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Development of a Web-GIS Framework for Billboard Management and Municipal Tax Administration in Kinondoni Municipality, Tanzania.

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ABSTRACT

Municipal authorities in Tanzania still rely largely on manual systems to manage billboards and collect related taxes. This makes it difficult to keep accurate records, monitor billboard installations and reduce revenue losses. This study developed a Web-based Geographic Information System framework to support billboard management and municipal tax administration in Kinondoni Municipality, Dar es Salaam, Tanzania. The system was developed using the waterfall methodology which follows a step-by-step development process. Billboard locations and attribute data were collected using mobile data collection tools and stored in a PostgreSQL/PostGIS geodatabase. GeoServer was used to process and publish spatial data, Leaflet supported interactive web mapping and PHP was used for server-side functions, including billing and invoice generation. Functional testing was conducted in a localhost environment. Results showed that the prototype could store, retrieve, display and update billboard records. It also supported map interaction, spatial queries, inventory management and invoice generation. The system provides a central platform for managing billboard information and tax records. It may also be useful to companies that install and manage billboards to monitor locations, permits and maintenance needs. However, the prototype has not yet been tested in real municipal operations. Future studies should assess its usability, performance, revenue contribution and support for compliance monitoring.

Keywords: Web-GIS, Billboard Management, Municipal Revenue Management, Spatial Databases, Geospatial Technologies, Tax Administration

INTRODUCTION

Municipal revenue collection plays an important role in financing public services, infrastructure development and urban management (Venkatachalam, 2009). As cities continue to grow, outdoor advertising has become an increasingly important source of local government revenue. Billboard ad vertising is a popular form of outdoor advertising that uses large, strategically placed displays to attract the attention of passing vehicles and pedestrians (Bandyophadyay et al., 2012). Billboards are positioned in high-traffic areas where they can reach large and diverse audiences. They are often found along busy roads or in areas where people are likely to be stationary, such as rush-hour routes or outside stadiums (Nyerges,

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2021). Moreover, billboards remain one of the most cost-effective and far-reaching advertising options, often more affordable than TV or print ads, and delivering a lower cost per impression compared to many digital media (Saha and Frøyen, 2021). However, billboards are not only advertising platforms but also taxable urban assets that require effective inventory management, permit administration, compliance monitoring and revenue tracking (Kweka and Chikoyo, 2021; Wakil et al., 2021).

Despite their importance, many municipalities continue to rely on manual and fragmented systems for managing billboard information. Records are often maintained in paper files, spreadsheets or disconnected databases, making it difficult to maintain accurate information on billboard locations, ownership, permit status and payment records. Such limitations can contribute to unauthorized installations, weak compliance monitoring, delayed billing and potential revenue losses (Kweka and Chikoyo, 2021). Similar challenges have been reported in local government revenue systems, where inadequate digital infrastructure affects monitoring, billing efficiency and revenue administration (Munywoki and Singh, 2025). These challenges have important implications for municipal governance and service delivery. Revenue generated from billboard permits and taxes contributes to the financing of public infrastructure, environmental management and other municipal services. Consequently, ineffective billboard management may affect the ability of local authorities to mobilize and manage revenue efficiently. Addressing these challenges is consistent with global efforts to strengthen urban governance, improve institutional effectiveness and promote sustainable cities as reflected in Sustainable Development Goals (SDGs) 11 and 16 (UN, 2015).

Recent advances in Geographic Information Systems (GIS) and Web-based Geographic Information Systems (Web-GIS) provide new opportunities for addressing these challenges (Lai et al., 2017). Web-GIS enables the collection, storage, visualization, updating and sharing of spatial information through online platforms while supporting evidence-based decision-making and interdepartmental coordination (Ananda et al., 2016; Singh et al., 2012; Wu, 2021). Increasingly, municipalities are adopting Web-GIS to support asset management, infrastructure planning, revenue administration and urban monitoring (Mango et al., 2021; Munywoki and Singh, 2025). By integrating spatial and administrative information, Web-GIS improves data accessibility, operational efficiency and transparency, making it an important component of digital governance initiatives (Mango, Çolak and Li, 2021).

Within municipal revenue systems, Web-GIS offers particular value because it enables the integration of location-based assets with ownership records, permit information, inspection reports and billing databases. Such integration can improve inventory control, compliance monitoring, billing processes and revenue tracking (Munywoki and Singh, 2025; Wakil et al., 2021). By linking spatial information with taxation databases, municipal authorities can improve the identification, monitoring and management of taxable assets, thereby supporting more effective revenue administration and urban management (Wakil et al., 2021).

Kinondoni Municipality is one of the most commercially active municipalities in Dar es Salaam and hosts a large number of static and digital billboards located along major transport corridors and commercial centers. As Tanzania's largest urban region continues to expand, demand for outdoor advertising space has increased, placing additional pressure on municipal

authorities to effectively manage billboard assets and associated revenue streams (URT, 2022). Despite their significance as revenue-generating assets, billboard management in Kinondoni Municipality remains constrained by limited spatial data, manual record keeping and weak integration between inventory and taxation records. Municipal officers often face challenges in locating billboards, verifying ownership, identifying unauthorized installations and monitoring payment status. These challenges reduce the effectiveness of compliance monitoring and may affect municipal revenue performance.

Previous studies have demonstrated the usefulness of GIS and Web-GIS in spatial data management, urban planning, asset monitoring and municipal service delivery (Mango et al., 2021; Munywoki and Singh, 2025; Singh et al., 2012). Other studies have examined billboard placement, outdoor advertising visibility and urban visual management (Wakil et al., 2021). However, most existing studies focus either on technical GIS applications, urban visual assessment or general municipal information systems. Limited attention has been given to the integration of billboard inventory management, compliance monitoring and municipal tax administration within a single geospatial platform. This gap is particularly evident in Tanzania, where billboard management and taxation processes remain largely dependent on manual procedures and disconnected information systems. Consequently, there is limited empirical evidence on how integrated Web-GIS solutions can support billboard management and municipal revenue administration in the local context. This study addresses this gap by developing and demonstrating the feasibility of a Web-GIS framework for billboard management and municipal tax administration. The framework brings together billboard locations, inventory records and billing information in one platform. This supports monitoring, compliance management and revenue administration. The study also shows how open-source geospatial technologies can be used to link spatial and administrative data for municipal revenue management in a developing-country context.

STUDY AREA

Kinondoni Municipality is one of the administrative councils in Dar es Salaam Region, eastern Tanzania. It lies approximately between 6°40′S - 6°55′S latitude and 39°05′E - 39°20′E longitude (Figure 1). The municipality covers about 269.5 km². It is bordered by the Indian Ocean to the east, Ubungo Municipality to the west, Kibaha District to the northwest and Ilala Municipality to the south. According to the 2022 Population and Housing Census, Kinondoni Municipality had a population of 982,328 (URT, 2022). Kinondoni is one of the most commercially active municipalities in Dar es Salaam. It has major business centres, shopping areas, transport corridors and dense residential neighbourhoods. Major roads such as Morogoro Road, Bagamoyo Road, Ali Hassan Mwinyi Road, Kawawa Road and Kinondoni Road carry high flows of vehicles and pedestrians. These corridors create strong visibility for outdoor advertising. The municipality hosts many static and digital billboards of different sizes and designs. Most are concentrated along arterial roads, commercial centres and other high-traffic locations. This concentration makes billboard inventory management, permit monitoring and tax administration important municipal functions.

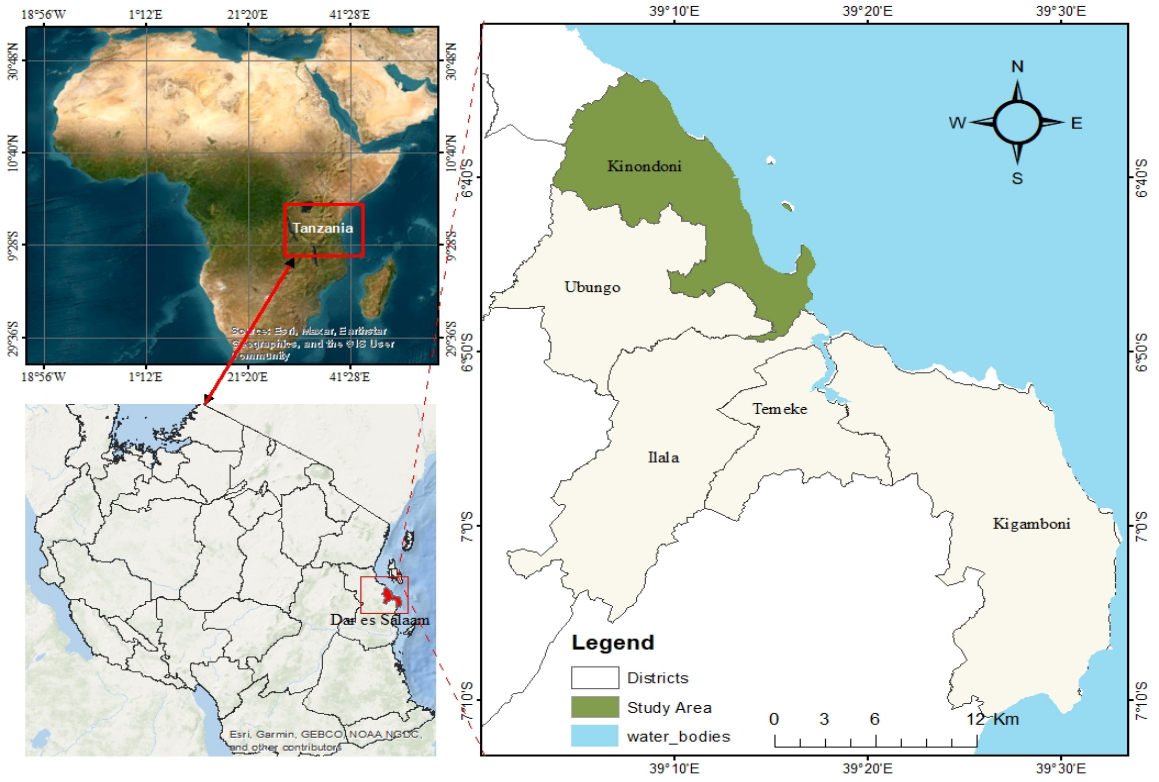

Figure 1: Location of Kinondoni Municipality in Dar es Salaam, Tanzania - Study Area

Kinondoni Municipality was selected because of its high commercial density, extensive road network and concentration of outdoor advertising infrastructure. These conditions make it a suitable case for testing a Web-GIS framework for billboard inventory management, compliance monitoring and municipal tax administration. The area also provides useful lessons for other rapidly urbanizing municipalities in Tanzania facing similar billboard management and revenue collection challenges. Figure 1 shows the location of Kinondoni Municipality within Dar es Salaam Region and its spatial relationship with neighboring municipalities, the Indian Ocean coastline and major urban corridors. This location is important because it places Kinondoni within one of Tanzania's most active urban and commercial zones, where outdoor advertising infrastructure is highly visible and requires effective spatial management.

DATASET AND METHODS

Dataset

The development of the Web-based GIS prototype for billboard management and municipal tax administration relied on spatial, attribute and billing-related datasets collected within Kinondoni Municipality, Dar es Salaam. The dataset was designed to support billboard inventory management, spatial visualization, compliance monitoring and integration with municipal billing workflows. A total of 194 billboard records were collected from selected transport corridors, commercial centres and high-density business areas within Kinondoni

Municipality. Geographic coordinates were captured using the Open Data Kit (ODK) Collect mobile application and recorded in the World Geodetic System 1984 (WGS 84: EPSG:4326) coordinate reference system. Spatial datasets included billboard geographic coordinates, municipal administrative boundaries, road networks and high-resolution satellite imagery used for spatial referencing and visualization. Additional spatial datasets were processed in QGIS to support mapping and system development. Attribute data included billboard identification number, ownership details, billboard type, advertisement category, dimensions, condition status, permit status, customer information and billing-related records. These datasets were linked to their corresponding spatial features through unique identifiers within a PostgreSQL/PostGIS geodatabase.

Data quality assurance involved field verification, coordinate validation, duplicate record checks, attribute completeness assessment and consistency check between spatial and non-spatial records before integration into the database. Historical billing information obtained from municipal spreadsheet-based and paper-based records was digitized and linked to billboard locations to support invoice generation, payment tracking and administrative management within the Web-GIS prototype. Satellite imagery was accessed through web map services displayed using the Leaflet JavaScript library. The satellite imagery was used as a base map to support data verification and spatial visualization during system development and testing. Table 1 present a list of datasets used for the development and testing of the Web-GIS prototype.

Table 1: Summary of datasets used for the development and testing of the Web-GIS prototype

Dataset	Source	Description	Format
Billboard location	Field survey using ODK Collect	GPS coordinates of billboard structures collected within Kinondoni Municipality	Point
Billboard attribute	Field survey and municipal records	Billboard ID, owner/customer details, type, size, condition, permit status and advertisement category	Tabular
Billing records	Municipal spreadsheet and paper-based records	Customer accounts, invoice records, payment status and related tax information	Tabular
Administrative boundary	Municipal/NBS spatial data	Boundary of Kinondoni Municipality used for study area mapping	Polygon
Road network	Municipal GIS / OpenStreetMap	Major roads and transport corridors used for spatial reference and map display	Line
Satellite imagery	leafletjs.com	Base map used for spatial visualization and verification	Raster imagery

Methods

This study adopted a Design Science Research (DSR) approach implemented through a waterfall system development methodology to guide the design, development and functional validation of the Web-GIS framework for billboard management and municipal tax administration. The Design Science Research approach was selected because the study aimed to develop and evaluate a practical technological artefact that addresses a real-world municipal management problem. The waterfall methodology was considered appropriate because the study objectives, user requirements and expected system functionalities were

identified and defined before system development commenced (Gupta et al., 2026; Pressman and Maxim, 2024). User requirements obtained from municipal officers responsible for billboard management and revenue administration provided a stable basis for system design. Consequently, a structured and sequential development process was suitable for progressing from requirements analysis to system implementation and testing. Alternative approaches such as Agile, prototyping and iterative development models are often preferred when user requirements are expected to change continuously throughout the development process. However, the primary objective of this study was to develop and functionally validate a prototype based on predefined requirements rather than undertake multiple cycles of system refinement. Therefore, the waterfall methodology provided a clear framework for organizing requirement elicitation, data collection, database design, system development, tax data integration and functional validation in a systematic and reproducible manner (Figure 2).

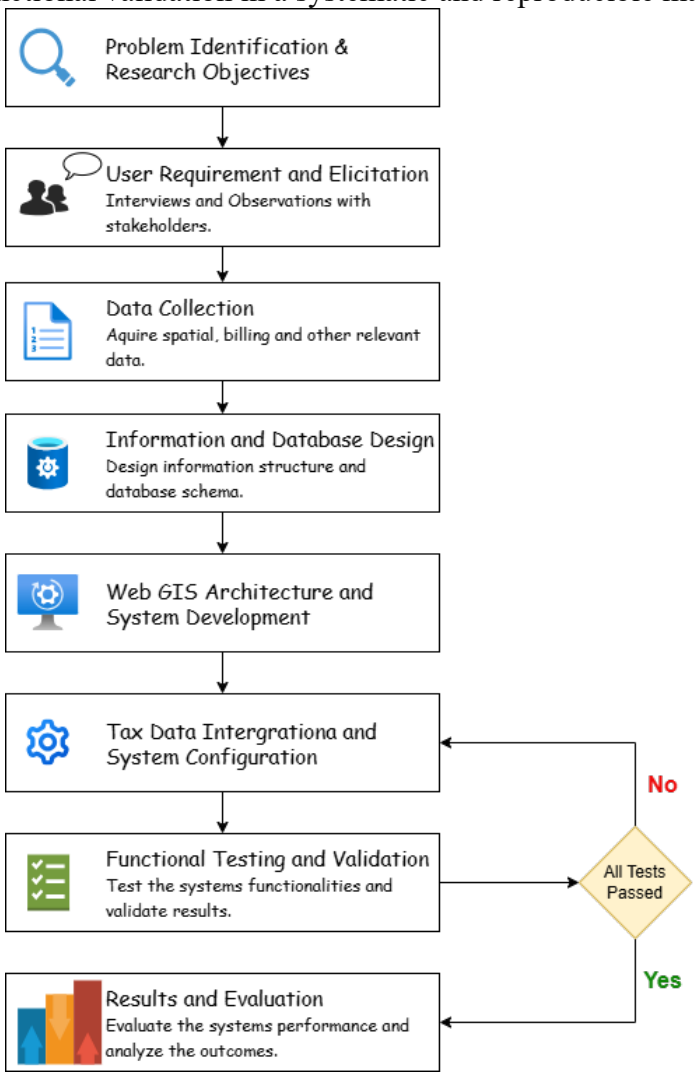

Figure 2: Methodological framework for the development and functional validation of the Web-GIS prototype

User Requirement Elicitations

User requirements were identified through semi-structured interviews and field observations with municipal staff involved in billboard management, field inspection, customer registration and revenue administration. Respondents were selected purposively because they work directly with billboard records, inspections and tax-related processes. The discussions focused on how billboard information is currently collected, updated, monitored and linked to billing. They also helped identify key operational challenges in the existing manual system. These included difficulties in locating billboards, updating records, monitoring permits, generating invoices and tracking payment status. The information collected from interviews and observations was reviewed and grouped into key functional requirements. These requirements guided the design of the geodatabase, system architecture, billing module and interactive map interface. Stakeholders also highlighted the need to improve access to billing and compliance information for billboard owners. For this reason, the system included user-oriented functions that allow taxpayers to view invoice information, check payment status and access selected compliance records. These functions are intended to improve transparency, communication and efficiency in billboard tax administration. The functional requirements identified during this process are summarized in Table 2.

Table 2: Functional requirements identified during user requirement elicitation.

Requirement Category	Functional Requirement	Purpose	Intended User
Spatial Management	Interactive map visualization	View and locate billboard assets	Municipal managers, inspectors
Data Management	Billboard registration and updating	Maintain billboard inventory records	Municipal officers
Field Operations	Mobile data collection	Capture billboard locations and attributes	Field inspectors
Customer Management	Customer registration and updating	Manage billboard ownership records	Revenue officers
Revenue Administration	Invoice generation and management	Support tax billing processes	Revenue officers
Financial Monitoring	Payment status tracking	Monitor tax compliance and payments	Revenue officers
System Administration	User account management	Control system access and security	System administration
Taxpayer Services	Access billing and compliance information	Allow billboard owners to view payment status, invoice records and permit compliance information	Billboard owners / taxpayers

Data Collection

Field data collection was conducted through a systematic survey of billboard structures located along major transport corridors, commercial centers and high-density business areas within Kinondoni Municipality. The survey focused on capturing both spatial and attribute information required for billboard inventory management and municipal tax administration. Data were collected using the Open Data Kit (ODK) Collect mobile application installed on Android devices. Geographic coordinates were recorded in the World Geodetic System 1984 (WGS 84; EPSG:4326) coordinate reference system. For each billboard, information was collected on location, ownership, billboard type, advertisement category, structure characteristics, permit status and physical condition. To ensure data quality, completed

records were reviewed for completeness, duplicate entries, logical consistency and coordinate accuracy. Attribute records were cross-checked against municipal records where available, while spatial data were visually verified against satellite imagery and field observations before integration into the geodatabase. The collected datasets were subsequently processed in QGIS and imported into the PostgreSQL/PostGIS database to support system development and testing. The attributes collected during the field survey are summarized in Table 3.

Table 3: Billboard attributes collected during field survey

Attribute Category	Data Attribute	Description
Spatial Information	Latitude, longitude	Geographic coordinate (x,y coordinate pair) of billboard location
Billboard Characteristics	Billboard Type	Illuminated, non-illuminated or electronic billboard
Billboard Characteristics	Structure Type	Ground-mounted, wall-mounted or rooftop-mounted
Advertisement Information	Advertisement Category	Commercial advertisement or public/service message
Physical Condition	Condition Status	Well-maintained, standard, defective, damaged or misaligned
Ownership Information	Billboard Owner	Name of owner or operating company
Compliance Information	Permit Status	Permitted, expired permit or non-permitted structure
Administrative Information	Billboard Identification Number	Unique identifier assigned to each billboard
Revenue Information	Customer Information	Customer details associated with the billboard
Revenue Information	Billing Information	Linked billing and payment records

Information and database design

Information management focused on how billboard-related data were organized, stored, updated, retrieved, and linked to support daily municipal operations. The system used a centralized PostgreSQL/PostGIS database to manage both spatial and non-spatial information, including billboard records, customer details, permits, inspections, invoices, payments, system users and audit logs. The database was designed using a relational model, as shown in the Entity–Relationship Diagram (Figure 3). It consists of eleven main entities: Customer/Taxpayer, Billboard, Location, Billboard Type, Advertisement Category, Permit, Invoice, Payment, System User, Role, Inspection Record and Audit Log. Each entity has a unique primary key, while foreign keys were used to link related records across the database.

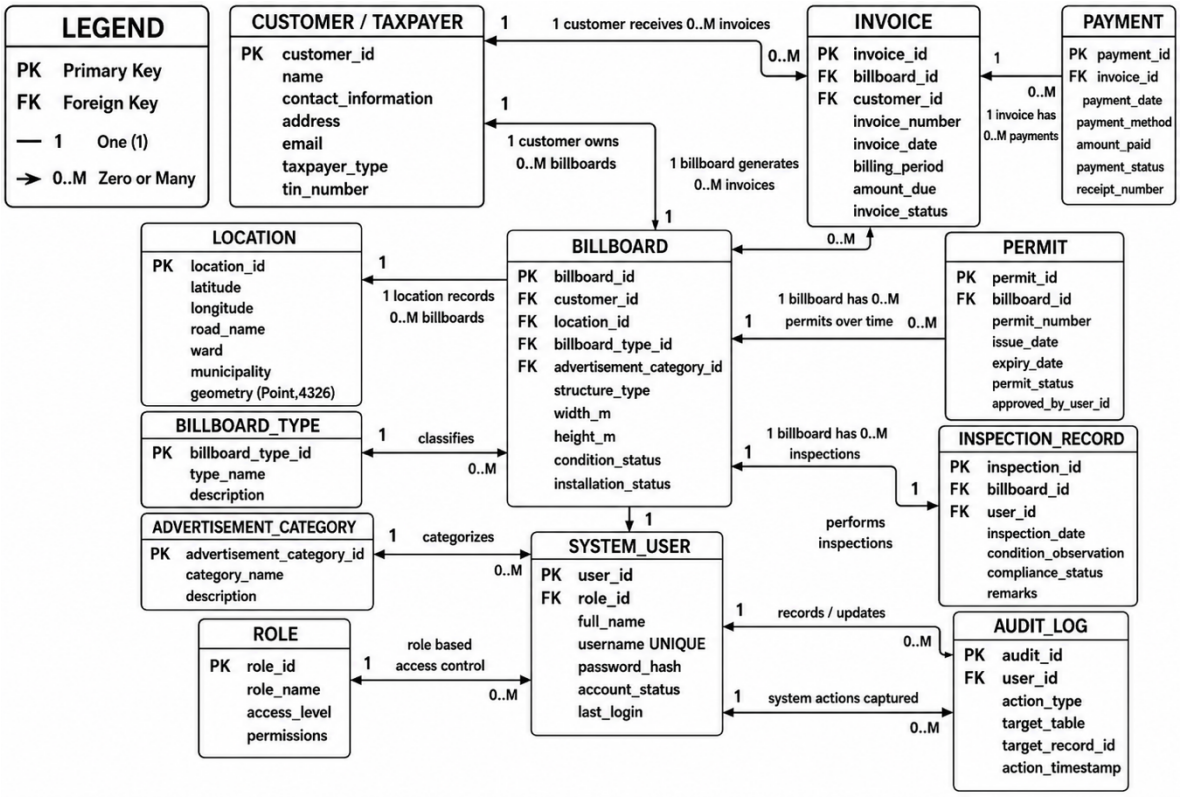

Figure 3: Entity-Relationship Diagram of the Billboard Management Database

The Billboard table is the central component of the database. It stores key details such as billboard structure type, width, height, condition status and installation status. Each billboard is linked to a customer, location, billboard type and advertisement category. This makes it possible to know who owns each billboard, where it is located, how it is classified and whether it is active or requires attention. The Customer/Taxpayer table stores details of billboard owners, including names, contacts, addresses, email addresses, taxpayer type and TIN numbers. One customer can own several billboards. The Location table stores the spatial position of each billboard, including latitude, longitude, road name, ward, municipality and geometry. This allows billboard records to be viewed, queried and analyzed on a map.
Permit and compliance information were managed through the Permit and Inspection Record tables. The Permit table stores permit numbers, issue dates, expiry dates, permit status and approval details. The Inspection Record table stores inspection dates, condition observations, compliance status and remarks. This helps the municipality track whether billboards are properly permitted, inspected and compliant with regulations.

Revenue information was managed through the Invoice and Payment tables. The Invoice table records billing periods, invoice numbers, amounts due and invoice status. The Payment table records payment dates, amounts paid, payment methods, payment status and receipt numbers. This structure supports better tracking of municipal revenue from billboard permits and related charges. The database also includes System User and Role tables to manage access control. Each user is assigned a role that defines what they are allowed to do in the system. User passwords are stored as hashed values to improve security. In addition, the Audit Log table records important system actions, including the user involved, action type, affected table, affected record and action timestamp. This improves accountability and makes it possible to trace changes made in the system. To reduce duplication and improve data

quality, the database was designed following Third Normal Form (3NF) principles. Information such as customer details, billboard categories, permit records, payment records, and user roles was stored in separate but linked tables. This helped improve consistency, reduce errors and make updating and reporting easier. In general, the information management component provided a structured and reliable database for managing billboard inventory, permits, inspections, payments, users and audit records within a Web-GIS environment.

System architecture and Development

The proposed Billboard Management System (BMS) was developed using a multi-layer architecture to ensure scalability, maintainability, security, and efficient handling of spatial and administrative data. The architecture consists of four main layers: the presentation layer, application layer, database layer, and geospatial services layer (Figure 4). This layered design separates user interaction, business logic, data management, and geospatial processing, allowing each component to operate independently while supporting system integration.

The presentation layer serves as the user interface through which both internal and external users interact with the proposed system. It was developed as a web-based application accessible through standard web browsers on desktop and mobile devices. Internal users include administrators, revenue officers, inspectors, and managers, while external users include billboard owners, customers, and taxpayers. The interface supports billboard registration, permit management, inspection reporting, invoice generation, payment tracking, and spatial visualization. Dashboards, forms, tables, and web maps allow users to view, query, update, and analyze billboard information.

The application layer acts as the core processing component of the system. It contains the business logic for validating user inputs, processing requests, applying municipal rules, generating invoices, managing permit workflows, tracking inspections, managing user roles, and coordinating communication between the user interface and the database. This layer also uses application programming interfaces (APIs) to support data exchange between the front-end interface, geospatial services, and the database. The database layer stores and manages all system data. A PostgreSQL/PostGIS geodatabase was used to maintain both spatial and non-spatial information, including billboard records, customer information, permits, inspections, invoices, payments, user accounts and audit logs. PostGIS supports the storage of geographic coordinates and geometry data, enabling spatial queries, proximity analysis and location-based reporting. The geospatial services layer provides mapping and spatial analysis functions. It retrieves spatial data from the PostGIS database and delivers map services to the presentation layer. It supports billboard location visualization, spatial searches, map navigation, spatial analysis and data publishing. These functions allow municipal officers to monitor billboard distribution, identify unregistered structures and analyze spatial patterns related to permit compliance and revenue collection.

Security is treated as a cross-cutting component of the proposed system. User authentication verifies user identities before access is granted, while Role-Based Access Control restricts system functions according to user responsibilities. Passwords are stored using secure hashing instead of plain text. Audit logging records critical system activities, including data creation, modification, approval, and deletion. Backup and recovery procedures are also

included to protect data and support system continuity. In general, the proposed architecture provides a secure, scalable, and integrated Web-GIS platform for billboard inventory management, permit administration, compliance monitoring, spatial analysis and municipal revenue management.

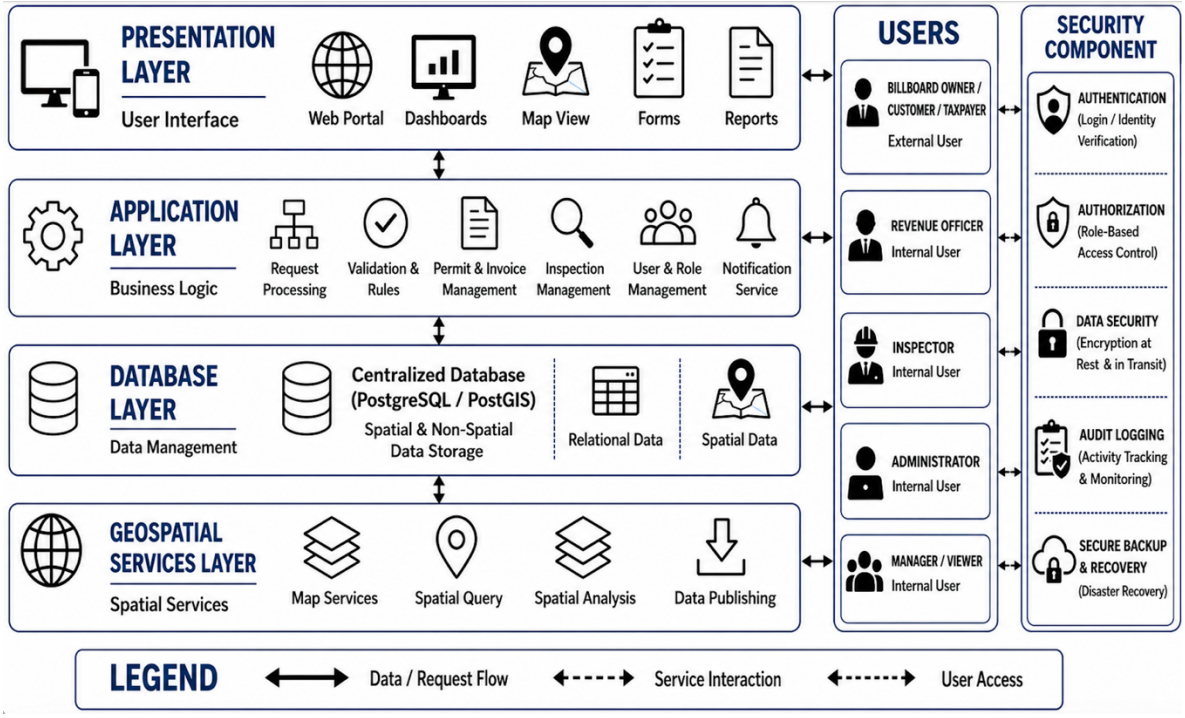

Figure 4: Multi-layer system architecture of the proposed Billboard Management System

Tax Data Integration

To support municipal revenue administration, historical billing records maintained in spreadsheet and paper-based formats were digitized and integrated into the geodatabase. Billboard ownership information, customer records, invoice data and payment status information were linked to corresponding billboard locations using unique identifiers. The integration of spatial and financial information enabled the development of a unified management environment capable of supporting inventory monitoring, invoice generation, payment tracking and administrative reporting.

Functional Testing and Validation

The developed Web-GIS prototype was subjected to functional testing within a controlled localhost environment. The objective was to assess whether the system could successfully perform the intended operational functions identified during the requirements analysis stage. Each function was tested using predefined test cases and expected outcomes. These included creating new billboard records, reading and displaying existing billboard information, updating billboard and customer details and deleting obsolete or incorrect records from the system. Validation also involved interactive map visualization, billboard location display, successful execution of spatial queries, invoice generation, payment status updating and user account management. The testing process confirmed successful interaction between the user interface, geospatial services and the underlying database. Spatial records were correctly displayed and queried, while administrative functions operated as expected. However, testing

was limited to a controlled development environment and did not include deployment under real municipal operational conditions. Consequently, the study did not measure technical benchmarking metrics such as system response time, database performance, usability scores, invoice accuracy or actual changes in tax revenue collection or compliance performance. Table 4 presents the functional validation criteria utilized.

Table 4: Functional validation criteria used during Web-GIS prototype testing

Component	Validation Criterion
Spatial database	Successful CRUD operations
Interactive map	Accurate display of billboard locations
Spatial query	Correct retrieval of billboard records
Billing module	Successful invoice generation
Payment management	Correct payment status updating
User management	Successful authentication and access control

RESULTS

The developed Web-GIS prototype brought together billboard spatial data, attribute information, customer records and billing functions within a single system. Functional testing was carried out in a controlled localhost environment, and all validation criteria presented in Table 4 were successfully met. The results confirmed that the prototype could store, retrieve, update and display billboard records. It also supported interactive mapping, invoice generation and payment status management. These findings demonstrate the technical feasibility of using a Web-GIS framework to support billboard inventory management and municipal tax administration in Kinondoni Municipality.

System dashboard and main interface

The system dashboard provided access to the main functions of the prototype, including billboard registration, map visualization, customer records, invoice management, payment tracking and user administration (Figure 5). The dashboard served as the entry point for municipal officers to manage billboard-related information from a central platform.

Figure 5: Web GIS System Dashboard

Spatial visualization and map interaction

The successful visualization of billboard locations demonstrates that the prototype can effectively integrate geospatial data with administrative records, enabling municipal officers to retrieve location-specific information in real time. The system provides an interactive environment for exploring and managing billboard information (Figure 6). Users could zoom, pan, switch map layers and query billboard records directly from the map interface. Executing a query automatically filtered the selected records and navigated the map to the corresponding billboard location, facilitating rapid retrieval of spatial information. Selecting a billboard marker displayed a detailed information panel containing both spatial and non-spatial attributes retrieved from the PostgreSQL/PostGIS database. In addition to ownership and billboard characteristics, the system linked each record to its corresponding field photograph, enabling users to visually verify the physical condition and identity of the billboard without conducting a field visit. The option to open the full-resolution image further enhanced inspection and verification.

The successful integration of the spatial database, GeoServer web services and the Web GIS interface demonstrates the system's ability to seamlessly combine geospatial data, attribute information and field imagery within a single platform. This functionality improves data validation, monitoring, permit verification and decision-making by providing an accurate and comprehensive spatial inventory of billboards across the municipality.

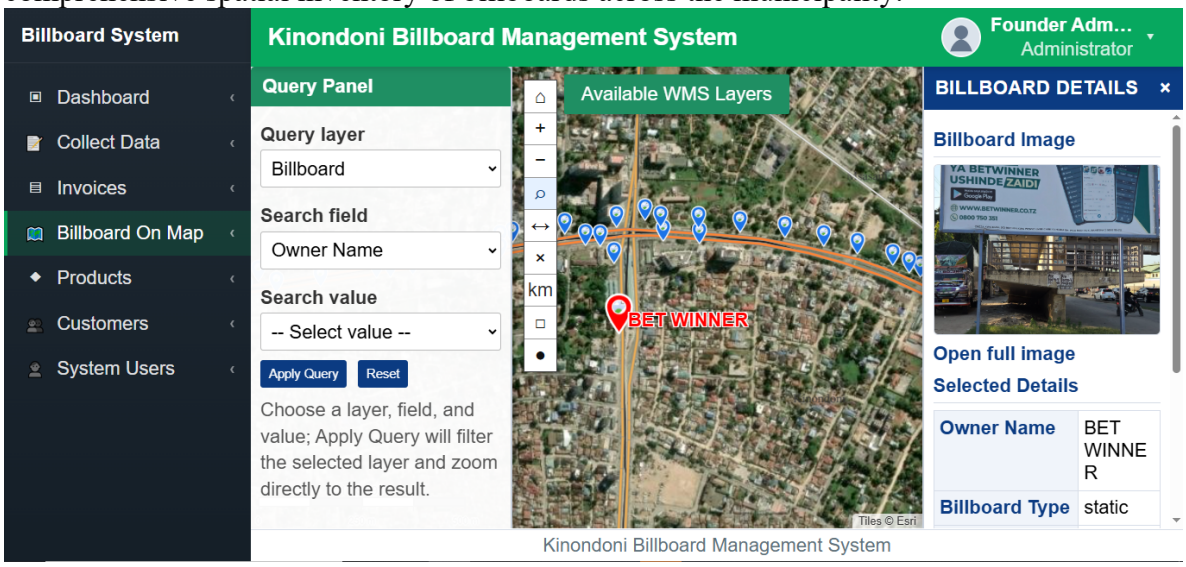

Figure 6: Interactive Web GIS interface illustrating spatial visualization of billboard locations, attribute querying and integration of field photographs for efficient billboard monitoring and management.

Billboard inventory management

The developed Web GIS provides a comprehensive billboard inventory management module that enables authorized users to efficiently store, retrieve, update and manage billboard information through an integrated spatial database. Each billboard record contains both spatial and descriptive information. This includes geographic location, owner name, billboard type, advertisement category, permit status, dimensions, and physical condition. The system incorporates a flexible attribute-based query interface that allows users to search billboard records using different criteria such as owner name, billboard type, permit status or advertisement category. As illustrated in Figure 7 (a-b), users first select the billboard layer, specify the search field and then choose the desired attribute value before executing the

query. The system automatically filters the database and displays only the matching billboard locations on the interactive map while simultaneously zooming to the selected results. For example, querying by Owner Name retrieves all billboards belonging to a particular advertiser, whereas selecting Billboard Type (e.g., non-illuminated) displays only billboards that meet the specified classification.

This query functionality significantly improves inventory management by enabling municipal officers to rapidly locate specific billboard records. They can also verify permit information, identify particular billboard categories and monitor spatial distribution patterns without manually searching through the entire database. The seamless integration of attribute querying with spatial visualization enhances the efficiency of inventory updates, regulatory inspections, compliance monitoring and decision-making. Generally, the system allows users to query billboard records using different search fields (e.g., owner name or billboard type), automatically filter matching records and visualize the corresponding billboard locations on the interactive map (Figure 7 (a-b)).

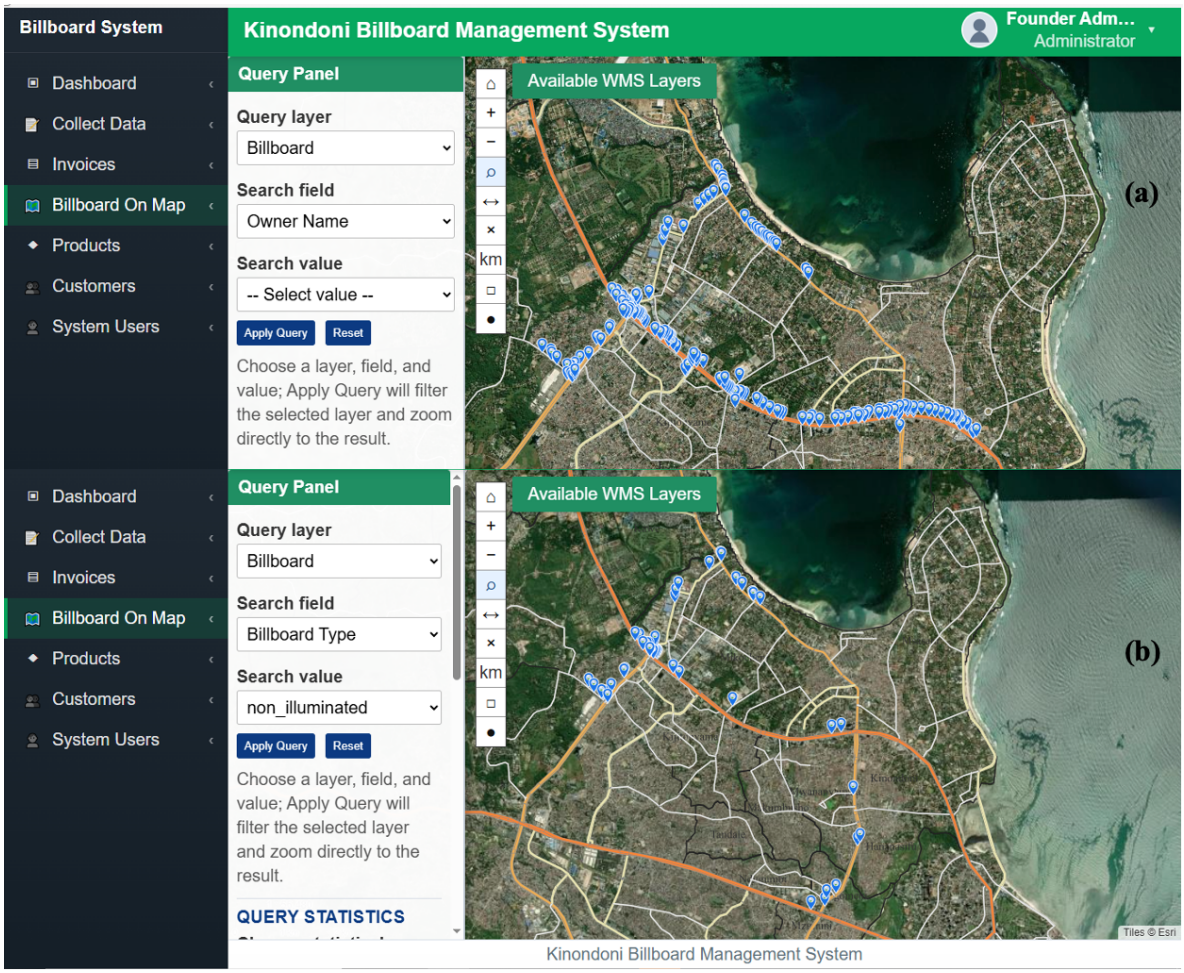

Figure 7: Attribute-based billboard inventory management module of the developed Web GIS (a) Before Query (b) After query.

Billing and payment management

The billing module supports generating and managing invoices (Figure 8). Users could generate invoices, view billing records and update payment information. The module also linked invoices to specific billboard and customer records. This function demonstrated that the prototype could combine spatial asset records with municipal tax administration processes.

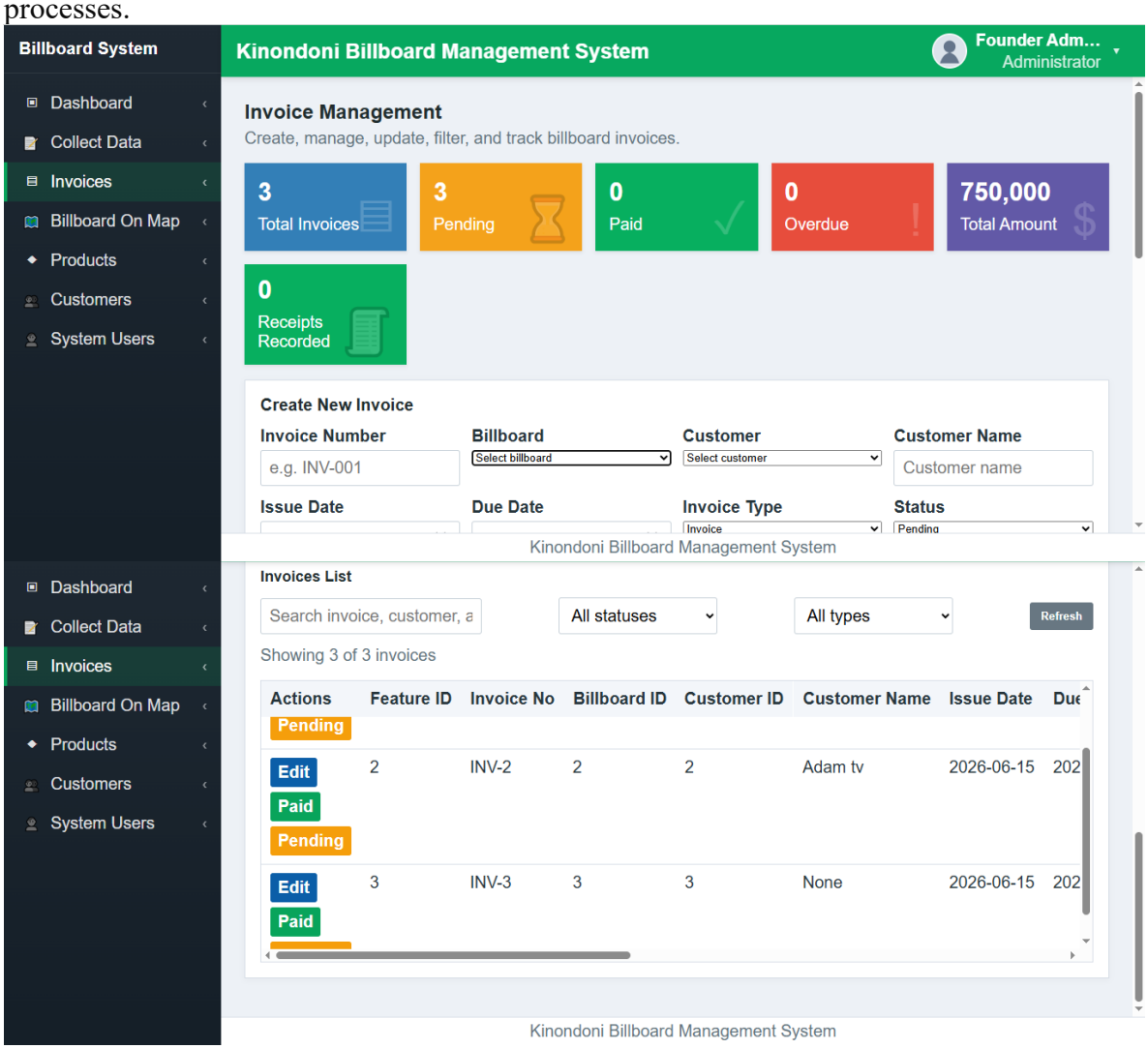

Figure 8: Invoice management module

Functional validation of the prototype

Figure 9 presents the functional validation workflow and outcomes of the developed Web-GIS prototype in a controlled localhost environment. The validation examined whether the main system components operated correctly and communicated effectively. The tested components included the web user interface, GeoServer services, and the PostgreSQL/PostGIS database. Functional testing covered CRUD operations, interactive map display, spatial queries, invoice generation, payment status updates and user authentication. Integration testing further confirmed that spatial and administrative data could be exchanged, stored, retrieved and displayed successfully across the system. The results showed that the prototype performed the intended functions under controlled testing conditions, demonstrating its technical feasibility. However, the validation was limited to

functional and integration testing. It did not include real-world deployment, usability testing, performance benchmarking, security assessment or evaluation of impacts on revenue collection and compliance monitoring.

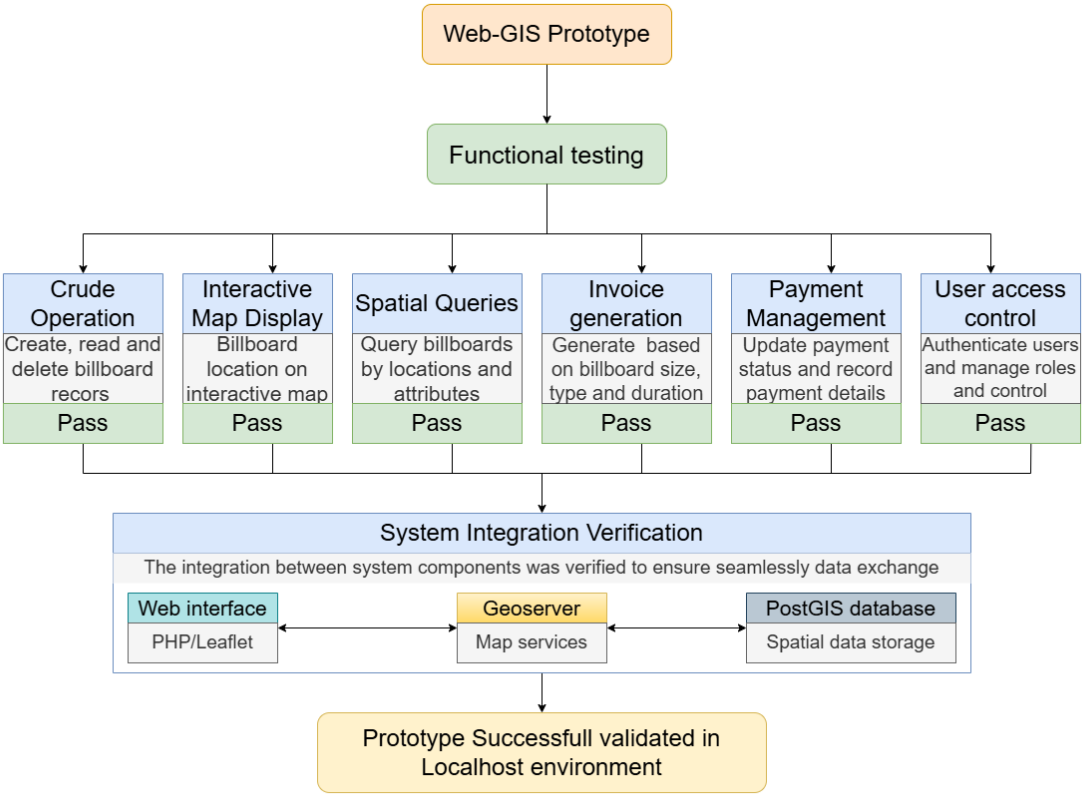

Figure 9: Functional validation workflow and outcomes of the developed Web-GIS prototype in a controlled localhost environment

DISCUSSION

This study developed and functionally validated the Web-GIS framework for billboard inventory management and municipal tax administration in Kinondoni Municipality. The successful operation of the prototype demonstrates the technical feasibility of integrating spatial information, billboard inventory records and billing functions within a single web-based platform. The findings address a common challenge faced by many municipalities where billboard records, permit information and revenue data are often maintained in separate systems, making information management and retrieval difficult. One of the most important outcomes of the study was the integration of spatial and administrative information within a PostgreSQL/PostGIS geodatabase. By linking billboard locations with ownership records, permit information and billing data, the framework established a centralized information repository for billboard management. This integration reduces data fragmentation and provides a more structured approach to managing billboard assets. Similar benefits of integrated geospatial information systems have been reported in municipal management studies, where the combination of spatial and administrative datasets improves data accessibility, consistency and information sharing across departments (Gil-Garcia J. Ramon and Pardo, 2016; Mango, Çolak and Li, 2021; Vinueza-Martinez et al., 2024).

The interactive mapping capability further demonstrated the value of Web-GIS technologies for municipal asset management. The ability to visualize billboard locations and retrieve associated attribute information directly from the map provides a spatial dimension that is often absent in conventional record management systems. Spatial visualization allows municipal officers to associate records with their geographic locations, potentially improving field verification, monitoring and inventory management activities. Similar observations have been reported in studies that highlight the role of Web-GIS in enhancing access to location-based information and supporting urban management processes (Gil-Garcia et al., 2018; Mango et al., 2021).

The implementation of CRUD operations confirmed that the system can support routine updating and maintenance of billboard records. The ability to create, retrieve, update and delete records is fundamental for ensuring that billboard inventories remain current and reliable. This is particularly important in dynamic urban environments where billboard ownership, permit status and advertisement content frequently change. The successful implementation of these functions demonstrates that the framework can support the continuous management of billboard information rather than serving solely as a static inventory database. The successful integration of billing and payment management functions represents another important contribution of the framework. Invoice records and payment status information were directly linked to billboard locations and customer records, allowing administrative and financial information to be managed within the same environment. This integration demonstrates the potential of Web-GIS to support not only spatial inventory management but also related administrative processes. However, because the prototype was evaluated through functional testing only, the study cannot determine whether such integration would improve revenue collection performance, compliance monitoring or administrative efficiency in practice. These aspects require evaluation under real operational conditions.

The study also demonstrates the practicality of using open-source geospatial technologies for municipal information system development. The successful integration of PostgreSQL/PostGIS, GeoServer, Leaflet and PHP shows that robust Web-GIS applications can be developed without reliance on proprietary software. This finding is particularly relevant for municipalities in developing countries where financial resources are often constrained. Open-source platforms provide opportunities for customization, local capacity development and incremental system expansion while reducing software acquisition costs (OSGeo, 2024; UN, 2024). Despite these positive outcomes, the findings should be interpreted within the limitations of the study. System validation was conducted in a controlled localhost environment and focused primarily on functional performance. Consequently, the results demonstrate technical feasibility rather than operational effectiveness. Important aspects such as system scalability, response time, usability, user satisfaction, database performance and impacts on municipal revenue administration were not evaluated. Therefore, the study provides evidence that the framework functions as intended, but it does not provide evidence regarding its institutional, financial or operational benefits.

Successful implementation of the framework will depend on factors beyond the technical design of the system. Adequate ICT infrastructure, reliable internet connectivity, staff capacity, institutional support and effective data management procedures will be necessary to sustain long-term operation. Similar challenges have been identified as major barriers to

the adoption of digital government systems in developing-country municipalities. (Gil-Garcia et al., 2018; UN, 2024). Consequently, technological innovation should be accompanied by organizational capacity building and institutional commitment. In general, the findings demonstrate that Web-GIS provides a technically viable platform for integrating billboard inventory management and municipal tax administration. The successful integration of spatial visualization, inventory management and billing functions within a single platform establishes a foundation for future operational deployment. Further research should focus on pilot implementation under real municipal conditions to evaluate usability, user acceptance, system performance and potential contributions to revenue administration and compliance monitoring.

Beyond the development of a prototype, the study contributes empirical evidence on the feasibility of integrating billboard inventory management and municipal tax administration within a single Web-GIS platform. The findings demonstrate that spatial records, ownership information, permit data and billing records can be effectively linked through a common geospatial database and accessed through a web-based interface. The study further demonstrates the applicability of open-source technologies, including PostgreSQL/PostGIS, GeoServer and Leaflet, for developing municipal revenue management solutions in resource-constrained environments. These findings extend existing research on municipal GIS applications by illustrating how spatial and financial information can be integrated to support billboard administration within a unified framework.

Limitations and Challenges of the WebGIS

The findings of this study should be interpreted within the scope of the prototype developed and evaluated. Although the Web-GIS framework successfully integrated billboard inventory management, compliance monitoring and municipal tax administration functions, the study primarily assessed technical feasibility rather than operational performance. The results therefore demonstrate that the system functions worked in a controlled testing environment, but they do not yet prove effectiveness under real municipal operating conditions.

The framework was tested in a controlled localhost environment and was not deployed within an operational municipal setting. Consequently, the study did not evaluate system performance under conditions involving multiple concurrent users, large transaction volumes, varying network conditions or long-term database operation. In addition, issues related to cybersecurity, data recovery, interoperability with existing municipal information systems and cloud-based deployment were beyond the scope of this study. These factors are widely recognized as important components of sustainable digital government transformation (OECD, 2024; World Bank, 2025).

The study focused on system development and functional testing. It did not assess operational outcomes such as revenue collection performance, tax compliance rates, processing time, user satisfaction or administrative efficiency. Therefore, the findings should not be interpreted as evidence of improved fiscal performance or cost savings. The practical value of digital government systems is usually established through implementation, user evaluation and long-term monitoring in real institutional settings (UN, 2024; World Bank, 2025). Successful implementation of the framework will depend on institutional readiness and effective data governance. Accurate and up-to-date records of billboard ownership, permits,

invoices and payments are essential for maintaining system reliability. Effective coordination among departments responsible for planning, licensing, revenue administration and ICT services will also be necessary. Digital government studies emphasize that institutional capacity, data governance, leadership commitment and cross-departmental coordination are critical for successful digital transformation (OECD, 2024; World Bank, 2025).

Although the framework was developed using open-source technologies, implementation and maintenance still require investment in hardware, network infrastructure, technical support, staff training and system administration. Municipalities operating under financial and human-resource constraints may face challenges in sustaining digital systems over time. Resource availability, technical capacity and sustained funding remain important factors affecting digital government implementation, particularly at local government level (UN, 2024; World Bank, 2025). The framework was designed and tested within a specific case-study context. Although its modular architecture suggests that it could be adapted to other municipalities and municipal assets, this has not yet been tested. Future studies should evaluate the system under real operating conditions, including its performance, user acceptance and effectiveness in different institutional settings. Further improvements may include mobile GIS tools, cloud-based deployment, UAV-supported inventory verification and artificial intelligence for automated billboard detection and compliance monitoring. In general, the study demonstrates the technical feasibility of the Web-GIS framework. However, pilot implementation and long-term operational testing are still needed before conclusions can be made about its effectiveness, efficiency and wider institutional impacts.

CONCLUSION AND RECOMMENDATIONS

Conclusion

This study successfully developed a Web-GIS framework for billboard management and municipal tax administration in Kinondoni Municipality, Tanzania. The framework brings together billboard locations, ownership details, permit records, invoices, payments and user management in one geospatial platform. The results show that the prototype can store, retrieve, display and manage billboard-related spatial and administrative information. Functional testing confirmed that key system components, including billboard registration, map visualization, invoice generation, payment tracking and user management, worked as intended. These findings demonstrate the technical feasibility of using Web-GIS technology to support billboard management and municipal tax administration. More importantly, the study shows that billboard inventory records and tax administration data can be linked within a single Web-GIS framework. It also demonstrates that open-source geospatial technologies can provide a practical foundation for developing municipal revenue management systems in developing-country contexts.

However, the study was limited to prototype development and testing in a controlled environment. The system was not deployed in actual municipal operations. Therefore, the study does not provide direct evidence of improved revenue collection, tax compliance, administrative efficiency or cost savings. These impacts can only be assessed through pilot implementation and long-term use under real working conditions. In general, the study provides a practical foundation for applying Web-GIS technologies in municipal asset management and revenue administration. It also contributes to the growing body of knowledge on municipal geospatial information systems and supports wider efforts to

promote digital transformation and evidence-based decision-making in local government institutions.

RECOMMENDATIONS

Based on the findings of this study, several recommendations are proposed. First, the Web-GIS framework should be piloted in a real municipal environment to assess its performance under actual operating conditions. This would help determine system usability, reliability, user acceptance and institutional readiness. Second, future evaluations should assess the operational impact of the system. These should include effects on revenue collection, tax compliance, processing time, data quality, invoice accuracy, user satisfaction and administrative efficiency. Such assessment is necessary before making conclusions about the system's practical benefits. Third, the framework should be integrated with existing municipal information systems, especially those used for planning, licensing, revenue administration and ICT services. This would improve data sharing and reduce duplication of records across departments. Fourth, municipalities should provide adequate staff training, technical support and clear procedures for system use. Regular updating of billboard locations, ownership records, permits, invoices and payment information will be essential for maintaining data quality and long-term system sustainability. Finally, future system enhancements should consider mobile GIS tools for field inspections, cloud-based deployment for wider access, automated reporting dashboards and the use of UAV imagery or artificial intelligence for billboard identification and compliance monitoring. Further research should also test the applicability of the framework in other municipalities and for managing other revenue-generating municipal assets.

Conflict of Interest

The authors report there are no conflict of interests to declare.

Ethics

The author declares that the Ethics declaration is not applicable.

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