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Spatial Crime Pattern Visualization and Monitoring System for Jolo, Sulu

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ABSTRACT

This study aimed to design and develop a Spatial Crime Pattern Visualization and Monitoring System for Jolo, Sulu, to improve crime record management, geographical visualization, and public safety monitoring. Guided by the Input-Process-Output framework, the study employed the Agile Software Development Life Cycle. Data were gathered through interviews, surveys, observations, and document reviews involving local authorities, law enforcement personnel, and community members in Jolo, Sulu. Crime records were analyzed descriptively according to location, category, and reporting period, while functional testing and user acceptance evaluation assessed system performance. The developed web-based system integrated centralized crime records, role-based access, interactive mapping, monitoring dashboards, search and filtering, and report generation. All ten evaluated system functions passed functional testing, demonstrating compliance with specified requirements. User acceptance findings indicated generally favorable perceptions, particularly regarding the clarity of geographical crime visualization. The study concluded that the system provides a functional platform for organizing crime information, examining spatial distributions, and supporting informed public safety decisions. Pilot implementation, strengthened data security, regular maintenance, and further operational evaluation are recommended. The study was limited to prototype development and testing within selected areas of Jolo, with effectiveness dependent on accurate and complete incident records. Its principal contribution is an integrated geographical crime monitoring platform that supports institutional information management, evidence-informed law enforcement planning, and community safety initiatives.

Keywords: *Crime Mapping, Crime Monitoring, Geographic Information Systems, Jolo Sulu, Public Safety, Spatial Crime Patterns, Web-Based System*

1. INTRODUCTION

Advancements in information and communication technology (ICT) have improved the collection, management, analysis, and visualization of information, particularly in law enforcement and public safety. Geographic Information Systems (GIS) enable authorities to examine the geographical distribution of crime incidents, identify areas with concentrated criminal activity, and support evidence-based crime prevention. Chainey and Ratcliffe (2005) explained that GIS-based crime mapping facilitates spatial analysis and informed decision-making, while Eck et al. (2005) emphasized its importance in identifying crime hotspots and prioritizing preventive measures. In Jolo, Sulu, conventional crime reporting practices and fragmented records present challenges in monitoring incidents, identifying spatial patterns, and accessing organized crime information. These limitations highlight the need for a centralized digital platform that integrates crime record management, geographical visualization, and monitoring capabilities. The study, entitled Spatial Crime Pattern Visualization and Monitoring System for Jolo, Sulu, focuses on developing a web-based application that enables authorized users to record crime incidents, visualize their locations through interactive maps, monitor geographical patterns, and generate reports. By integrating GIS technology, database management, and visualization dashboards, the system seeks to improve crime information accessibility and support law enforcement decision-making, crime prevention, and community safety.

Research Problem

Crime monitoring and analysis are essential to effective law enforcement and public safety planning. However, traditional recording practices, including manual reports and scattered digital files, can limit the efficient retrieval, organization, and geographical interpretation of crime information. In Jolo, Sulu, informal observations and discussions with local authorities and community members identified challenges involving the absence of centralized monitoring tools, limited crime location visualization, and difficulty recognizing recurring geographical patterns. Research demonstrates that crime incidents are not uniformly distributed across geographical areas. Brantingham and Brantingham (1993) emphasized the influence of environmental characteristics, activity nodes, travel paths, and geographical boundaries on crime patterns. Similarly, Anselin (1995) introduced Local Indicators of Spatial Association (LISA) for examining local spatial clustering and outliers, while Weisburd (2015) highlighted the importance of geographical concentration in place-based crime analysis. The identification of crime-prone areas is important for targeted monitoring and prevention. Chainey et al. (2008) demonstrated the usefulness of hotspot mapping in examining spatial crime concentrations, although predictive performance differs across techniques. Turchan and Braga (2024) further indicated that geographically focused policing strategies can contribute to reducing crime in targeted locations. Moreover, Clarke and Eck (2005) emphasized systematic problem identification, analysis, response development, and assessment in addressing recurring crime concerns. Despite these developments, the identified local monitoring challenges demonstrate the need for an accessible system that consolidates crime records and presents geographical information in an understandable format. The central research problem is therefore the lack of an integrated digital platform for recording, visualizing, and monitoring spatial crime patterns in Jolo, Sulu. The proposed system addresses this gap through centralized data management, interactive crime mapping, monitoring dashboards, and report generation to support informed public safety decisions. Routine activity theory also explains crime occurrence through the convergence of motivated offenders, suitable targets, and the absence of capable guardianship (Cohen & Felson, 1979). The Global Study on Homicide 2023 provides a broader international context for the importance of systematic crime information in public safety analysis (United Nations Office on Drugs and Crime, 2023). Reviews of remote sensing in urban crime analysis further illustrate the range of geographical data sources considered in contemporary crime

research, although remote sensing was not implemented in the present system (Ceccato & Ioannidis, 2025).

Assumptions of the Study

The study is guided by the assumption that centralized digital crime records and geographical visualization can improve the organization, accessibility, and interpretation of reported incidents. It assumes that available crime information, including incident locations, dates, categories, and geographical coordinates, can be systematically processed to reveal spatial distributions and identify areas requiring closer monitoring. The study further assumes that interactive mapping and organized dashboards can help authorized personnel interpret crime information more efficiently. Nielsen (1994) emphasized the importance of understandable, consistent, and efficient user interfaces, while the International Organization for Standardization and International Electrotechnical Commission (ISO/IEC, 2023) established software quality characteristics related to functionality, reliability, security, and interaction capability. The effectiveness of the system also depends on the accuracy and completeness of submitted crime records, as well as the proper implementation of user authentication and access controls. The system's geographical coverage is limited to selected barangays within Jolo, Sulu, and its primary purpose is to visualize recorded crime incidents rather than predict future criminal activities or replace official law enforcement procedures.

Objectives of the Study

The general objective of the study is to design and develop a Spatial Crime Pattern Visualization and Monitoring System for Jolo, Sulu that addresses challenges in crime data management and geographical analysis, enabling authorities to identify crime locations, observe spatial patterns, and support public safety decision-making. Specifically, the study aims to develop a centralized digital database for recording, storing, organizing, and retrieving crime incident information; create an interactive spatial visualization feature that displays recorded crime locations and enables users to recognize geographical concentrations of incidents; and design a monitoring dashboard that allows authorized personnel to examine crime patterns, access incident summaries, and generate reports to support law enforcement decision-making. Furthermore, the system incorporates administrator and authorized user accounts with differentiated permissions to ensure controlled access to crime record management, reporting, and monitoring functions.

Conceptual and Theoretical Framework

The study is grounded in Geographic Information Systems (GIS), spatial crime analysis, data-driven decision-making, and the Input-Process-Output (IPO) Model. These concepts provide the foundation for developing a centralized system that transforms recorded crime information into geographical representations and monitoring outputs. GIS-based crime mapping supports the identification and interpretation of crime distributions. Chainey and Ratcliffe (2005) and Eck et al. (2005) established the relevance of geographical visualization in examining crime concentrations and supporting preventive strategies. Spatial crime analysis is further supported by Brantingham and Brantingham (1993), Anselin (1995), and Weisburd (2015), whose studies emphasize environmental influences, spatial clustering, and place-based patterns of criminal activity. These concepts support the system's use of incident locations, categories, and dates to visualize geographical distributions without performing advanced statistical hotspot analysis. The system's development also incorporates principles of software engineering, usability, security, and quality evaluation. ISO/IEC (2023) emphasized structured development, reliable architecture, and effective information management, while Nielsen (1994) highlighted usability in interactive applications. The National Institute of Standards and Technology (2024) provided guidance on information security and access controls. Republic Act No. 10173, also known as

the Data Privacy Act of 2012 (Republic of the Philippines, 2012), provides the legal framework for protecting personal information. Additionally, the International Organization for Standardization and International Electrotechnical Commission (2023), through ISO/IEC 25010:2023, established software quality characteristics relevant to evaluating functionality, reliability, efficiency, security, and interaction capability. Additionally, the International Organization for Standardization and International Electrotechnical Commission (2023), through ISO/IEC 25010:2023, established software quality characteristics relevant to evaluating functionality, reliability, efficiency, security, and interaction capability. The conceptual framework follows the IPO Model. Inputs consist of crime incident information, including locations, geographical coordinates, dates, categories, descriptions, and user details. Processes involve data validation, database storage, geographical mapping, searching, filtering, visualization, and report generation. Outputs include interactive crime maps, incident summaries, monitoring dashboards, and organized crime reports. The system uses HTML, CSS, JavaScript, PHP, and an SQL-compatible database, with Leaflet.js and OpenStreetMap supporting interactive geographical visualization. Its development follows the Agile Software Development Life Cycle, emphasizing iterative design, implementation, testing, and improvement. Through this framework, the study integrates crime information management and spatial visualization into a web-based platform intended to support systematic monitoring and informed public safety decisions. The unpublished capstone research by Basri et al. (2026) documents the project's earlier conceptual foundation; it is cited here as project background rather than independent evidence of system effectiveness. Getis and Ord (1992) introduced distance-based measures of spatial association, and Esri (n.d.) documents the Getis-Ord Gi* hot spot analysis procedure. These methods provide context for possible future analytical enhancements but were not implemented in the prototype. Vilalta (2026) also discusses the interpretation of crime hotspot findings as inferential claims, underscoring the need to distinguish visual concentrations from statistically established hotspots.

Sustainable Development Goal and Multidisciplinary Sustainability Relevance

The study aligns with three Sustainable Development Goals: SDG 9 (Industry, Innovation, and Infrastructure), SDG 11 (Sustainable Cities and Communities), and SDG 16 (Peace, Justice, and Strong Institutions). These goals reflect the project's contributions to technological innovation, community safety, and institutional crime information management. SDG 9 is addressed through the development of a web-based crime monitoring system that integrates centralized data management, GIS mapping, and interactive visualization. By digitizing crime records and improving access to organized information, the project supports technological and digital sustainability in local public safety operations. SDG 11 is supported through the system's intended contribution to safer and more resilient communities. Geographical visualization of recorded crime incidents enables authorities to recognize areas requiring closer monitoring and consider appropriate preventive measures. These capabilities support community sustainability by providing information that may assist public safety planning and crime prevention initiatives in Jolo, Sulu. SDG 16 is addressed through improved crime information organization, controlled access, monitoring, and reporting. The system is designed to assist law enforcement personnel in maintaining structured records, examining incident distributions, and making informed decisions. Its emphasis on secure information management and organized reporting supports institutional and governance sustainability. Overall, the study contributes to technological, community, and institutional sustainability by providing a digital framework for crime monitoring, geographical analysis, and public safety decision-making. Its contribution remains focused on improving information management and supporting preventive planning rather than directly establishing reductions in crime. The United Nations Department of Economic and Social Affairs

(2024) provides the wider SDG reporting context for the goals to which the project seeks to contribute; this study does not claim to measure SDG-level outcomes.

2. METHODOLOGY

Research Design

The study adopted a system development approach using the Agile Software Development Life Cycle (SDLC), which emphasizes iterative development, continuous testing, and improvements based on user requirements and feedback. The process involved planning, requirements analysis, system design, development, testing, deployment, and maintenance. Planning established the project's objectives and scope, while requirements analysis identified challenges in existing crime reporting practices. System design focused on the database structure, user interfaces, architecture, and operational workflows. Development involved integrating crime management and geographical mapping features, followed by testing to verify functionality, visualization accuracy, and usability. Implementation and maintenance addressed system configuration, operational readiness, and necessary improvements.

Research Locale or Study Setting

The study was conducted in the municipality of Jolo, Sulu, Philippines, focusing on selected barangays where crime incidents could be recorded, mapped, and monitored. The setting was selected to address challenges associated with fragmented crime records, limited geographical visualization, and difficulties identifying spatial crime patterns. The developed system was designed to assist local law enforcement personnel and authorized users in organizing incident information and examining geographical distributions. Its coverage was limited to available crime records within selected areas of the municipality, without extending to full-scale implementation across government agencies.

Participants or Data Sources

The study gathered information from local authorities, law enforcement personnel, and community members to identify existing crime reporting procedures and system requirements. Data sources included interviews, surveys, observations, available crime logs, incident reports, and geographical information. Crime-related records contained details such as incident locations, barangays, geographical coordinates, dates and times, crime categories, descriptions, and reporting statuses. These sources supported requirements identification, system development, and spatial visualization. The system also distinguished between administrators responsible for managing crime records and user accounts and authorized users permitted to submit reports and access monitoring functions.

Research Instruments or Materials

The study utilized interviews, surveys, observations, and document reviews as data-gathering instruments. Software development materials included HTML, CSS, and JavaScript for interface development, PHP for server-side processing, and an SQL-compatible database for storing and retrieving crime records. Leaflet.js and OpenStreetMap provided interactive geographical mapping through location markers and recorded coordinates. The development environment included a code editor, local server environment, web browsers, computers, network connectivity, and storage facilities. The system followed a three-layer architecture consisting of presentation, application, and data components. The presentation component provided login interfaces, dashboards, reporting forms, maps, and reports. The application component managed authentication, data validation, user requests, and database communication, while the data component stored crime records, user information, categories, and geographical coordinates. The system incorporated administrator and authorized user accounts, centralized

crime management, search and filtering functions, geographical visualization, and report generation.

Data Gathering Procedure

Data gathering involved interviews, surveys, observations, and document reviews to determine the requirements of the proposed system. Interviews with local authorities, law enforcement personnel, and community members examined existing crime reporting and monitoring practices. Surveys gathered perceptions regarding the effectiveness of current procedures and the need for a digital monitoring platform. Observations focused on how crime incidents were recorded, organized, and retrieved, while document reviews examined available crime logs, incident reports, and geographical information. The collected information was used to identify challenges involving scattered records, limited spatial visualization, and difficulties monitoring crime patterns. These findings guided the specification of functional requirements, including crime recording, incident management, mapping, dashboard monitoring, searching, filtering, and reporting. Non-functional requirements included usability, reliability, security, efficiency, responsiveness, and maintainability. The identified requirements informed the system architecture, database design, user interfaces, and development procedures.

Data Analysis

Data analysis focused on organizing and interpreting crime-related information and evaluating the developed system's functionality. The system followed the Input-Process-Output (IPO) Model, wherein incident details, geographical coordinates, dates, crime categories, and user information served as inputs. Processing involved data validation, database storage, geographical mapping, searching, filtering, and report generation. The resulting outputs included interactive crime maps, incident summaries, monitoring dashboards, and organized reports. Crime records were analyzed descriptively according to geographical location, crime category, and reporting period to identify observable concentrations and distributions of recorded incidents. Leaflet.js and OpenStreetMap displayed incident locations using geographical coordinates, while the dashboard presented crime statistics and reporting information. The system emphasized spatial visualization rather than advanced statistical hotspot detection or crime prediction. System evaluation involved functional testing of login, dashboard display, crime record creation, editing, deletion, geographical mapping, visualization, search and filtering, report generation, and access control. All ten documented functions received passing results. User Acceptance Testing (UAT) was also described to assess functionality, usability, reliability, efficiency, and security, while performance testing was intended to examine responsiveness and geographical visualization accuracy. These evaluation procedures provided a basis for determining whether the developed system met its specified requirements.

Ethical Consideration

The study considered the protection of sensitive crime-related information through user authentication, authorization, and role-based access control. The system differentiated administrator and authorized user privileges to restrict access to administrative functions and modifications of sensitive records. Administrators could manage user accounts, crime information, and reports, while authorized users could submit incidents and access permitted monitoring features. Data validation and controlled database operations were incorporated to support accurate record management and reduce unauthorized modification of information. The system was designed to manage crime-related records responsibly while supporting authorized monitoring and reporting activities. Its functions were limited to recording, organizing, and visualizing available crime information and were not intended to replace official law enforcement investigations or decision-making procedures. For future security strengthening, the Digital Identity Guidelines provide relevant guidance on identity and authentication controls (National

Institute of Standards and Technology, 2025), while the OWASP Foundation (2023) identifies common API security risks. These publications inform recommended improvements and should not be interpreted as evidence that the prototype has been audited against either framework.

3. RESULTS AND DISCUSSION

3.1 System Development and Main Findings

The developed system implemented the primary functionalities identified during requirements analysis, including user authentication, crime record management, interactive geographical mapping, monitoring dashboards, search and filtering, and report generation. These components were integrated into a centralized web-based application accessible through administrator and registered user accounts.

3.1.1 System Interface and User Access

The system provides a landing page with administrator login, user login, registration, and crime reporting options. The administrator dashboard displays crime statistics, including total incidents, pending cases, investigating cases, and critical incidents, together with an interactive geographical map. Registered users have a separate dashboard for submitting crime reports, monitoring their submissions, and viewing case statuses such as pending, verified, and resolved. Access permissions distinguish administrative functions from standard user operations. These results demonstrate the system's capability to organize crime monitoring activities through role-specific interfaces. Separating administrator and user functions supports controlled access to crime information while allowing registered users to monitor their reports. The dashboard also provides a consolidated overview of recorded incidents, reducing the need to examine individual records when reviewing available crime information.

3.1.2 Crime Incident Recording and Management

The Crime Record Management Module allows authorized personnel to add, view, update, and delete crime-related information through a centralized database. Incident recording includes crime title, category, description, date and time, severity level, case status, and geographical location. The system also provides an interactive map for selecting incident locations and associating them with recorded crime information. The implementation addresses the limitations of scattered and manually maintained crime records by consolidating information within a structured digital platform. Centralized record management supports more systematic storage, retrieval, and updating of incident information. Associating records with geographical locations also establishes the foundation for spatial crime visualization and monitoring.

3.1.3 Spatial Crime Mapping and Pattern Visualization

The Spatial Crime Map Module displays recorded incidents according to their geographical locations within Jolo, Sulu. Users can interact with the map to examine incident distributions and identify locations with multiple recorded reports. The visualization component also organizes crime information according to crime type, location, and reporting period, depending on available records. These findings demonstrate how geographical visualization transforms stored crime information into a more understandable spatial representation. The mapping feature allows users to recognize possible concentrations and recurring distributions of reported incidents, supporting the identification of areas requiring closer monitoring. However, the system focuses on visualizing existing records and does not automatically establish the causes of crime or predict future criminal activity.

3.1.4 Monitoring Dashboard and Crime Information Retrieval

The monitoring dashboard presents summarized crime information, including reported incident totals, crime categories, case statuses, and geographical distributions. The search and filtering functions allow users to retrieve specific records according to available criteria, including crime category, date, and location. Functional testing confirmed that the search and filtering component successfully located the required records. These features improve the organization and accessibility of crime information by allowing users to examine relevant records without reviewing the entire database. The dashboard supports the monitoring of recorded incidents, while filtering enables more focused examination of crime information associated with particular locations, categories, or periods.

3.1.5 Crime Report Generation

The developed system generates organized crime-related reports using information stored in the database. These reports present incident information in a structured format and can be accessed for monitoring, documentation, and reference purposes. Functional testing confirmed that the report generation feature performed its intended operation. The reporting functionality provides a more systematic approach to documenting crime incidents by reducing the need to compile information manually from separate records. Organized reports also support administrative monitoring and provide accessible summaries that may assist authorized personnel in reviewing crime-related information.

3.2 System Testing and Evaluation

3.2.1 Functional Testing Results

Functional testing covered ten major system functions: user login, dashboard display, crime record addition, editing, deletion, geographical mapping, crime visualization, search and filtering, report generation, and user access control. All ten functions received passing results, indicating that the tested components performed according to their specified functional requirements. The results demonstrate that the developed application successfully implemented its primary operational features. The passing outcomes support the functional readiness of the tested modules for crime recording, management, geographical visualization, and monitoring. However, these results establish compliance with the tested requirements rather than demonstrating long-term operational performance under actual deployment conditions.

3.2.2 User Acceptance Evaluation

User Acceptance Testing (UAT) was conducted to assess the system in terms of functionality, usability, reliability, efficiency, and security. The manuscript reports that the system was generally acceptable to intended users, particularly because its spatial visualization feature presented geographical crime information more clearly than conventional record listings. The evaluation addressed interface understandability, navigation, responsiveness, dependable operation, and controlled access to information. These findings suggest that the developed system provides an accessible approach to managing and interpreting crime records. The geographical visualization feature was particularly relevant to users' understanding of incident locations and distributions. However, the manuscript does not provide a consolidated numerical acceptance score or detailed respondent-level results, limiting the extent to which user satisfaction and system quality can be quantified.

3.3 Discussion of Overall Findings

The overall findings demonstrate that the Spatial Crime Pattern Visualization and Monitoring System for Jolo, Sulu implemented its major development requirements through centralized crime record management, interactive mapping, dashboard monitoring, information retrieval, and report generation. The integration of these features provided a functional platform for recording and presenting crime information geographically. Functional testing confirmed successful operation of the ten evaluated features, while user acceptance findings indicated generally favorable perceptions of the system. The results indicate that integrating centralized information management with geographical visualization provides a practical approach to addressing challenges in conventional crime monitoring. The system's principal contribution is its ability to present recorded incidents as location-based information that can support spatial interpretation and public safety planning. Nevertheless, its effectiveness depends on the accuracy, completeness, and timeliness of submitted crime records. The application remains a supporting tool for crime monitoring and visualization rather than a replacement for professional law enforcement investigations or official decision-making procedures. Further evaluation under actual operating conditions is necessary to establish its long-term usability, reliability, security, and operational effectiveness.

4. CONCLUSIONS AND RECOMMENDATIONS

The study concluded that the Spatial Crime Pattern Visualization and Monitoring System for Jolo, Sulu provides a practical web-based solution for improving crime information management and geographical monitoring. Developed using the Agile Software Development Life Cycle (SDLC), the system integrates Geographic Information System (GIS) technology, centralized crime record management, interactive mapping, monitoring dashboards, and reporting functions. Through Leaflet.js and OpenStreetMap, the system enables authorized personnel to visualize reported crime incidents, examine spatial distributions, and identify areas requiring closer monitoring. The developed functionalities demonstrate the potential of digital technology to support organized crime reporting, informed decision-making, and public safety initiatives. However, further evaluation and real-world implementation are necessary to establish its operational effectiveness, reliability, usability, and contribution to crime prevention.

The study recommends pilot implementation of the system among authorized law enforcement personnel and relevant local government offices in Jolo, Sulu to evaluate its practical effectiveness. Future improvements should prioritize stronger authentication, role-based access control, database security, regular backups, and compliance with data privacy regulations. Additional enhancements may include advanced crime hotspot identification, incident clustering, location- and time-based analysis, real-time reporting, and automated notifications. Regular maintenance, software updates, performance optimization, user training, and comprehensive system evaluation are also recommended. Future researchers may explore predictive crime analysis, mobile application integration, and expansion to other municipalities in Sulu, subject to institutional approval, available resources, and data-sharing requirements.

The study is limited to the development and testing of a system intended for crime recording, monitoring, and geographical visualization within selected areas of Jolo, Sulu. Its effectiveness depends on the accuracy, completeness, and timeliness of submitted crime records. The system does not predict future crimes or replace official law enforcement investigations and decision-making procedures. Furthermore, full-scale deployment and operational validation were not

included in the study, indicating the need for further assessment under actual implementation conditions.

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