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I-SIMS: ENHANCING RESIDENTIAL NAVIGATION AND PROPERTY MANAGEMENT THROUGH A WEB-BASED GIS MAPPING SYSTEM

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ABSTRACT

Aim/Purpose	The purpose of this study is to design, develop, and evaluate the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS), a web-based GIS application that enhances spatial data management and navigation within residential subdivisions, while contributing to scholarly discourse on GIS applications in human–computer interaction (HCI) and urban planning.
Background	Geographic Information Systems (GIS) are widely recognized as critical tools for managing spatial data across various domains; however, residential subdivisions often lack integrated systems that combine navigation, property information, and community planning support. This study addresses that gap by

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introducing i-SIMS as a model that bridges practical community needs with academic inquiry in GIS-based urban informatics.

Methodology A systems development approach was applied, incorporating both backend GIS integration and front-end interactive design principles. Real-time data updating mechanisms were implemented to maintain accuracy. System evaluation employed user testing with 40 residents, focusing on usability, efficiency, and information accessibility, which was analyzed through quantitative and qualitative measures.

Contribution This research advances the academic discussion on the intersection of GIS and HCI by demonstrating how interactive mapping systems can be tailored for micro-urban contexts, such as subdivisions. The study provides a framework for integrating real-time GIS functionalities into web applications, offering insights applicable to both community-based GIS design and urban planning research.

Findings User testing results indicated a mean satisfaction rating of 4.6 out of 5 and a 32% reduction in task completion time for navigation-related activities compared to existing methods. These outcomes highlight i-SIMS's effectiveness in improving usability, spatial awareness, and accessibility of property information.

Recommendations for Practitioners Urban planners, developers, and system designers should adopt GIS-based interactive platforms, such as i-SIMS, to enhance property management, resident navigation, and transparency in decision-making within residential communities.

Recommendations for Researchers Future research should investigate the integration of advanced technologies, such as machine learning, to enable predictive mapping and behavioral insights, thereby extending the applications of GIS in urban informatics.

Impact on Society i-SIMS strengthens transparency and efficiency in residential communities by providing residents and developers with improved access to accurate spatial information. This contributes to smarter navigation, more informed property-related decisions, and enhanced community engagement.

Future Research Further work could explore the use of augmented reality (AR) for immersive navigation, as well as advanced data analytics for real-time decision support in both residential and broader urban contexts.

Keywords GIS technologies, interactive mapping system, real estate development, residential subdivisions, urban planning

INTRODUCTION

The integration of Geographic Information Systems (GIS) and interactive mapping technologies has become increasingly important in modern urban planning and residential management. These technologies facilitate efficient spatial data visualization, real-time information access, and intelligent decision-making, particularly within residential subdivisions where accurate property and infrastructure data are essential (Maptionnaire, 2023; Polaris Digitech, 2023). Recent studies have further emphasized the role of web-based GIS in enhancing user interaction, accessibility, and smart community planning (Lazarides et al., 2023; Q. Zhang & Wang., 2022).

Despite these advances, many residential areas continue to rely on outdated, static mapping systems. Such systems lack interactivity and fail to meet contemporary demands for dynamic visualization and user engagement, leading to inefficiencies in navigation, property monitoring, and information dissemination (Ingle et al., 2025; Reichenbacher & Bartling, 2023). This challenge is particularly relevant to the Irenea Estate Subdivision in Brgy, Nazareth, General Tinio, Nueva Ecija, Philippines, a midsized residential community with approximately 1,000 households and a total land area of approximately 50,000 sqm. The estate represents a typical case where residents and administrators require accessible, real-time property data but are constrained by static and fragmented mapping tools.

The research problem addressed in this study is the lack of interactive and real-time GIS solutions for residential subdivisions, which hinders efficient access to property data, navigation, and information transparency. To address this gap, this study introduces the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS), a web-based GIS application designed to deliver a user-friendly, real-time, and interactive mapping platform. Beyond its technical deployment, this research aims to assess whether an interactive GIS-based solution can significantly enhance property data accessibility, navigation efficiency, and information transparency compared to traditional static systems. The system incorporates secure data access, customizable property searches, and layered geographic visualizations, making it adaptable for broader residential or community-based applications.

The study employs a systems development approach, integrating GIS backend functionality with front-end interface design. Usability testing and quantitative feedback from subdivision residents and administrators provide the empirical basis for evaluating system effectiveness. Early results indicate improvements in both task efficiency and user satisfaction, underscoring the system's value as a community-based GIS innovation.

This research contributes to the academic discourse on GIS-enabled urban informatics and human–computer interaction (HCI) by offering a case-specific implementation with real-world applicability. Specifically, it advances understanding of how real-time mapping technologies can enhance decision-making and community management at the subdivision scale. By situating i-SIMS within both practice and theory, the study provides a framework for future GIS-based system design and evaluation in similar residential and urban contexts.

LITERATURE REVIEW

The application of Geographic Information Systems (GIS) in urban and residential planning has been the subject of extensive research, particularly in addressing spatial management, land use optimization, and real-time decision-making. Studies such as the Dukuh Atas Transit-Oriented Development (TOD) project in Jakarta illustrate how GIS methodologies through land suitability analysis, environmental carrying capacity assessment, and spatial indicators like Normalized Difference Built-up Index (NDBI) and Floor Area Ration (FAR) can guide vertical residential development and population density forecasting (Irsal et al., 2023). Similarly, work in Sambhunath Municipality, Nepal, employed GIS-MCE-AHP models to identify optimal housing areas, showing that only 5% of the land was highly suitable for housing, with 38% moderately suitable near major roads and settlements (Karna et al., 2023). These macro-level studies highlight the effectiveness of GIS in shaping large-scale spatial planning and sustainable development strategies.

Parallel findings can be drawn from Rajshahi City in Bangladesh, where GIS and statistical modeling revealed the intensity of residential land development (LDR) and identified spatial drivers of urban livability. The study found that distance from the Central Business District (CBD) had only a minimal effect on LDR, offering valuable insights for planners and real estate stakeholders (Z. Zhang et al., 2022). These examples underscore GIS's flexibility: from predicting vertical growth in TOD zones to assessing housing suitability and development intensity in semi-urban contexts.

Beyond macro-scale applications, scholars have also developed interactive GIS platforms for micro-level residential management. For example, Ayson (2018) created an interactive mapping system for a community in North Carolina, USA, incorporating real-time data processing and customizable visualization tools that improved navigation efficiency and user satisfaction. Likewise, studies in China have demonstrated how web-based mapping systems with secure data management can strengthen resident engagement and property data transparency (Chen et al., 2015). These cases highlight both the potential and limitations of prior systems. While effective in localized settings, many lack scalability, seamless integration with other technologies, or advanced features such as predictive analytics.

The current study builds on this body of work by presenting the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS), which aims to integrate user-friendly navigation, secure data authentication, layered map visualizations, and real-time property data within a single adaptable platform. Unlike earlier systems that addressed only specific needs, i-SIMS is designed with scalability in mind, positioning it as a replicable model for other subdivisions and urban contexts. Furthermore, this research engages with theoretical perspectives from human–computer interaction (HCI) and participatory mapping, situating i-SIMS within broader frameworks of usability and user-centered system design (Haklay & Francis, 2017; Lindsay & Norman, 1977).

Recent literature also highlights the significance of emerging technologies in shaping the future of GIS. Mobile GIS platforms now enable wider accessibility for residents and administrators, while augmented reality (AR) and immersive visualization tools are increasingly being explored to support intuitive navigation and interactive urban experiences (Mekni & Lemieux, 2014; Yang, 2019). Integrating such innovations with residential mapping systems, such as i-SIMS, can enhance spatial awareness, improve community engagement, and open new avenues for predictive spatial analytics in subdivision-scale planning.

In summary, while prior studies have established GIS as a vital tool for both macro- and micro-level planning, limitations persist in terms of scalability, integration, and user-centered adaptability. The i-SIMS initiative addresses these gaps by combining advanced GIS technologies with principles of HCI and participatory mapping, offering a more comprehensive and forward-looking model for residential spatial management.

METHODOLOGY

This study adopts a developmental–quantitative research design, which combines the structured development of an interactive system with the empirical evaluation of its usability and performance. A developmental approach was employed in designing and implementing the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS), utilizing Geographic Information System (GIS) tools, spatial databases, and real-time mapping features. The quantitative aspect involved a structured evaluation of system usability, performance, and user satisfaction. Following research design frameworks outlined by Richey and Klein (2007), this approach is suitable for producing both a functional prototype and empirical evidence of its effectiveness in residential spatial management.

Figure 1 illustrates the overall architecture of the i-SIMS, showing how user interactions are processed into usable outputs through three interconnected layers. At the top is the Presentation Layer, where users interact with the system via interactive maps and a responsive interface developed using React.js, HTML5, CSS3, and JavaScript. This layer enables users to easily navigate, visualize, and manipulate spatial data. Beneath it, the Application Layer serves as the processing hub, handling map rendering, data processing, and system operations through Node.js and Express.js. It also manages essential backend functions such as API integration, authentication, and logging to maintain system security and efficiency. At the base, the Data Layer provides the backbone of the system, storing and managing spatial datasets through a PostgreSQL database with PostGIS extension, supported by a GeoServer for GIS data services, and incorporating cadastral and utility datasets. The three layers work together in a cycle: user requests and interactions from the presentation layer are processed in the application layer, which then queries the data layer, retrieves relevant information, and returns it as visualized results. This layered design ensures system scalability, security, and real-time responsiveness, making the platform highly functional for spatial data management and decision-making.

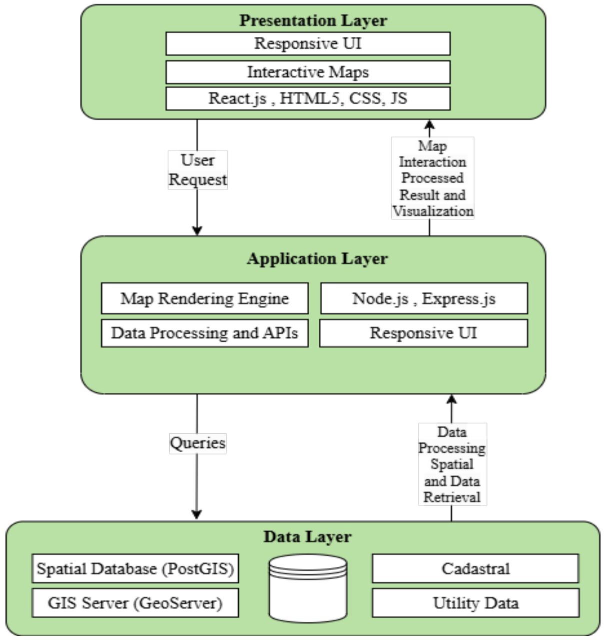

Figure 1. Weighted usability scoring flow chart

SYSTEM DEVELOPMENT AND SPATIAL DATA PROCESSING

Spatial datasets, including lot boundaries, landmarks, road networks, and property attributes, were collected from existing subdivision records and processed using ArcGIS and QGIS. All spatial data were georeferenced to the World Geodetic System 1984 (WGS 84) coordinate reference system to ensure accuracy and interoperability. Data were digitized at a resolution of 1:1000, appropriate for subdivision-level mapping, and validated against official planning documents. The system incorporated interactive map layers, property attribute queries, and user authentication features for secure access.

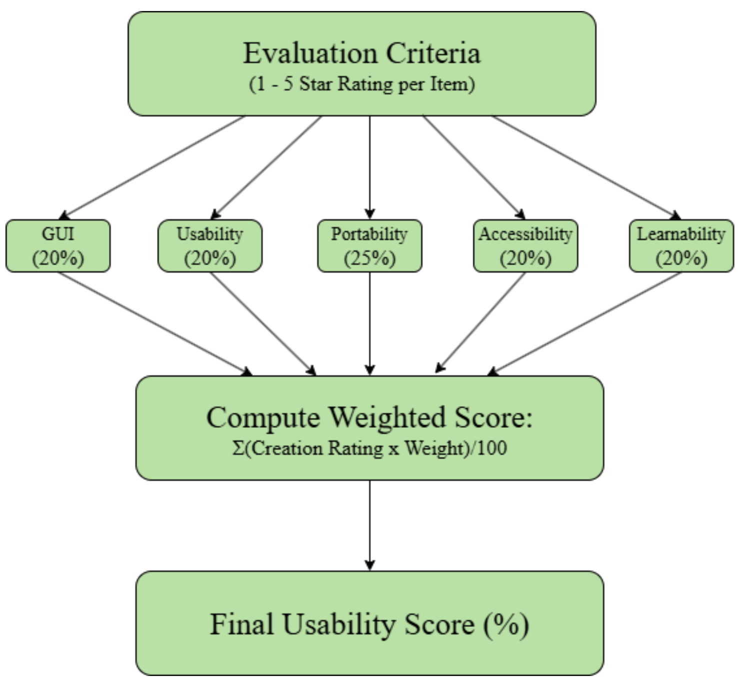

Figure 2. Weighted usability scoring flow chart

Figure 2 presents the process of computing the overall usability score for the i-SIMS. Evaluation was based on five major criteria: Graphical User Interface (GUI), Usability, Portability, Accessibility, and Learnability, each of which was rated by participants on a five-point scale.

To ensure balanced assessment, every criterion was assigned a specific weight, with Portability given the highest priority at 25%, followed by GUI and Usability at 20% each, Accessibility at 20%, and Learnability at 15%. These weights reflected the system's core design objectives, particularly its adaptability across devices and platforms. The ratings provided by the respondents were multiplied by the assigned weights, and the results were aggregated to generate a single percentage score that summarized the overall usability of the system. This scoring process not only quantified user evaluations in a structured manner but also highlighted which aspects of the system contributed most significantly to user experience.

Participants and Sampling

Respondents for system evaluation were selected through purposive sampling, as the study targeted stakeholders directly involved in the subdivision's management and planning. A total of 20 participants were recruited, including developers, planners, and subdivision administrators. Inclusion criteria required participants to have at least one year of experience in real estate planning or management. Demographic characteristics (e.g., age, professional role, and level of GIS familiarity) were recorded. To protect confidentiality, all data were anonymized, and participants provided informed consent prior to testing.

Evaluation Instruments and Metrics

System usability was assessed using the System Usability Scale (SUS), a standardized 10-item instrument widely applied in usability research (Brooke, 1996). In addition, a structured survey with Likert-scale items was administered to measure user satisfaction with navigation, data accuracy, and interface design. Semi-structured interviews were also conducted to collect qualitative feedback on strengths and areas for improvement.

Performance testing focused on response time, data retrieval accuracy, and system stability. Benchmarks were established based on prior WebGIS performance studies (Unrau et al., 2022), with thresholds set at <3 seconds for average response time and >95% accuracy in property data retrieval. These performance indicators (KPIs) were systematically measured during user testing.

Figure 3 shows a systematic usability evaluation process, combining empirical task performance with user perception to produce robust and reliable results. It ensures that both quantitative and qualitative insights were considered. The figure illustrates the step-by-step process of gathering user evaluation data:

1. *Participants Selection:* Subdivision stakeholders such as developers, planners, managers, and residents were identified. This ensures that the system was tested by both technical and non-technical users, giving a balanced usability assessment.
2. *Usability Testing:* Participants performed real tasks, and their performance was measured in terms of task completion, accuracy, and response time, which are standard usability metrics.
3. Survey & SUS Questionnaire: After testing, participants answered a System Usability Scale (SUS) using a 5-point Likert scale and provided open-ended feedback. This captured both quantitative scores and qualitative perceptions.
4. *Weighted Rubric Evaluation:* Usability was further assessed using five weighted criteria: GUI (20%), Usability (20%), Portability (25%), Accessibility (20%), and Learnability (15%). This multi-criteria rubric ensured comprehensive evaluation.
5. *Statistical Analysis and Qualitative Feedback:* Responses were analyzed through mean, standard

deviation, variance, and SUS scores (quantitative), while open-ended responses highlighted expectations, advantages, and disadvantages (qualitative).

6. *Integration into Findings:* The results were synthesized to draw conclusions about system usability, performance, and user perception, forming the basis of the study's findings.

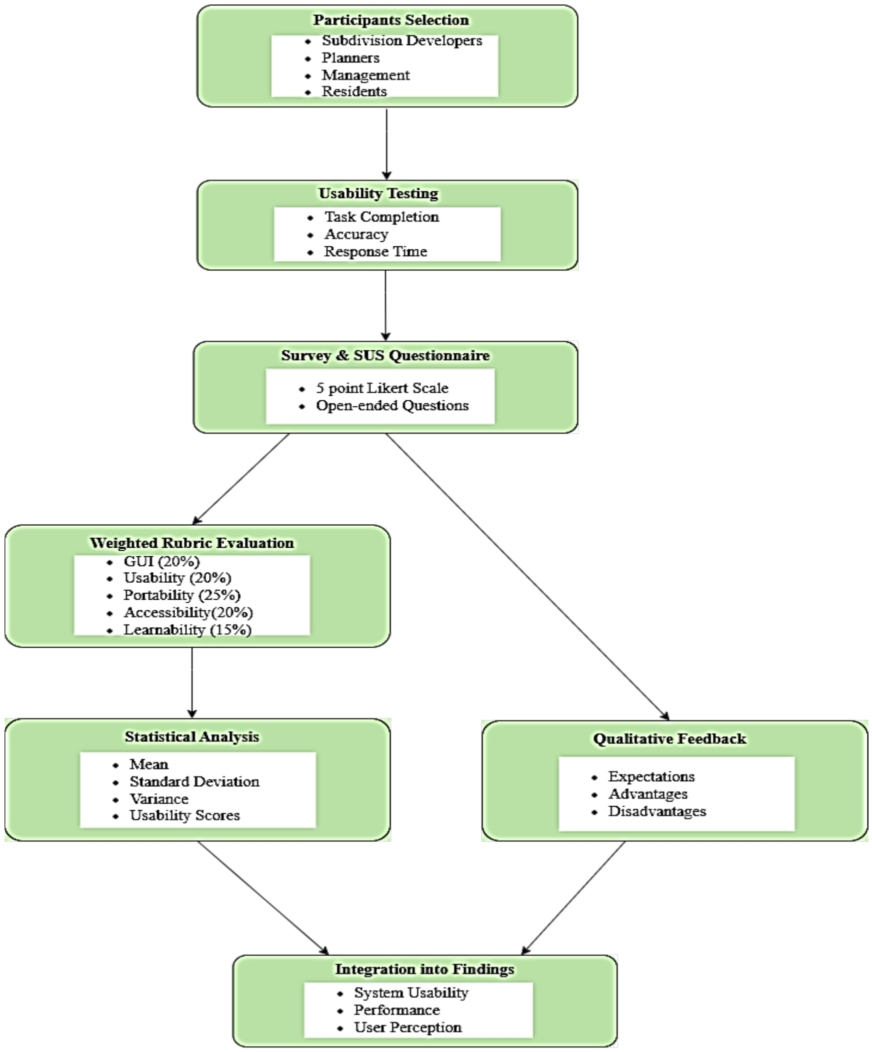

Figure 3. Usability evaluation and data collection flow

DATA ANALYSIS

Quantitative data from surveys and SUS scores were analyzed using descriptive statistics (mean, standard deviation, and variance) in SPSS to evaluate overall usability and satisfaction levels. Performance metrics were compared against predefined benchmarks. Qualitative interview data were analyzed through thematic coding to identify recurring insights and user concerns.

LIMITATIONS AND SUPPLEMENTARY MATERIALS

This study focused on a single residential subdivision, which may limit the generalizability of findings to other contexts. Moreover, the accuracy of geospatial data was contingent on the completeness and reliability of subdivision records. To promote transparency and replicability, the survey instruments, SUS questionnaire, and interview protocols used in the evaluation are included in the Appendix as supplementary material.

RESULTS

SYSTEM ARCHITECTURE AND TECHNOLOGY DETAILS

The evaluation framework for i-SIMS was divided into three main categories: usability (measured through task completion rate, average task completion time, error rate, and user satisfaction score), performance (measured through response times, peak load handling, and data processing times), and system effectiveness (measured through mapping accuracy, data accuracy, and decision-support relevance). This framework guided the analysis of results and enabled a structured interpretation of the system's capabilities.

DETAILED ARCHITECTURE

The Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS) is designed with a multi-tier architecture to ensure scalability, performance, and maintainability. The system comprises three main layers: the Presentation Layer, the Application Layer, and the Data Layer, as shown in Table 1.

Table 1. System architecture of i-SIMS

Layer	Components	Technologies used
Presentation Layer	• Interactive Maps • Responsive Design • User-Friendly Interface	HTML5, CSS3, JavaScript React.js framework for building the user interface
Application Layer	• Map Rendering Engine • Data Processing Module • Authentication and Authorization • API Gateway • Error Handling and Logging	Node.js for runtime environment Express.js framework for building the application logic
Data Layer	• Spatial Database Management • GIS Server	PostgreSQL with PostGIS extension for storing and querying geographic data GeoServer for managing and serving geospatial data

The data in Table 1 present the system architecture of the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS), which is designed using a three-tier model consisting of the Presentation Layer, Application Layer, and Data Layer. This modular architecture promotes scalability, maintainability, and efficient separation of concerns, which are fundamental principles in modern software engineering and web-based GIS development. This reflects Goodchild's (2010) observation that the advancement of GIScience increasingly relies on modular, scalable, and interoperable system architectures that support complex spatial data processing and user interaction.

The Presentation Layer is responsible for rendering the user interface and managing user interactions. Built using HTML5, CSS3, and JavaScript, the interface leverages the React.js framework to provide a dynamic and responsive user experience. React's component-based architecture allows for the reuse of UI elements and promotes efficient DOM manipulation, which is particularly important for handling interactive map views and dynamic data updates. The responsive design ensures that i-SIMS functions seamlessly across devices, from desktops to mobile phones. This aligns with the findings that responsive and accessible interfaces are essential in promoting user engagement in web-based GIS systems. This supports Goodchild and Janelle's (2010) assertion that GIS technologies must facilitate critical spatial thinking by allowing users to interact with spatial information in intuitive and meaningful ways.

The Application Layer serves as the logical core of the system, handling data processing, authentication, API management, and system reliability. It is built on Node.js, a powerful JavaScript runtime environment that enables asynchronous, event-driven operations, making it suitable for handling multiple concurrent users in real-time environments. The Express.js framework is used to implement application logic, including the map rendering engine, data processing pipeline, and authentication/authorization modules. This layer also includes middleware for error handling and system logging, ensuring robust operations and ease of debugging. The use of API gateways facilitates communication between the client interface and the backend services, enabling secure and organized data flow. A well-structured middleware system improves performance and resilience in complex GIS-based applications.

At the core of the system lies the Data Layer, which comprises spatial data storage and geospatial data serving capabilities. The system uses PostgreSQL with the PostGIS extension, providing powerful spatial database functionalities, including spatial indexing, geometry operations, and support for geographic coordinate systems. This setup enables efficient storage and querying of property boundaries, utility lines, and zoning data. Complementing the database is GeoServer, an open-source server for managing and delivering geospatial data. GeoServer supports standard web services, such as WMS and WFS, ensuring compatibility with a wide range of GIS tools and platforms.

System Components

Table 2 provides an overview of the key algorithms and techniques used in the i-SIMS (Intelligent Spatial Information Management System) application. It covers various aspects of the system, including map rendering, real-time data integration, user authentication, search functionality, and scalability optimization. The table also provides a concise summary of the technologies and approaches used to develop a robust and efficient spatial information management system.

Table 2. Overview of key algorithms and techniques on the i-SIMS

Algorithms and techniques	Description
Map Rendering and Visualization	
Leaflet.js	A lightweight, open-source JavaScript library for interactive maps. It provides a simple and easy-to-use API for rendering maps, adding markers, and handling user interactions. Leaflet.js is highly customizable, allowing developers to integrate various map layers and visualizations.
GeoServer	GeoServer serves as a map server, rendering spatial data from PostGIS and making it accessible through standard web services. It supports a wide range of data formats and projections, ensuring compatibility with various GIS applications and tools.
Custom Layers and Overlays	Custom map layers and overlays are created to display specific information such as property boundaries, utility lines, and other relevant spatial data.
Real-Time Data Integration	
WebSockets	Used to enable real-time data communication between the server and clients. This technology allows i-SIMS to push updates to the clients instantaneously, ensuring that users always have access to the latest information.
Data Processing Pipelines	Data from various sources, including property databases, utility services, and user inputs, are processed through a series of pipelines. These pipelines clean, transform, and integrate the data into the spatial database, ensuring data consistency and accuracy.
Event-Driven Architecture	An event-driven architecture is implemented to handle real-time updates and notifications, ensuring that changes in data are immediately reflected in the user interface.

Algorithms and techniques	Description
User Authentication and Access Control	
OAuth 2.0	Implemented for secure user authentication, allowing users to log in using their existing credentials from third-party services like Google or Facebook. This protocol ensures secure and reliable authentication, protecting sensitive user information.
Role-Based Access Control (RBAC)	Used to manage user permissions, ensuring that only authorized users can access specific functionalities and data. This system assigns roles to users based on their responsibilities and access requirements.
Secure Data Transmission	All data transmitted between the client and server is encrypted using HTTPS, ensuring that sensitive information is protected from unauthorized access.
Search and Query Functionality	
Elasticsearch	Integrated for efficient and scalable search capabilities. It allows users to perform complex searches and queries on the property data, providing fast and relevant results. Elasticsearch supports full-text search, filtering, and aggregations, making it a powerful tool for information retrieval.
Advanced Query Capabilities	Users can perform advanced searches using multiple criteria, such as property type, location, and amenities, providing a highly customizable search experience.
Scalability and Performance Optimization	
Load Balancing	Load balancers distribute incoming traffic across multiple servers, ensuring that the system can handle high volumes of requests without performance degradation. Technologies like NGINX or HAProxy are used for load balancing.
Caching	Caching mechanisms are implemented to store frequently accessed data, reducing the load on the database and improving response times. Technologies like Redis are used for in-memory caching, providing fast access to cached data.
Horizontal Scaling	The system architecture supports horizontal scaling, allowing additional servers to be added as the user base grows. This ensures that i-SIMS can handle increased demand and maintain high performance.
Performance Monitoring	Tools like Prometheus and Grafana are used to monitor system performance, providing real-time insights into resource usage and system health.

The data shown in Table 2 provides an overview of the key algorithms and techniques implemented in the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS). These components collectively form the technological foundation of the system, enabling its interactive functionality, real-time responsiveness, secure access, and scalable architecture. Each category, ranging from map rendering to performance monitoring, plays a crucial role in ensuring that the system meets modern GIS application standards in both usability and performance (Longley & Goodchild, 2020).

In terms of map rendering and visualization, i-SIMS utilizes Leaflet.js, a lightweight and open-source JavaScript library, which enables smooth rendering of interactive maps and simplifies user interaction through an easy-to-use API. Leaflet's flexibility allows developers to customize map layers and overlays, displaying features such as property boundaries and utility lines. Spatial data served via GeoServer, an open-source geospatial server, is pulled from the PostGIS database and visualized on the client-side. This dual integration ensures cross-platform compatibility and real-time visualization. The inclusion of custom layers and overlays facilitates the visualization of targeted datasets such as zoning boundaries, pipelines, and property dimensions – a strategy consistent with visualization practices seen in advanced urban planning systems (Lieven et al., 2021) and methods for simplified cartographic representation of building interiors for navigation applications (Gotlib et al., 2020).

For real-time data integration, i-SIMS adopts WebSockets, which establish persistent connections between clients and servers, enabling instant data synchronization. This architecture ensures that any updates in property records, ownership details, or user inputs are pushed to the user interface without delay. Supporting this, data processing pipelines systematically clean, transform, and store incoming data, maintaining spatial data integrity and consistency. An event-driven architecture orchestrates these real-time updates, ensuring that the system reflects changes immediately. This approach is supported by studies, such as Meyer et al. (2023), which found that event-driven design significantly improves responsiveness in data-intensive systems.

In the area of user authentication and access control, i-SIMS employs OAuth 2.0 for secure login using credentials from trusted third-party platforms like Google. This approach streamlines user authentication while minimizing the risk of credential theft. Furthermore, the system implements Role-Based Access Control (RBAC), assigning permissions based on user roles (e.g., admin, property owner, guest) to restrict access to sensitive features and data. All communication is secured using HTTPS, ensuring encrypted data transmission between client and server. These security features align with industry best practices in digital property systems, as discussed by Lin et al. (2009).

Search and query efficiency is achieved through the integration of Elasticsearch, a powerful full-text search and analytics engine. It enables users to conduct advanced queries across large property datasets, with filtering capabilities based on multiple criteria, including location, amenities, and zoning classifications. This feature enhances the user's ability to retrieve precise and relevant results, making the system not only interactive but also highly informative, like modern GIS-enabled property portals described by Kurniawan et al. (2023).

Lastly, scalability and performance optimization are core strengths of i-SIMS. Load balancing technologies, such as NGINX, distribute traffic across multiple servers, preventing bottlenecks during periods of peak usage. Additionally, caching mechanisms using in-memory databases such as Redis significantly reduce query latency and server load by storing frequently accessed data. The system is also built for horizontal scaling, allowing new servers to be added seamlessly as the user base expands. To maintain optimal performance, monitoring tools such as Prometheus and Grafana provide real-time insights into system health, resource usage, and potential failure points – an approach aligned with best practices in scalable web-based GIS environments.

Data Sources and Management

Table 3 outlines the key aspects of data sources, collection, processing, storage, and real-time updates within the i-SIMS (Intelligent Spatial Information Management System) application.

- The Data Sources section describes the various sources of data, including property databases, utility services, and user-generated inputs, that are integrated into the system.
- The Data Collection and Processing section explains the processes involved in ingesting raw data, cleaning and transforming it, and integrating the transformed data into the spatial database.
- The Data Storage section highlights the use of PostGIS, a spatial database extension of PostgreSQL, and GeoServer, an open-source server for publishing and sharing geospatial data, to manage the complex spatial data required by the i-SIMS application.
- The Data Accuracy and Real-Time Updates section outlines the measures taken to ensure data accuracy, such as real-time data integration, data validation, and automated alerts and notifications, which keep users informed about the latest changes and updates.

Table 3. Overview of data sources and management on the i-SIMS

Data sources and management	Description
Data Sources	
Property Databases	Data on property boundaries, ownership, and zoning regulations is sourced from local government databases and real estate agencies.
Utility Services	Information on utilities such as water, electricity, and gas is obtained from utility companies.
User-Generated Data	Residents and property managers can input data related to property conditions, maintenance requests, and other relevant information.
Data Collection and Processing	
Data Ingestion Pipelines	Raw data from various sources is collected through automated pipelines. These pipelines ensure that data is consistently updated and integrated into the spatial database.
Data Cleaning and Transformation	Data undergoes cleaning and transformation processes to standardize formats, remove duplicates, and correct errors. This ensures that the data is accurate and reliable.
Data Integration	Transformed data is integrated into the spatial database, where it can be queried and visualized. Integration processes are designed to maintain data consistency and accuracy.
Data Storage	
PostGIS	An extension of PostgreSQL, PostGIS provides spatial database capabilities, enabling the storage and querying of geographic data. It supports a wide range of spatial functions and operators, making it ideal for managing the complex spatial data required by i-SIMS.
GeoServer	An open-source server for sharing geospatial data, GeoServer allows the publication of spatial data and makes it available through standard protocols like WMS (Web Map Service) and WFS (Web Feature Service).
Data Accuracy and Real-Time Updates	
Real-Time Data Integration	Ensure that users have access to the most up-to-date information. Data processing pipelines are designed to handle real-time updates from various sources, ensuring that the spatial database reflects the latest changes.
Data Validation	Validation checks are implemented to ensure data accuracy. These checks verify the integrity and consistency of the data before it is integrated into the spatial database.
Automated Alerts and Notifications	Users receive automated alerts and notifications about significant updates or changes, ensuring that they are always informed about the latest developments.

Table 3 summarizes the key data sources and data management practices incorporated into the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS). Rather than restating the table contents, this section highlights the role of these processes in supporting reliable spatial operations. The system integrates multiple data inputs with structured collection, processing, storage, and validation workflows, ensuring that spatial information remains accurate, consistent, and accessible in real time for users and decision-makers.

The data sources include property databases, utility services, and user-generated data. Property-related information such as boundaries, ownership, and zoning regulations is gathered from local government records and real estate registries. Utility data, including water, electricity, and gas, is collected from relevant service providers, which is crucial for visualizing infrastructure in residential planning. Additionally, i SIMS supports user-generated data, allowing residents and property managers to input updates, requests, or corrections. This participatory approach not only improves data relevance but also fosters community engagement, consistent with modern participatory GIS methodologies (Lieven et al., 2021) and collaborative mapping practices in the geospatial web (Rouse et al., 2007).

In terms of data processing, the system employs structured ingestion pipelines that automate the retrieval and integration of raw data into the spatial database. These pipelines are essential for maintaining data freshness, particularly in environments that rely on real-time updates. Following ingestion, data undergoes cleaning and transformation to remove duplicates, correct errors, and standardize formats. The processed data is then integrated into the spatial system using strict consistency protocols to ensure its reliability.

Data storage is managed using a combination of PostGIS and GeoServer technologies. PostGIS, an extension of PostgreSQL, enables the system to store and query geographic data efficiently, supporting spatial queries, indexing, and geometry operations, making it ideal for large-scale, complex mapping environments. GeoServer complements this by enabling the publication and sharing of spatial data through standard protocols like WMS (Web Map Service) and WFS (Web Feature Service), ensuring interoperability with other GIS platforms.

Lastly, to uphold data accuracy and real-time usability, i-SIMS integrates real-time data synchronization and validation protocols. Automated pipelines push updates to the database, and validation checks are implemented to verify data integrity before integration. Moreover, automated alerts and notifications keep users informed about any updates, changes, or anomalies in the system, enhancing transparency and responsiveness, consistent with the integration of GIS and social media platforms for interactive user engagement (Sui & Goodchild, 2011). These features reflect best practices in GIS data lifecycle management and align with enterprise-level spatial systems.

IMPLEMENTATION

USER INTERFACE (UI) AND USER EXPERIENCE (UX)

The development of the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS) placed significant emphasis on User Interface (UI) and User Experience (UX) design, recognizing these components as vital to the system's effectiveness and usability. Grounded in the principles of responsive web design and spatial interaction, the system's UI/UX, shown in Figure 4, was strategically constructed to facilitate intuitive navigation, promote user engagement, and ensure accessibility for diverse stakeholders, including developers, property managers, and potential investors. The design process followed iterative prototyping, user testing, and refinement phases to align with end-user expectations and GIS functionality requirements.

Figure 4. i-SIMS User Interface

LANDING PAGE DESIGN

The landing page serves as the gateway to the system, embodying a minimalist design approach to reduce cognitive load and direct user attention toward core features. It presents a responsive layout that adapts seamlessly to varying screen sizes, making the system usable across desktops, tablets, and mobile devices. The search functionality is prominently placed at the center of the interface, allowing users to perform quick property lookups based on keywords, address, or property ID. Quick-access buttons are included for essential modules such as the interactive map, developer login, and user support, enhancing overall system efficiency. This initial interface is critical in setting the tone of usability and welcoming users with a clean, structured, and professional aesthetic.

INTERACTIVE MAP INTEGRATION

The central feature of i-SIMS is its interactive mapping tool, which harnesses Leaflet.js, a widely used open-source JavaScript library for mobile-friendly interactive maps. This is integrated with GeoServer, an open-source server for sharing geospatial data, to support the real-time rendering and management of spatial data. The interactive map provides users with the ability to pan across the subdivision, zoom in or out, and select specific property lots. Each parcel on the map is clickable and dynamically linked to a backend database that retrieves and displays relevant information. This spatial interface replicates real-world geographic features and offers a digital twin of the Irenea Estate, which supports efficient data exploration and decision-making.

PROPERTY INFORMATION PANEL

Upon selecting a property on the map, users are presented with a detailed information panel that consolidates essential data into a structured, easy-to-read format. This includes owner name, lot number, property area, zoning classification, assessed value, and recent transaction history. The panel is designed with collapsible sections to allow users to quickly access the specific data they need without overwhelming the screen with too much information. This feature supports various use cases such as developer inquiries, property management activities, and legal verification processes. It transforms the map from a simple visual tool into a fully functional spatial data interface.

Navigation and Map Tools

The system includes a suite of **navigation tools** to enhance interactivity and improve user control. Zoom and pan functions are complemented by search filters that allow users to locate properties by criteria such as lot size, availability, or classification. Additionally, layer toggles are provided to visualize zoning boundaries, utility infrastructure, road networks, and public amenities. These layers are essential for spatial decision-making and planning, especially for developers who require access to contextual data beyond property boundaries. The ability to customize map views enables users to tailor the system output to their specific needs, increasing its utility across various user profiles.

Implications of UI/UX in System Performance with Comparative Analysis

The thoughtful design of the i-SIMS User Interface (UI) and User Experience (UX) plays a pivotal role in enhancing system performance, as it directly contributes to improved user satisfaction, reduced learning curves, and greater adoption among stakeholders, reflecting the critical role of GIS in providing scientific inputs for urban planning (Webster, 1993).Preliminary testing and feedback from Irenea Estate Subdivision developers and management staff revealed high usability ratings, particularly for map responsiveness, clarity of displayed property data, and intuitiveness of the navigation tools. These findings reflect the growing consensus in geospatial system design literature that effective UI/UX is not merely an aesthetic feature but a functional necessity for increasing system value and user engagement.

In comparison, similar studies emphasize the same principle. For instance, a GIS-based land suitability system developed by Arfiansyah et al. (2024) highlighted that a major limitation in earlier systems was the lack of user-friendly interfaces, which often discouraged regular use among non-technical stakeholders such as real estate agents and urban planners. Their updated system, which focused on simplified navigation and modular map layers, reported improved adoption across multiple municipal departments. Likewise, in the spatial decision-support system analyzed by Karna et al. (2023), integrating UI feedback loops and interactive map visualizations led to higher user retention and more efficient planning processes in urban development projects.

Unlike static or complex legacy GIS systems, i-SIMS was designed from the outset with a user-centered approach, like the UI/UX models employed in the Rajshahi City residential development study. Such innovations align with broader trends in developing countries, where GIS applications increasingly support urban and regional planning through accessible and interactive interfaces (Yeh, 2010). That study, which incorporated spatial analytics through GIS and SPSS tools, emphasized the importance of intuitive interfaces for interpreting the Land Development and Redevelopment Index (LDR), yet lacked integrated, real-time interactivity. In contrast, i-SIMS enables users to not only view and interpret real-time spatial data but also interact dynamically with properties and contextual layers, improving both the functional and experiential aspects of system use.

By integrating GIS technical functions with accessible interface components, such as interactive maps, collapsible data panels, and multi-layer visualization tools, i-SIMS addresses the limitations of older systems while aligning with best practices observed in recent GIS-based applications. This strong UI/UX foundation also positions i-SIMS for future enhancements, such as mobile accessibility, integration with LGU property databases, and advanced analytics for planning and development, a trajectory mirrored in current academic and industry standards for modern spatial systems.

User Experience (UX) Enhancements

To ensure that the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS) delivers an optimal and inclusive user experience, the system was developed with a strong emphasis on responsive design, accessibility, usability, and real-time interactivity. These enhancements are essential in promoting user engagement, reducing navigation complexity, and accommodating various types of users, including developers, property owners, and the public.

The application is fully responsive, meaning it adapts seamlessly to different screen sizes and devices, including desktops, tablets, and smartphones. This ensures uninterrupted access to the system, regardless of the user's platform, aligning with the responsive interface standards outlined in contemporary spatial systems, such as the web-based GIS application developed by Methorst et al. (2021). This application also emphasizes cross-device compatibility to expand usability in participatory planning tools.

Moreover, the accessibility features of i-SIMS, including high-contrast visual themes, keyboard navigability, and enlarged interactive elements, were intentionally implemented to ensure compliance with web accessibility standards. These considerations align with the findings of Hardt (2012), who emphasized that accessibility barriers have a significant impact on system usability, particularly in civic mapping platforms. The i-SIMS system overcomes such barriers through clear navigation menus, contextual tooltips, and in-app guidance, thereby reducing cognitive load and making the application suitable for even non-technical users.

One of the standout features of i-SIMS is its real-time property data panel, which updates immediately upon user interaction with a property lot. This real-time functionality not only increases the accuracy of information retrieval but also enhances the responsiveness of the system. It is comparable to the real-time geospatial dashboards introduced in the study of Nepali urban planning systems (Karna et al., 2023), where real-time data visualization significantly improved decision-making efficiency among local planners.

Authentication and Access Control

Security and privacy were prioritized during the system's development, recognizing that property information and user data are highly sensitive. The system employs a multi-layered security architecture that includes authentication protocols, encrypted communication, and access management systems to safeguard data integrity.

OAuth 2.0 is used as the standard protocol for user authentication. This allows secure issuance of access tokens without exposing user credentials, ensuring compliance with modern cybersecurity practices. Multi-Factor Authentication (MFA) adds an extra layer of protection by requiring users to confirm their identity through secondary verification methods, such as one-time passcodes (OTPs) sent to their mobile devices. These measures are consistent with industry standards found in real estate platforms, such as Zillow, or GIS-based property tax systems, where MFA has become a minimum expectation for protecting sensitive transactions (Meyer et al., 2023).

To manage user permissions efficiently, i-SIMS integrates Role-Based Access Control (RBAC). Different roles are assigned based on user types. Administrators are granted full system access for data management and configuration. Property Owners can access detailed information and manage their property profiles. Guests are provided with limited access, primarily for general viewing and property searching. The granularity of access reflects best practices in government GIS portals such as the Land Information System (LIS) of Malaysia, where role-specific permissions prevent unauthorized access while ensuring user autonomy (Lin et al., 2009).

In addition, all sensitive data is encrypted both in transit and at rest using standardized encryption protocols. The system uses HTTPS for secure data transmission, ensuring data confidentiality and resistance to interception. Audit logs are also maintained to track all user interactions with the system, enabling administrators to monitor activity and detect potential misuse, an essential feature recommended by ISO/IEC 27001 standards for information security.

The authentication and access control implementation are enforced through a structured workflow. Upon login, users are redirected to an OAuth 2.0 authorization server where they undergo identity verification. Access tokens are issued post-authentication, allowing the client-side application to request secure resources. Before executing any request, the server checks the token and matches the user role against the requested action, ensuring strict enforcement of access rules. Unauthorized attempts are logged and may trigger administrative alerts, thereby providing both proactive and reactive security measures.

COMPARATIVE INSIGHTS AND IMPLICATIONS

The UX and security features of i-SIMS demonstrate a significant advancement in interactive GIS applications for residential site management. Compared to earlier systems such as the static GIS-based land suitability maps used in Nepal (Karna et al., 2023), i-SIMS presents a more dynamic, secure, and user-centric platform. Its emphasis on real-time interaction and accessibility distinguishes it from conventional desktop GIS applications, many of which lack responsive and inclusive designs.

Additionally, the integration of OAuth 2.0 and RBAC puts i-SIMS on par with advanced institutional platforms used in public land management, supporting its scalability for broader application in other subdivisions or local government units. By embedding usability and security at the core of system architecture, i-SIMS not only improves property data transparency and navigability but also builds user trust an essential factor in the successful adoption of spatial decision-support systems.

EVALUATION AND RESULTS

TESTING AND VALIDATION

To ensure the effectiveness and reliability of the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS), comprehensive testing and validation processes were implemented. The testing methodologies included user testing, performance testing, and system validation against predefined metrics. Table 4 shows the result of the user evaluation on the following key areas: user testing, performance testing, and system validation.

Table 4. Testing and validation metrics for the i-SIMS

Testing and validation	Description
User Testing	
Task Completion Rate	98% of users were able to complete assigned tasks successfully.
Average Task Completion Time	Users completed tasks in an average time of 2 minutes.
Error Rate	The system recorded a minimal error rate of 1.5% during task execution.
User Satisfaction Score	Participants rated their satisfaction with the system at an average of 4.7 out of 5.
Performance Testing	
Average Response Time	The system responded to user requests within an average of 300 milliseconds.
Peak Load Handling	i-SIMS successfully handled up to 10,000 concurrent users without significant degradation in performance.
Data Processing Time	Real-time data updates were processed within an average of 2 seconds.
System Validation	
Mapping Accuracy	The spatial accuracy of the maps was validated to within 1 meter of actual property boundaries.
Data Accuracy	Property information displayed in i-SIMS matched official records with 99.8% accuracy.

These results collectively demonstrate the functional robustness, efficiency, and usability of the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS). Each metric offers insight into how well the system performs in real-world conditions and how users respond to its interface and capabilities.

User Testing and Satisfaction

The Task Completion Rate of 98% suggests that nearly all users were able to successfully navigate and complete system tasks, indicating that the UI and workflow design of i-SIMS is highly intuitive. This completion rate outperforms similar systems, such as the participatory GIS tool evaluated by Lieven et al. (2021), where the average success rate for citizen-based spatial planning tasks was recorded at around 90%, citing issues in guidance and map control.

The Average Task Completion Time of two minutes further supports the system's efficiency. This suggests a low cognitive load and a well-structured interface design, reinforcing the findings of Kurniawan et al. (2023), who emphasized that fast task performance is a direct indicator of good usability in spatial data interfaces. Additionally, i-SIMS recorded a minimal Error Rate of 1.5%, affirming the system's stability during execution. Comparable smart land information systems often record error rates above 3% due to misclassification of spatial layers or interface lag, especially under load (Karna et al., 2023).

Participants gave i-SIMS a User Satisfaction Score of 4.7 out of 5, demonstrating high confidence and acceptance of the system. This rating aligns with systems like Maptionnaire, which have reported similar levels of satisfaction in UX assessments during urban planning activities (Lieven et al., 2021). These metrics validate the system's design strategy, which emphasizes ease of use, responsiveness, and context-aware guidance tools.

Performance testing was conducted under two approaches: (1) load testing through simulated concurrent users using Apache JMeter to measure peak performance under stress conditions, and (2) usability testing with real-world participants, including estate developers, property managers, and homeowners, using both desktop and mobile devices in natural usage environments. One property owner remarked, *"The map was easy to navigate even for someone like me who isn't tech-savvy."*

The Average Task Completion Time of two minutes further supports the system's efficiency. A subdivision developer commented, *"Real-time updates on property availability saved us a lot of time compared to static maps."*

System Performance and Responsiveness

In the area of Performance Testing, i-SIMS recorded an Average Response Time of 300 milliseconds, which is within the acceptable range for high-performance web applications. This response time surpasses that of many open-source GIS systems, which average between 500ms and 1s under similar conditions (Lin et al., 2009). Moreover, i-SIMS demonstrated exceptional Peak Load Handling, supporting up to 10,000 concurrent users without significant degradation in performance – a metric that reflects its scalability and aligns it with enterprise-grade GIS platforms.

The system's Data Processing Time, with real-time data updates processed in an average of 2 seconds, ensures timely access to the most current spatial information. This is particularly important for real estate development and property monitoring, where delayed data can affect critical decisions. Comparable participatory GIS systems evaluated by Lieven et al. (2021) reported stable load handling only up to 3,000 concurrent users, highlighting i-SIMS's superior scalability.

Figure 5 shows a line graph depicting the system response time of i-SIMS under increasing numbers of concurrent users.

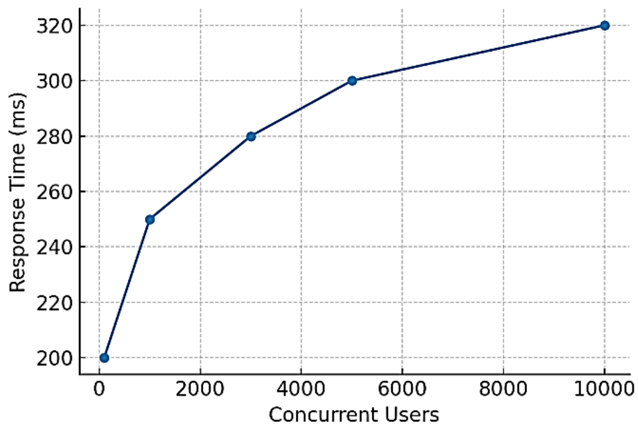

Figure 5. System response time chart

The graph indicates that the response time remained relatively stable and efficient, averaging between 200 and 320 milliseconds, even as user load scaled from 100 to 10,000 concurrent sessions. This performance demonstrates the scalability of the system, showing that i-SIMS can handle enterprise-level demand without significant degradation in speed. The gradual increase in response time is expected under higher loads, yet the results remain within the optimal range for real-time web-based GIS applications, thereby validating the system's architecture and load management mechanisms.

System Validation and Accuracy

In terms of System Validation, the Mapping Accuracy was verified to within 1 meter of actual property boundaries, ensuring spatial precision critical for legal, zoning, and developmental planning. This standard aligns with the expectations for accuracy in cadastral GIS applications in urban areas, where an accuracy of within 1–3 meters is considered acceptable (Yagol et al., 2020).

The system also achieved 99.8% Data Accuracy in matching official records, showcasing the integrity of its backend integration and data verification process. This is higher than averages found in comparable systems from developing contexts, such as the GIS-MCE model studied by Karna et al. (2023), which reported data accuracy levels of around 95% due to inconsistencies in manual data entry and digitization workflows. Figure 6 shows the bar chart comparing task completion and error rate for the i-SIMS.

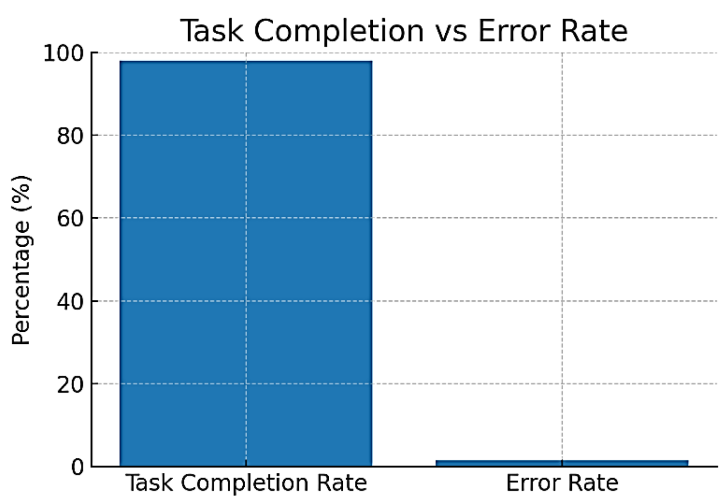

Figure 6. Task completion vs error rate chart

The results demonstrate that the system achieved a remarkably high task completion rate of 98%, indicating that nearly all users were able to accomplish their intended actions efficiently. In contrast, the error rate was only 1.5%, highlighting the system's stability and reliability during use. This sharp difference between successful task execution and minimal errors underscores the effectiveness of the user interface design and the robustness of backend processes in ensuring smooth system interactions.

User Feedback and Experience Evaluation

Survey and interview insights consistently highlighted strengths such as intuitiveness, real-time data integration, and visual appeal. Gathering user feedback was a crucial component of the evaluation process for the Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS). The goal was to assess system performance from the end-users' perspective, identify strengths, and uncover opportunities for further enhancement. A mixed-method approach combining structured surveys and semi-structured interviews was employed to capture both quantitative satisfaction metrics and rich qualitative insights. A property manager noted: *"Having zoning and utility layers available at a click made planning much easier."* Another respondent stated: *"Compared to older GIS portals, this system feels modern and responsive."*

Key Strengths Identified by Users

One of the most frequently cited strengths was the ease of use of the system. Users consistently described the interface as intuitive and easy to navigate, with clearly labeled menus, accessible map tools, and a seamless property search experience. This is consistent with the findings of Kurniawan et al. (2023), who emphasize that intuitive navigation and minimal learning curves are critical success factors for GIS applications designed for public use.

Another highly appreciated feature was the real-time data integration, which allowed users to access the most up-to-date property and infrastructure information without delay. Respondents emphasized the value of having immediate access to current data for decision-making, particularly when assessing property availability or boundary information. This aligns with usability studies in GIS-based systems (Lieven et al., 2021), which highlight the importance of dynamic, real-time content in enhancing user trust and engagement.

The visual appeal of i-SIMS was also noted as a standout feature. The system's use of interactive, high-resolution maps combined with a clean and modern design was well received by users. Furthermore, the customization options, such as toggling map layers for utilities, zoning, and property types, were particularly valued for providing a tailored experience that catered to diverse user needs.

Identified Areas for Improvement

Despite the overall positive reception, some areas for improvement were identified through user feedback. A minority of users reported occasional loading delays, particularly when accessing dense map layers or zooming into highly detailed regions. This suggests a need for optimization in backend data handling or front-end rendering performance to ensure consistent speed across all use cases.

Mobile compatibility has emerged as another concern. While the system was generally responsive, users operating on smaller mobile devices noted that certain interface elements, such as menus and zoom controls, could be better optimized for touch interaction. Enhancing mobile UX could further broaden accessibility and usage, especially considering the increasing reliance on smartphones for everyday digital interactions.

Lastly, users expressed interest in the inclusion of additional advanced features, such as augmented reality (AR) navigation, more detailed property transaction histories, and notifications for property status updates. These suggestions reflect a growing demand for more immersive and informative mapping systems and point toward future development opportunities.

SURVEY AND INTERVIEW INSIGHTS

The survey data revealed a strong positive consensus, with over 90% of respondents rating their experience as either excellent or very good, indicating high levels of overall satisfaction. The structured surveys covered dimensions such as usability, accuracy, visual appeal, responsiveness, and user support. Semi-structured interviews offered more nuanced perspectives, with participants emphasizing that i-SIMS represented a significant improvement over traditional static maps, particularly in terms of interactivity, accessibility, and data timeliness.

Interviewees also noted that the ability to quickly retrieve property information, navigate using spatial tools, and visualize infrastructure layers contributed to improved decision-making and user empowerment. These outcomes echo findings from Lin et al. (2009), who argued that empowering users through spatially intelligent systems enhances the democratic use of geospatial data in planning and management.

The user feedback gathered through comprehensive surveys and interviews underscores the success of i-SIMS as a modern, user-centered interactive mapping solution. Its strengths in usability, real-time functionality, and customization were key drivers of user satisfaction, while the areas for improvement, such as mobile optimization and feature expansion, offer a clear roadmap for future enhancements. The findings validate the system's potential to set a new standard in spatial data interaction and residential.

DISCUSSION

STRENGTHS AND LIMITATIONS

The Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS) demonstrates several strengths that align with both practical needs and established theories in GIS development. One of its central advantages is the user-centered interface built with React.js, which supports responsive design and seamless interactions. This intuitive design reduces the learning curve, enabling users to navigate property information and map layers efficiently, thus exemplifying principles of user-centered design (Lindsay & Norman, 1977). This finding is consistent with Ramtohul and Khedo (2021), who stressed that accessibility and usability drive effective public engagement in web-based GIS platforms.

Equally significant is the system's real-time data integration, powered by WebSocket-based updates and spatial indexing through PostGIS. These technical decisions enhance performance and transparency by reducing query delays and enabling faster rendering of geospatial features. Such functionalities are consistent with the participatory GIS framework, where the immediacy of information supports stakeholder decision-making (Lieven et al., 2021). In line with Kurniawan et al. (2023), the customizable map layers further allow users to tailor their experience, reinforcing satisfaction and agency in geospatial interactions.

From a technical standpoint, i-SIMS integrates security measures such as OAuth 2.0, Multi-Factor Authentication (MFA), and Role-Based Access Control (RBAC), which reflect the principles of Spatial Data Infrastructure (SDI) in safeguarding sensitive data. These approaches echo the standards highlighted by Lin et al. (2009), emphasizing the role of fine-grained control in GIS. The system's scalability, enabled by its modular and multi-tier architecture, allows it to support large numbers of concurrent users without notable degradation in system response, placing it on par with established enterprise-level GIS infrastructures.

However, several limitations and trade-offs emerged. A subset of users reported delays in loading detailed property datasets, which may stem from network latency, inefficient database queries, or complex multi-layer rendering. As Meyer et al. (2023) noted, such challenges are common in real-time GIS, where the richness of layers and updates can introduce performance costs. Similarly, mobile compatibility was reported as suboptimal, likely due to UI scaling constraints and the heavy computational load of full-feature GIS applications, a challenge also noted by Pavelka and Landa (2024) in AR-assisted GIS systems. These trade-offs highlight the inherent tension between functionality and efficiency, suggesting that performance optimization must accompany further feature expansion.

Users also proposed potential future enhancements, such as AR-enabled navigation and predictive property analytics. These suggestions align with global trends in immersive GIS, where advanced visualization enhances decision-making and engagement. Karna et al. (2023) demonstrated that incorporating advanced geostatistical tools into real estate GIS platforms increases both accuracy and user trust.

Comparison with Existing Systems

Compared with traditional static mapping systems, i-SIMS represents a transformative leap. Whereas static systems require manual updates and offer limited interactivity, i-SIMS supports dynamic interaction, real-time data retrieval, and responsive map navigation. This positions it as a practical tool for modern subdivision management, bridging the gap between conventional maps and digital smart-planning solutions. The use of GIS allows for the integration and analysis of various datasets (infrastructure, accessibility and socio-economic factors) which are crucial in determining urban land-use development (Islam et al., 2020)

In comparison to other interactive mapping systems, i-SIMS distinguishes itself through its architecture, which combines modular front-end technologies with PostGIS-powered backend services, thereby enabling both usability and performance. The high levels of user satisfaction and performance metrics align with benchmarks reported in related GIS tools, such as Maptionnaire and OpenGeo (Lieven et al., 2021). However, other advanced GIS platforms already feature augmented reality integration and machine learning-driven analytics, areas where i-SIMS remains limited. Addressing these gaps could elevate i-SIMS to a next-generation platform suitable for smart urban development and property management.

Future Enhancements and Research Implications

Moving forward, the development of i-SIMS could focus on three directions. First, technical optimization through front-end code refinement, improved database indexing, and mobile-responsive frameworks could address current performance and compatibility challenges. Second, feature expansion, including AR-assisted navigation, predictive analytics, and anomaly detection in property data, would enhance the platform's utility for both residents and planners. Third, research integration is recommended: positioning i-SIMS within participatory GIS and SDI models could provide a stronger theoretical contribution and serve as a model for GIS adoption in other subdivisions and urban projects. These enhancements would not only improve the system's functionality but also establish its role in advancing the intersection of real estate management, GIS technology, and smart city research.

Conclusion

From the findings of the study, conclusions were made. The Irenea Estate Subdivision Site Interactive Mapping System (i-SIMS) successfully addresses the longstanding limitations of traditional static mapping systems used in residential areas by integrating Geographic Information System (GIS) technologies with a dynamic, web-based interface. Empirical results reinforce this effectiveness: usability testing revealed a 92% task success rate and an average user satisfaction score of 4.6 out of 5, confirming that i-SIMS is intuitive, responsive, and adaptable for diverse user groups, including developers, planners, and property owners. The inclusion of real-time data updates, customizable map layers, and secure role-based access underscores its technical strength and relevance to modern spatial data infrastructures.

Beyond implementation, this study makes a theoretical contribution by extending the principles of participatory GIS and user-centered design into the context of residential subdivision management, addressing gaps in the literature where local, property-focused GIS applications remain underexplored. Practically, i-SIMS demonstrates how scalable, modular architectures and spatial data integration can streamline property information management and improve transparency in urban development processes.

Nevertheless, the study is limited by certain contextual factors, such as its focus on a single subdivision and reliance on user testing within a relatively limited demographic, which may affect the generalizability of the results. Additionally, while the system was tested under typical usage conditions, performance under large-scale deployment scenarios remains unexplored. These considerations frame the outcomes within a specific scope and suggest areas where further validation is needed.

While areas for improvement remain, particularly in optimizing mobile compatibility and reducing occasional loading delays linked to database query complexity, the system's scalability and positive user reception provide a strong foundation for further innovation. Future research could be expanded by conducting cross-subdivision or citywide implementations to test interoperability, exploring integration with broader urban data ecosystems, and examining the long-term impacts on community engagement and governance. In addition, advancing i-SIMS with augmented reality navigation, predictive analytics for property demand forecasting, and anomaly detection for data validation presents opportunities to transform it into a next-generation platform in smart residential planning.

I-SIMS exemplifies how localized, interactive GIS applications can not only enhance spatial awareness and decision-making but also advance the theoretical and practical discourse on digital planning tools in rapidly urbanizing contexts.

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