road crash distributions in Abha and Bisha, employing hotspot techniques to show strong correlations between accident frequency and road type, offering insight into spatial clustering of incidents [15]

Web-based systems for managing accident data in GIS environments are also emerging. A Development of Web Based Road Accident Data Management System in GIS Environment case study described how a GIS-integrated web platform was built using MapInfo and web technologies to manage and visualize accident data [16]. Another project, the Online Road Traffic Accident Monitoring System (RTAMS) in Nigeria, developed a web interface that allows stakeholders (e.g. road safety officers, policy makers) to submit, query, and visualize accident reports via PHP/MySQL, thus replacing paper-based systems [17].

These works demonstrate capabilities in spatial analysis, data extraction, and web deployment for traffic incident systems. However, gaps remain in integrating real-time reporting, multi-user interfaces (drivers, police, admin), and combining these functionalities into an operational Web-GIS traffic incident management system.

Table 1 Comparison Between Existed and Proposed System

Ref	Method / Tool Used	Key Findings	Identified Gaps
[13]	GIS-based probability mapping, spatial modelling	Identified high-risk roads and prioritized safety awareness campaigns	Focused on risk mapping only, no web-based system or multi-user interface
[14]	Geo-parsing of text data, GIS visualization	Extracted geographic information from news reports, expanding accident datasets	Limited to secondary data (news articles); lacks real-time reporting
[15]	GIS hotspot analysis (KDE, clustering)	Identified blackspots in Abha and Bisha; linked accident risk to road types	Purely spatial analysis; no integration with web systems or user roles
[16]	MapInfo, GIS, Web-based system	Demonstrated ability to manage accident records online with visualization	Prototype-level; lacks real-time updates and multi-role accessibility
[17]	Web-based accident monitoring (PHP/MySQL)	Allowed submission, querying, and visualization of accident data online	Limited scalability, no GIS integration, no predictive analytics

METHODOLOGY

The development of the Web-GIS Traffic Incident Management System (WGTIMS) followed a structured methodology adapted from four main phases: Planning, System Design, Development, and Evaluation, ensuring a systematic and iterative approach.

Planning

The planning phase was the foundation of the Web-GIS Traffic Incident Management System (WGTIMS) development. It involved identifying the scope of the project, defining objectives, and gathering requirements from relevant stakeholders. At this stage, traffic accident statistics and trends in Malaysia were reviewed to highlight the urgent need for an integrated system capable of supporting real-time reporting and visualization. Stakeholders, including police officers, system administrators, and drivers, were consulted to ensure that the system addressed practical needs in traffic incident management.

The functional requirements identified during this phase included modules for user registration and authentication, incident reporting, accident visualization on interactive maps, and report generation for administrative decision-making. Non-functional requirements such as usability, reliability, and scalability were also outlined to ensure the system could operate efficiently in real-world conditions. Specific performance metrics were defined, including system response time for database queries and map loading, and data refresh rates for near-real-time updates.

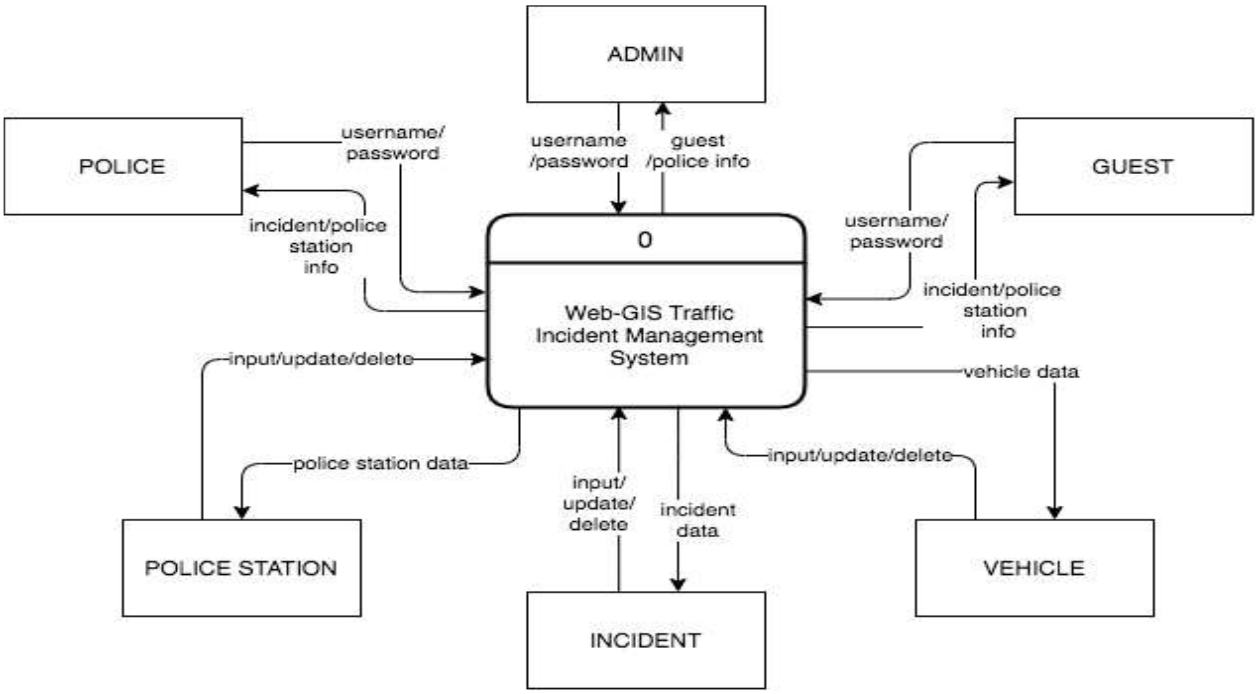
In addition, this phase established the project's constraints and assumptions, including the reliance on open-source tools (PHP, MySQL, Leaflet.js), the use of a local hosting environment for initial deployment, and the availability

of internet access for end-users. The planning phase concluded with the formulation of a project roadmap, serving as a guideline for subsequent phases of design, development, and evaluation.

System Design

The system design phase focused on translating the functional requirements identified during planning into a structured architecture for the Web-GIS Traffic Incident Management System (WGTIMS). The design emphasizes modularity, role-based access, and centralized management of data related to incidents, vehicles, users, and police stations.

Fig 1. Dfd Level 0 Wgtims



As shown in Fig. 1, WGTIMS operates as the central platform that integrates multiple modules and user roles. Administrators manage system configurations, user credentials, and overall data integrity. Police officers interact with the system to input, update, or delete traffic incident records and associated police station information. Guests are provided with limited access, allowing them to view general traffic incident data without modification privileges. Vehicles and police stations are managed as separate modules, providing structured data that can be linked to individual incidents.

Each module communicates directly with the central system. For example, the Incident Module accepts inputs such as accident details, location, and related vehicle or police data. Similarly, the Vehicle Module stores vehicle information associated with reported incidents, while the Police Station Module manages station-specific data. Input, update, and delete operations are restricted to authorized users based on their login credentials, ensuring controlled data flow and integrity. Security measures including role-based authentication protocols were incorporated into the design to ensure data privacy and system security.

To enhance usability and visualization, the system incorporates a GIS mapping component that spatially represents reported incidents. This enables stakeholders to monitor accident locations in real time and supports decision-making in traffic management. By integrating role-based access with GIS functionality, the design ensures that data collection, storage, and visualization are streamlined within a single platform.

Development

The development WGTIMS was carried out using open-source technologies to ensure efficiency and scalability. The system was implemented in PHP with MySQL as the database, managed through phpMyAdmin, and hosted locally using XAMPP.

The back-end logic handled operations such as incident reporting, vehicle registration, and police station management, while the front-end used HTML, CSS, and JavaScript to provide an intuitive interface. An interactive GIS component was integrated using Leaflet.js to display accident locations and police stations on real-time maps. Additional SQL features, including indexes and triggers, were applied to automate data operations and maintain consistency. Database optimization techniques were implemented to ensure acceptable response times for data queries and map rendering.

Security measures were implemented during development, including role-based authentication to control data access and protect sensitive information. The system architecture was designed to support future enhancements such as data encryption and secure API integrations.

This phase successfully transformed the system design into a functional Web-GIS platform capable of supporting traffic incident reporting, visualization, and decision-making for multiple user roles.

Evaluation

The evaluation of WGTIMS was conducted through a comprehensive approach combining technical verification and user feedback. Black-box testing was employed to validate whether system functionalities met their requirements by examining inputs and outputs without reference to internal code structure. Each module was tested by providing different types of input through the interface and observing the system's response.

The results showed that valid inputs produced the expected outcomes, such as successful logins, incident reporting, and data visualization on maps. Invalid or incomplete inputs triggered error messages and prevented data submission, confirming the system's ability to enforce data integrity. System performance was evaluated through response time measurements for critical operations including database queries and map loading, which demonstrated acceptable performance levels for initial deployment.

Table 2 Black-Box Testing Results For Proposed System

Test Case	Test Case Description	Input	Expected Output	Actual Output	Result
TC01	User login with valid credentials	Correct username & password	Access to dashboard	Access granted	Pass
TC02	User login with invalid credentials	Wrong username/ password	Error message, deny access	Error displayed	Pass
TC03	Submit complete incident form	All fields correctly filled	Incident saved & displayed on map	Incident saved & mapped	Pass
TC04	Submit incomplete form	Missing required fields	Error message, form not submitted	Error displayed	Pass
TC05	Add new vehicle record	Valid vehicle data	Vehicle record stored in database	Record stored	Pass
TC06	Display incident on map	Stored incident coordinates	Pinpoint incident on interactive map	Incident shown on map	Pass
TC07	Generate summary report	Query request	System displays accurate report	Report generated	Pass

In addition to technical testing, preliminary user feedback was gathered from potential stakeholders including police officers and system administrators. Feedback indicated that the interface was intuitive and easy to navigate, with particular appreciation for the spatial visualization capabilities. Users reported that the system showed potential for improving situational awareness and incident response coordination.

The evaluation confirmed that the system satisfied its functional requirements while identifying areas for future enhancement, such as implementing data encryption for sensitive information and incorporating automated backup features to improve system robustness.

RESULT

The WGTIMS was successfully implemented as a functional web-based platform with comprehensive role-based access. The system's performance was validated through rigorous testing, and its interface was refined based on preliminary user feedback to ensure usability and effectiveness for all stakeholder groups.

System Implementation and Performance

The WGTIMS platform was deployed on a local server using XAMPP, with PHP handling server-side operations and MySQL managing the database. The front-end interface, developed with HTML, CSS, and JavaScript, provided an intuitive and responsive experience across different user roles. The integration of Leaflet.js enabled dynamic spatial visualization of accident data and police stations, enhancing situational awareness for users.

Black-box testing results demonstrated that all critical functional requirements were met. Key performance metrics, including system response times for database queries and map rendering, were measured and found to be within acceptable limits for initial deployment. The database optimization techniques, such as indexing, contributed to efficient data retrieval and management. Security protocols, including role-based authentication, were successfully implemented to ensure controlled access to sensitive information.

Role-Based Modules and Features

Guest Module

The guest module provided public users with limited access to essential features. The Home Page (Fig. 2) featured an interactive map displaying accident locations, allowing guests to visualize spatial distributions of incidents. The Incident List Page (Fig. 3) enabled users to browse reported traffic accidents with basic details, while the Police Station List Page (Fig. 4) provided information on enforcement stations, including locations and contact details.

Fig 1 Home Page

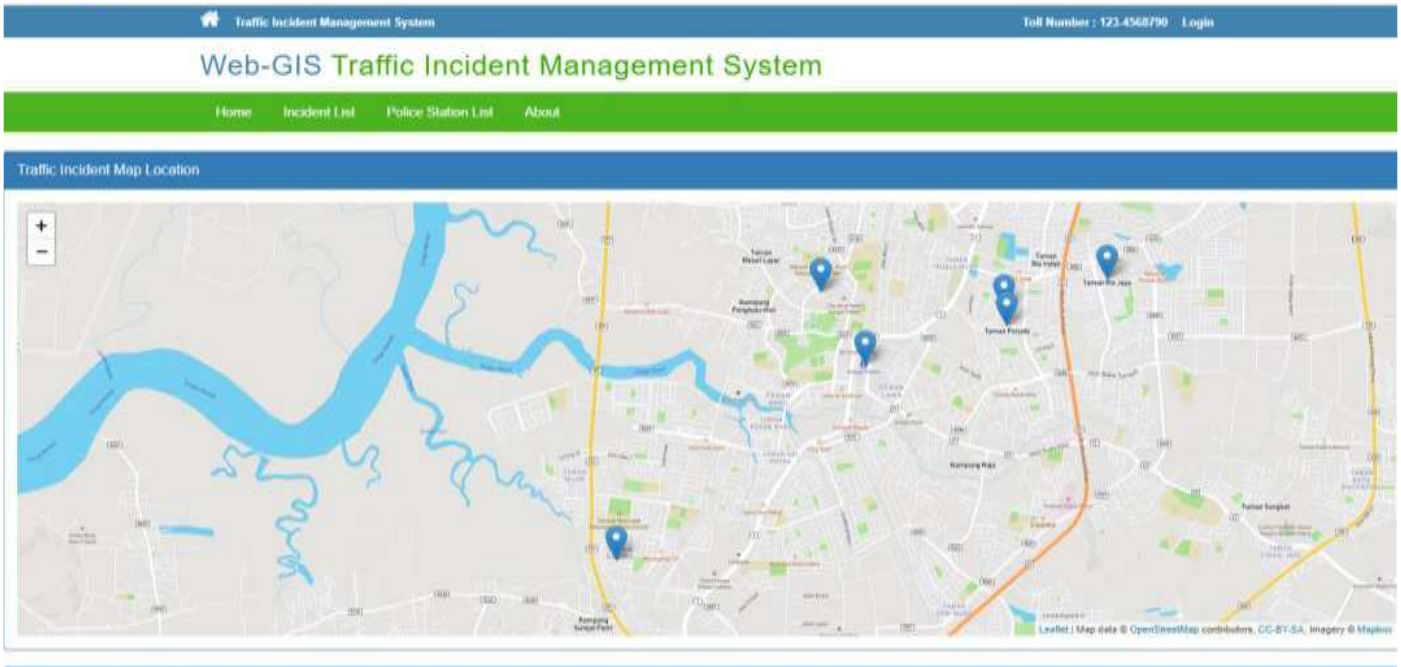


Fig 2 Incident List Page

Fig 3 Police Station List Page

Administrator Module

Administrators were granted comprehensive system management capabilities. The Manage Incident Data Page (Fig. 5) allowed full CRUD (Create, Read, Update, Delete) operations on accident records. Vehicle records were managed through the Manage Vehicle Page (Fig. 6), while police station and administrator accounts were handled via the Manage Police Station Page (Fig. 7) and Manage Admin Page (Fig. 8) respectively. Spatial management of accidents was facilitated through the Manage Incident Map Page (Fig. 9), and user management was handled through dedicated pages for guest and police data (Fig. 10 and Fig. 11). The Admin Report Page (Fig. 12) enabled generation of statistical summaries for decision-making purposes.

Fig 1 Manage Incident Data Page

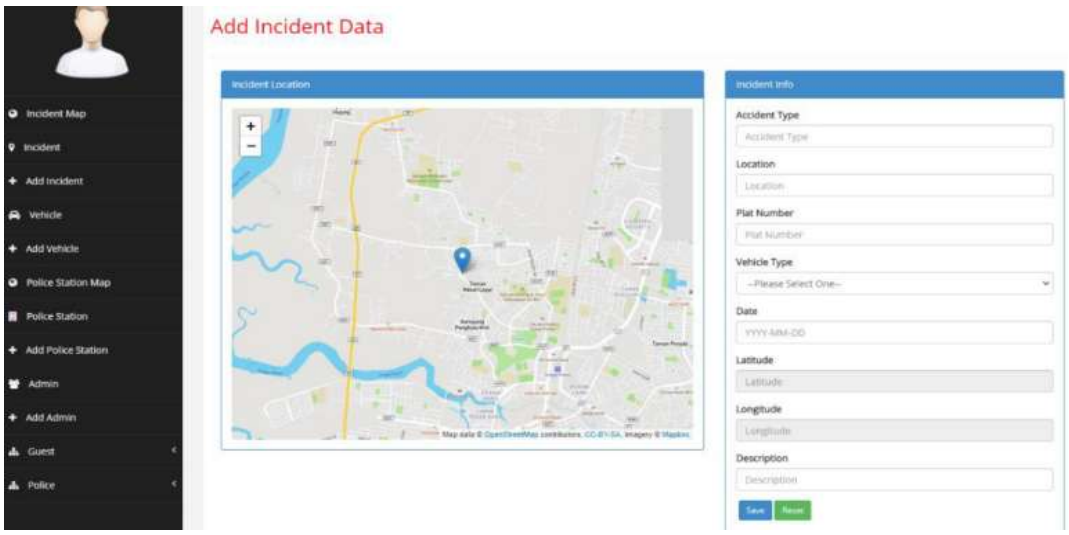


Fig 2 Manage Vehicle Page

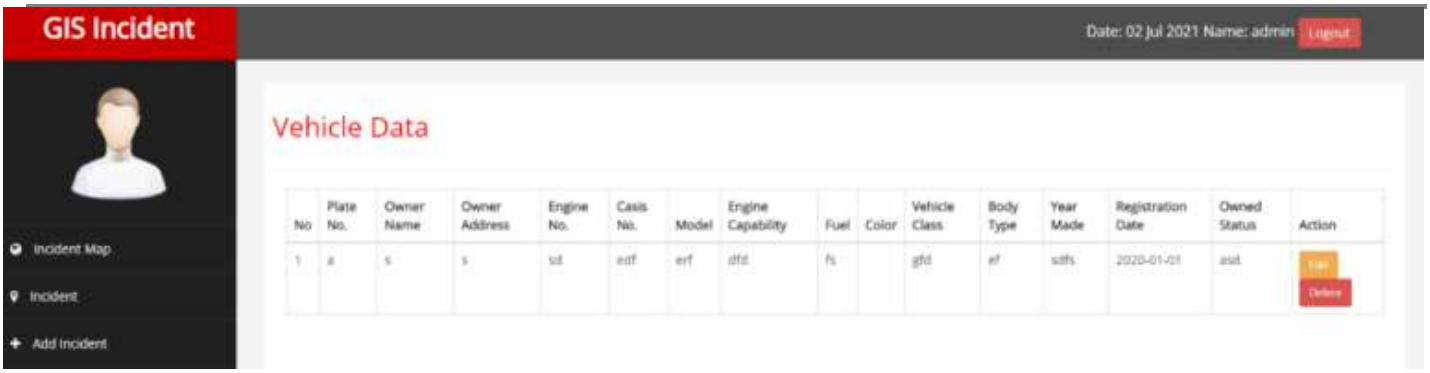


Fig 3 Manage Police Station Page

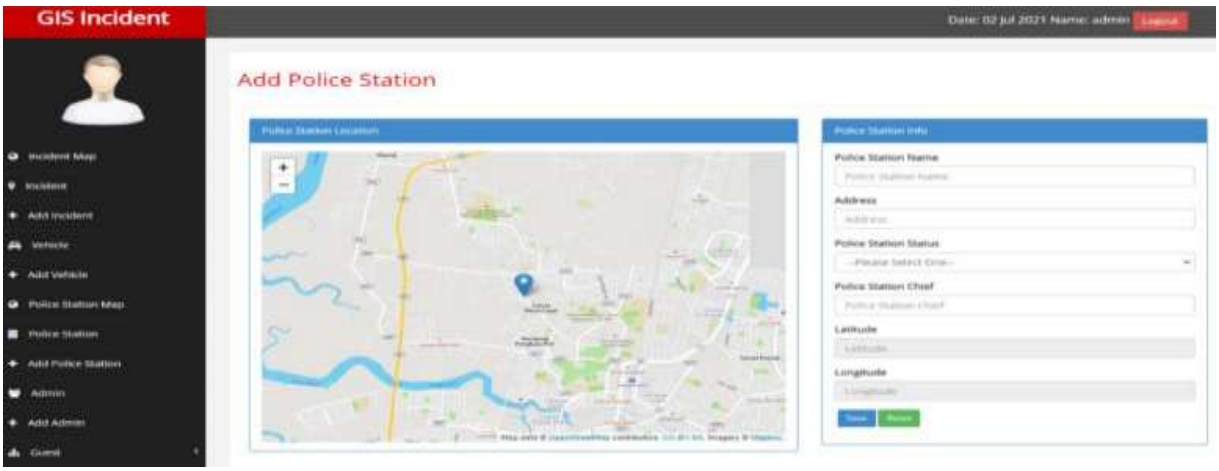


Fig 4 Manage Admin Page

Fig 5 Manage Incident Map Page

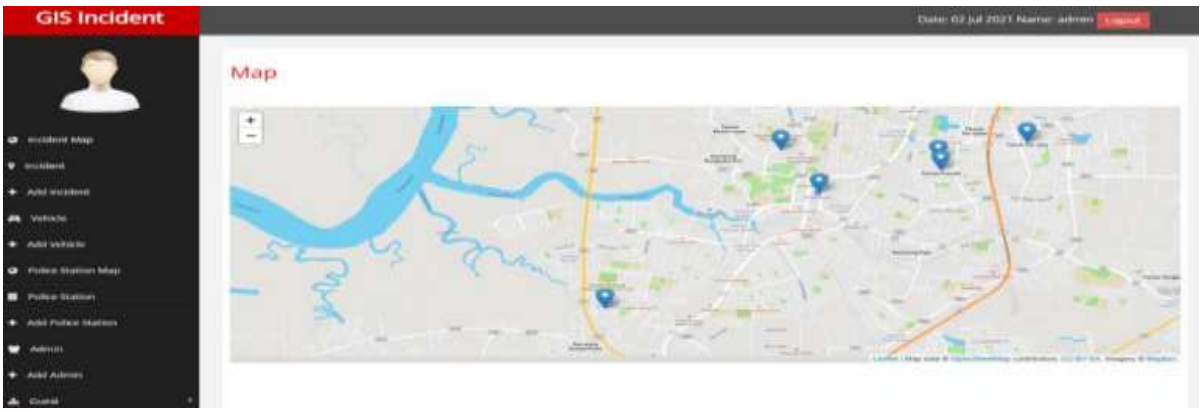


Fig 6 Manage Guest Data Page

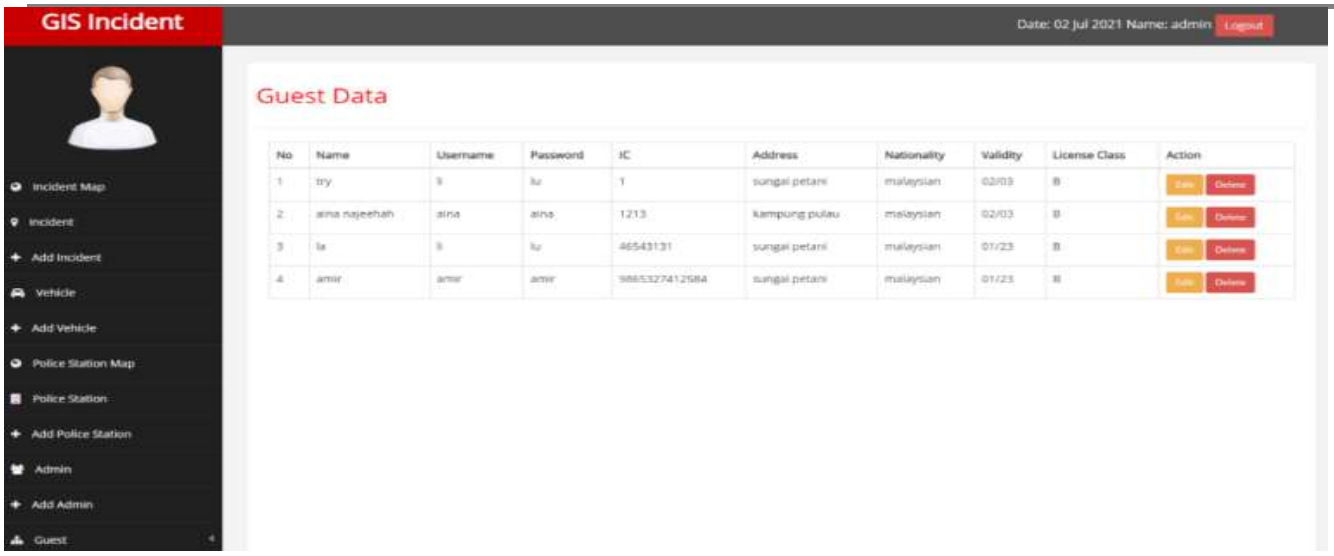
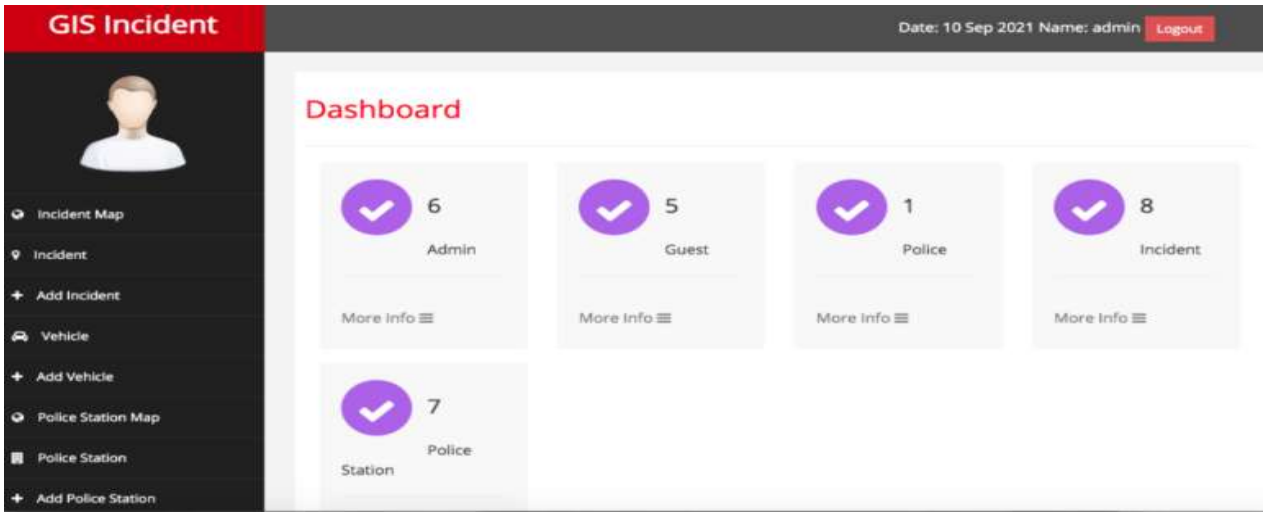


Fig 7 Manage Police Data Page

Fig 8 Admin Report Page



Police Officer Module

The police officer module supported law enforcement activities with tailored functionalities. After authentication, officers could add and update traffic accident data using the Manage Incident Map Page (Fig. 9) and manage station-specific details through the Manage Police Station Page (Fig. 7). The Police Station Map Page (Fig. 13) provided spatial visualization of enforcement stations, while the Police Officer Data Page (Fig. 14) maintained accurate records of officer assignments and responsibilities.

Fig 1 Police Station Map Page

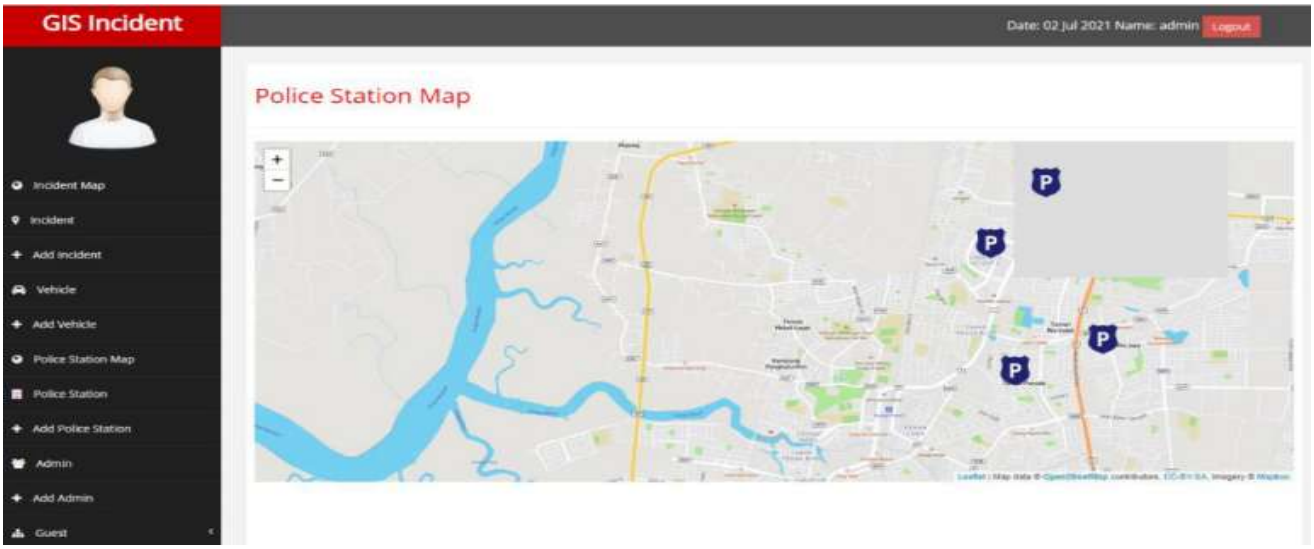
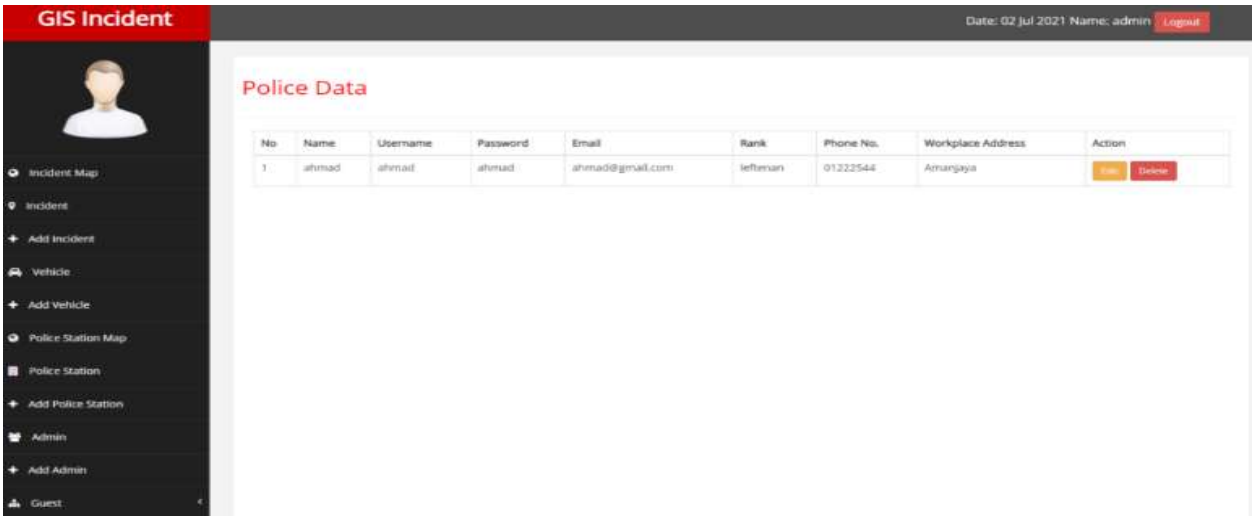


Fig 2 Police Officer Data Page



User Feedback and System Validation

Preliminary user testing with representative stakeholders, including traffic police officers and system administrators, yielded positive feedback regarding the system's usability and functionality. Participants reported that the interface was intuitive to navigate and that the spatial visualization capabilities significantly enhanced their understanding of accident patterns. The role-based access system was found to be effective in maintaining data security while providing appropriate functionality for different user types.

The system successfully demonstrated its capability to handle multiple simultaneous users and manage large datasets of incident information. The integration of GIS functionality with traditional database management proved particularly valuable for spatial analysis and decision-making processes. All test cases for critical workflows, including data entry, retrieval, and visualization, were executed successfully, confirming the system's reliability and readiness for operational deployment.

CONCLUSION

This study developed the Web-GIS Traffic Incident Management System (WGTIMS) to improve the reporting, management, and visualization of road accidents. By integrating web technologies with GIS, the system supports real-time incident reporting, structured data storage, and spatial analysis. Administrators manage incidents, vehicles, and users; police officers record and update cases, while guests can view accident and station data.

Black-box testing confirmed that all modules performed as expected, with accurate outputs for valid inputs and proper handling of invalid data. The system proved to be functional, user-friendly, and effective in enhancing decision-making for traffic management.

In future work, the system could be expanded with cloud deployment, mobile applications, and AI-based analytics to provide broader accessibility and predictive capabilities.

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