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Development of WebGIS for Street Light Mapping Using Geospatial Tools

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Abstract

Padang City, as one of the cities the largest on the west coast of Sumatra Island, plays a strategic role in the economy and government. One of the vital infrastructures that supports public activities is the street lighting system. However, the monitoring and maintenance of streetlights still face obstacles, especially in North Padang District, which is the busiest area due to the presence of numerous educational facilities, government offices, and economic centers. This research aims to develop a WebGIS application that facilitates the monitoring and management of street lighting more efficiently. Our research contributes by introducing a new approach to spatial-based streetlight management strategies. This approach is based on a methodology for field data collection and spatial database development to manage all stages of streetlight infrastructure management. This application integrates geospatial technology by utilizing GeoServer, QGIS, and PostgreSQL for visualization and spatial data management. With this system, information about the location and condition of streetlights can be accessed in real-time, thereby facilitating better planning and maintenance of street lighting infrastructure. The result of this study is a WebGIS application capable of mapping and monitoring streetlight points interactively. The implementation of this system is expected to assist relevant authorities in improving the effectiveness of street lighting management in Padang City and contribute to the development of geospatial technology-based solutions for urban infrastructure.

Keywords : *Geoserver, Spatial Data Management, Street light, WebGIS.*

1. INTRODUCTION

West Sumatra is a province in Indonesia, with Padang City as its capital and one of the major cities along Sumatra Island's western coast. [1]. The city acts as Indonesia's primary entry point from the Indian Ocean. [2]. Padang is encircled by towering hills that rise up to 1,853 meters above sea level and spans an area of 1,414.96 square kilometers, with more than half of its territory consisting of protected forest [3]. Based on data from the Central Bureau of Statistics (Indonesia) in 2022, the population of Padang City reached 919,145 people [4]. increasing to 928,541 in mid-2023. The economy of Padang City is also supported by the tourism sector and the MICE (Meeting, Incentive, Convention, and Exhibition) industry [5]. Padang has served as the educational hub of West Sumatra since the Dutch colonial period [6, 7], attracting many students from surrounding areas.

Padang city has 11 sub-districts, one of which is North Padang District. This district consists of seven sub-districts, including Mount Pangilun and North Padang, which play an important role in economic, educational, and tourism development [8]. With a coastal area offering significant economic potential, North Padang serves as one of the city's main economic hubs [9, 10]. Its adequate infrastructure and easy access to public facilities make it one of the fastest-growing districts in Padang. Overall, this district has remarkable potential for continued development and significantly contributes to the economic growth and welfare of Padang City's population [11, 12].

One of the key infrastructures supporting Padang City's economy is street lighting. This infrastructure plays a crucial role in daily public life. A study conducted by Liu showed that well-maintained street lighting can increase the sense of security and comfort for road users while also supporting nighttime economic activities [12]. Based on verified reports from official news portals in Padang City, the Department of Transportation, through the Public Street Lighting Technical Service Unit, manages 32,054 streetlight points across Padang City [13]. With such a large number of streetlights, a well-organized monitoring and maintenance system is essential. One of the main challenges in this maintenance is identifying malfunctioning streetlights and determining the type of lamps used at each location. This issue aligns with findings by Pardo and Siwar, who highlighted the common difficulties faced in the efficient monitoring and maintenance of public infrastructure [15, 16].

In the context of infrastructure management, WebGIS offers high flexibility as it can be accessed from various internet-connected devices [16]. WebGIS (Web-based Geographic Information System) is a geographic information system that operates online [17], allowing for more efficient and real-time management, visualization, and analysis of spatial data [18]. Moreover, WebGIS serves as a framework that integrates software and hardware to handle spatial data in the form of maps, offering a valuable source of information and knowledge [19]. With these features, WebGIS is an effective solution for improving the efficiency of asset planning and maintenance [20], as well as supporting transparency and public participation in managing public services [21]. Asset management by government institutions encompasses the entire process from planning to the systematic inventory of existing assets, including those acquired through legitimate means. This management ensures that assets are properly handled to maximize benefits for the community [22].

Visualizing street lighting using a WebGIS system is essential for the Department of Transportation to better understand its work areas and facilitate streetlight maintenance planning. With digital maps displaying the location and condition of streetlights, the Department of Transportation can easily identify lamps that require repairs, optimize maintenance routes, and ensure adequate lighting coverage in all areas. This is consistent with the findings of Xin Feng, who stated that a city's economy improves when street lighting is evenly distributed on public roads [23]. Furthermore, research conducted by Raffaele Carli highlights that visualizing street lighting enables efficient resource allocation, repair planning, and real-time asset monitoring, ultimately enhancing the overall quality of street lighting management and public services [24].

This study aims to develop an application for monitoring and maintaining streetlights in Padang City, specifically focusing on the North Padang District. As one of the city's most densely populated and economically active areas, this district is home to numerous offices and public facilities that support local economic activities. To better understand the characteristics of street lighting, we develop management strategies based on spatial data. This new approach involves a methodology for field data collection and spatial database development to manage all aspects of streetlight maintenance. This strategy has proven highly effective in transferring streetlight data to a new storage facility and developing new analytical frameworks.

Unlike previous studies that primarily focused on road infrastructure or general utility networks, this research addresses streetlight management through a spatially-integrated WebGIS approach specifically designed for dense, coastal urban environments such as North Padang. This localized and infrastructure-specific focus introduces a novel contribution to the field of smart urban infrastructure management.

We also present a geographic approach to mapping the spatial locations of streetlights to support effective street lighting management in Padang City. By incorporating real-time field data into a centralized spatial database, this study delivers a dynamic and responsive system for monitoring and maintenance an approach that has not yet been widely applied in Indonesian municipal infrastructure. In this study, we also present a geographic approach to mapping the spatial locations of streetlights to support the effective management of street lighting in Padang City.

Several prior studies have explored WebGIS applications for infrastructure and environmental management. For example, Mazhindu & Madamombe [25], focused on designing and developing an

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interactive web-based GIS tool for digital road infrastructure management. This application not only allows users to visualize road infrastructure content but also aids in decision-making. The system utilizes open-source GIS tools, including PostgreSQL and PostGIS for managing spatial and non-spatial data, GeoServer for connecting the database to the mapping application, and Apache Tomcat for building and deploying the application. Maps are published through GeoServer, with information presented using JavaScript libraries such as OpenLayers and GeoExt. Advanced spatial analysis (attribute queries) can be performed online. The study resulted in a system capable of managing road infrastructure assets, such as road signs, bridges, animal crossing networks, and rest areas. Users can query specific assets they wish to visualize, such as damaged bridges.

Another study by Cui [26], developed a WebGIS system based on the GeoServer platform. It employed an open-source spatial database (PostgreSQL), the Vue front-end framework, and OpenLayers for WebGIS client-side visualization. The system integrates OGC services (such as WFS and WMS) to manage land garden information. It supports key functions, including order management, evaluation management, fruit sales tracking, and user information management.

Shaohua [27] conducted related research, developing a GIS-based visualization system for monitoring power transmission channels. The system uses the OpenLayers GIS engine and incorporates Vue, JavaScript front-end technologies, Express framework, Node.js, MariaDB, and GeoServer. The study demonstrates the effectiveness of a two-dimensional GIS solution for managing power transmission networks, ensuring efficient daily operations and maintenance.

In 2023, Alberto conducted a study focused on designing a Web GIS platform that enables stakeholders, including domain experts, decision-makers, researchers, and students to (i) manage flood data and simulation results across different contextual levels, (ii) process and curate sensory data from physical and social sensors, and (iii) update simulation parameters through continuous data assimilation techniques for objective forecasting. The study provided real-world validation using the "Águeda 2016" flood event dataset, which is publicly available for further research and experimentation [28].

Another study [29] updated the "Geological Atlas Interactive Portal", which provides access to an integrated research database for environmental studies. This service includes geodata visualization, layer selection, legend views, metadata access, and tectonic evolution analysis. The system applies the FAIR (Findability, Accessibility, Interoperability, and Reusability) Guiding Principles to improve data visibility and accessibility. The research data is exported as HTML pages and can be navigated using an embedded web viewer, which can be integrated with multi-user databases with different access levels (e.g., editor, administrator).

Similar research was conducted by Grigory [29] and Gleb Igorevich Zagrebin [30], who developed a web-based mapping system that allows for easy database updates. The data is stored remotely in a spatial database and is dynamically retrieved upon user requests. This approach ensures fast information delivery to end users and provides an optimized geoinformation service.

According to Somnath Chaudhuri in his book [31], GIS researchers have begun to explore methods of sharing GIS features online rather than using them as standalone systems. As WebGIS continues to evolve, the concept of Geospatial Mashups has gained traction. In the context of WebGIS, a Mashup refers to the integration of multiple data sources both spatial and non-spatial into a unified spatial representation. This process involves retrieving spatial data from non-spatial sources, merging it with other spatial datasets, and finally visualizing it on a map. Mashups have the potential to combine various types of content and functionalities via the web, regardless of whether a formal programming interface is available [32].

This study utilizes PostgreSQL/PostGIS as its database platform. Our research references a study conducted by [33], highlights the increasing demand for large-scale data management, leading to the emergence of NoSQL Database Management Systems (DBMS) as an alternative to traditional relational databases. One commonly used NoSQL database is a graph-based database, with Neo4j being a well-known Graph DBMS. However, Neo4j has limited spatial data processing capabilities. In their study, the researchers developed an SQL interface to enable spatial data retrieval by integrating PostGIS extensions with Neo4j. The key difference between their study and ours is that we store spatial data directly in PostgreSQL without utilizing Neo4j's graph-based features.

A comparable system by Andre da Silva Mano, focusing on the management of natural history and paleontology collections. The researcher applied a strategic management approach based on the spatial

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location of fossil discoveries. To achieve this, they implemented a field collection methodology and developed a spatial database in PostgreSQL/PostGIS to manage all stages of paleontological collection management. On top of the database, additional Web GIS services, a Geographic Information System (GIS) application, and a QGIS-based desktop GIS system were developed. These systems facilitate data access for both internal and external researchers, institutional partners, and public institutions. Andre stated that PostgreSQL is highly capable of managing spatial data, including the earth's surface locations [34].

Our research contributes by introducing a new approach to spatial-based streetlight management strategies. This approach is based on a methodology for field data collection and spatial database development to manage all stages of streetlight infrastructure management. This new strategy has proven effective in transferring streetlight location data to a new storage facility and developing new research directions. Therefore, this study aims to develop a WebGIS-based solution for visualizing streetlight locations in North Padang District, enhancing the effectiveness and efficiency of street lighting infrastructure management.

2. METHOD

2.1 System Scenario Framework

The WebGIS system is designed to visualize streetlights, allowing users to view locations and related information through an interactive and user-friendly web-based interface. In the system scenario shown in Figure 3, the researchers provide the necessary software for the development of this WebGIS application.

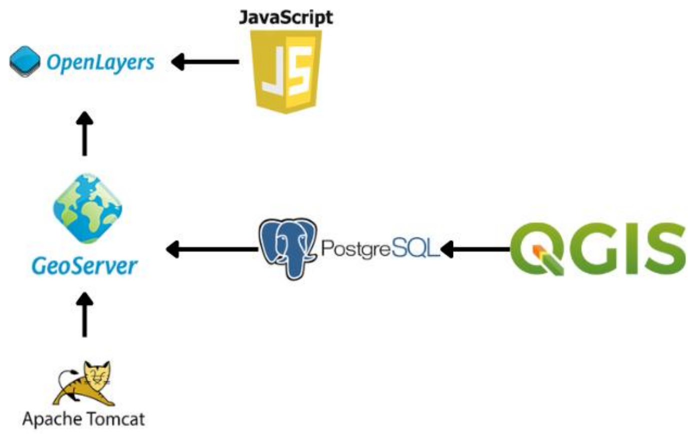

Figure 1. System Scenario Components

In Figure 1, OpenLayers is used to build an interactive web interface that displays maps and streetlight data using the JavaScript programming language. OpenLayers requires GeoServer, as GeoServer functions as a server for publishing geospatial data that has been collected, analyzed, and stored in PostgreSQL [37]. GeoServer also depends on an active Apache Tomcat service, as Apache Tomcat is an application server used to operate GeoServer and provide a stable and reliable environment for web applications [38]. Figure 1 also illustrates that the data processed in PostgreSQL originates from geospatial data that has been prepared and managed using QGIS software.

2.2 Webgis Development Stages

In this research, the researchers developed a Geographic Information System (GIS) based on WebGIS. The development of this WebGIS requires QGIS, GeoServer, PostGIS, and PostgreSQL software to store and visualize streetlight data in the WebGIS platform. The development stages can be seen in Figure

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23. In this figure, the contribution of each software used in the development process of this application is illustrated.

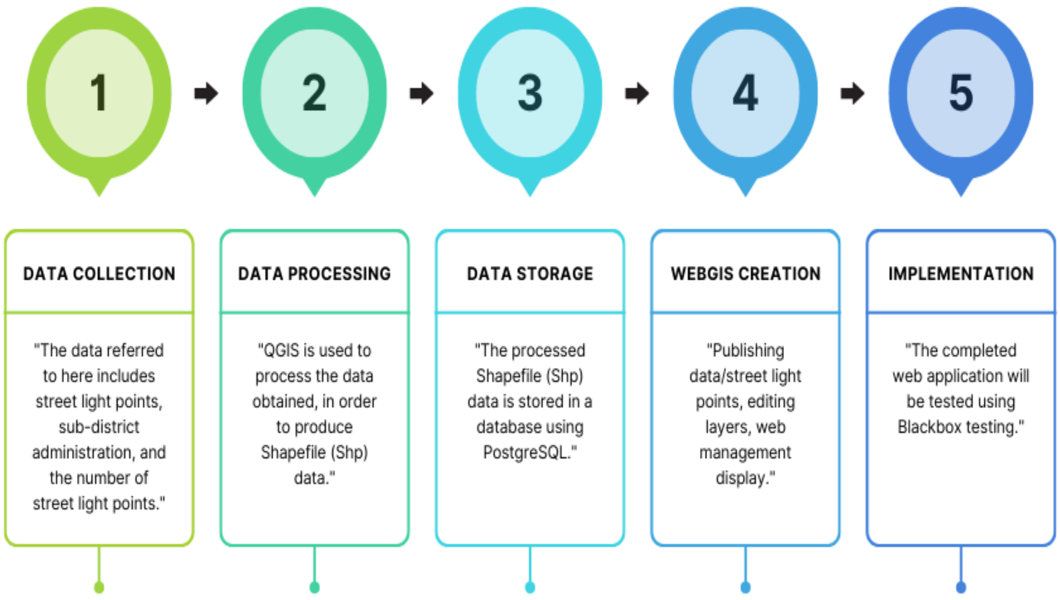

Figure 2. Stages of WebGIS Development

The following stages were carried out in building this WebGIS :

2.2.1. Data Collection

In this study, the data collection phase involved the acquisition of both spatial and non-spatial data. Spatial data were obtained in the form of shapefiles (.shp), including the geographic coordinates of streetlight locations, administrative boundaries of North Padang District, and associated infrastructure. These data were primarily gathered from field observations, publicly available spatial databases, and official city planning resources. Meanwhile, non-spatial data comprised descriptive attributes of the streetlights, such as lamp types (LED or conventional), pole material and height, usage categories (e.g., smart or conventional system), and electrical specifications. This dual-data approach allows for a more comprehensive representation of each lighting point, ensuring that both location and attribute data are well-integrated in the GIS platform.

2.2.2. Data Processing

Once the spatial and non-spatial data were collected, the next step involved processing and cleaning the data to ensure quality and consistency. Spatial data were imported into QGIS using the "Add Layer" functionality to overlay basemaps from OpenStreetMap (OSM) as references. Streetlight locations were digitized using coordinate information derived from Google Earth and validated through the Street View feature to increase spatial accuracy. Each location was marked as a point feature and assigned attribute information sourced from the Padang City Transportation Agency. Attribute tables were created and populated with complete metadata for each streetlight. The use of KML to SHP conversion ensured compatibility with PostgreSQL/PostGIS later in the pipeline. This careful preparation of data facilitates more reliable visualization and analysis in the subsequent stages.

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2.2.3 Data Storage

After preprocessing in QGIS, the spatial data in SHP format were uploaded into a PostgreSQL database environment that had been extended with the PostGIS spatial module. This setup allowed for efficient storage, indexing, and querying of geospatial information. Prior to uploading, the PostgreSQL environment was configured using pgAdmin to define schemas, set roles, and enable spatial references using SRID (Spatial Reference System Identifier) codes—specifically EPSG:4326 for global compatibility. The use of PostGIS enhances the capability of the database to handle geometry-based operations, making it suitable for WebGIS applications. This spatial database acts as the backbone for GeoServer to retrieve and serve map layers dynamically. The structured approach in data storage ensures data integrity, scalability, and high-performance access for WebGIS rendering.

2.2.4 WebGIS Development and Implementation

The implementation phase focused on developing the WebGIS application that integrates the spatial database with a dynamic web-based map interface. The SHP files, which were previously processed and stored in PostgreSQL with PostGIS extension, were published using GeoServer. This open-source server enables the exposure of geospatial data through web services such as WMS (Web Map Service) and WFS (Web Feature Service).

The integration process involved creating a workspace and data store in GeoServer, establishing a connection to the PostGIS database, and registering spatial layers representing streetlight locations. Each layer was configured with appropriate symbology and coordinate reference system to ensure accurate rendering. On the client-side, the WebGIS interface was developed using OpenLayers, a JavaScript library for web mapping. This library allows the creation of an interactive map interface that can communicate directly with GeoServer. The front end was designed to support core functionalities such as data visualization, layer toggling, and attribute access.

The system architecture emphasizes modularity and scalability, enabling future integration with additional tools such as data filters or analytical plugins. This development process lays the foundation for a robust spatial information system that facilitates efficient access to streetlight data in a user-friendly format.

The SHP data that has been processed in QGIS and stored in PostgreSQL is then uploaded to GeoServer. Once uploaded, the data is published and visualized in the WebGIS system. The SHP data in GeoServer is structured into layers, which can be edited and combined to form interactive maps. This process involves merging multiple layers within GeoServer and displaying them using OpenLayers. The WebGIS application is then used by relevant stakeholders to evaluate the system's effectiveness. To ensure its functionality, the application undergoes a black-box testing process. This testing method evaluates the application's features and performance without examining the internal code structure or implementation details [39] [40].

3. RESULTS

3.1. Data Collection

Based on official data from the Department of Transportation, Padang City manages approximately 32,054 streetlights across various areas. However, for this study, a sample of 200 streetlights from North Padang District was selected. This sample provides a representative overview of streetlight distribution and conditions in the area, serving as the dataset for WebGIS development.

The collected data includes technical aspects such as power capacity, lamp type (e.g., LED or conventional), usage category (e.g., smart system or conventional), and physical structure (e.g., pole type and materials used). This data is processed using QGIS and stored in a PostgreSQL/PostGIS database for visualization in WebGIS, which maps the distribution of street lights in North Padang District in detail.

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Table 1 shows the number of streetlights recorded for input into WebGIS, covering the area from Prof. Dr. Hamka Street to Teuku Umar Street. The data includes detailed specifications for each streetlight, with a total of 200 streetlights.

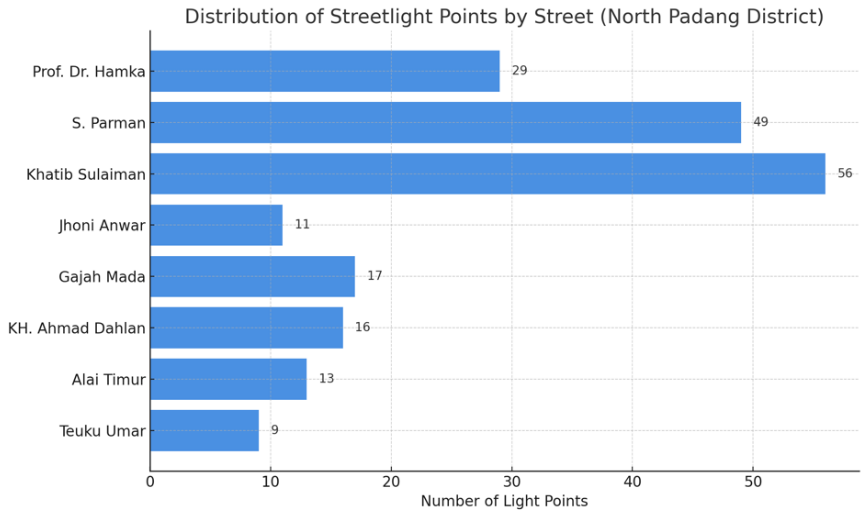

Figure 2. Number of Light Points

3.2. Data Processing

Data from the Padang City Transportation Agency was processed into SHP format through a digitization process using QGIS. Before digitization, the data from the Padang City Transportation Agency needed to be equipped with point coordinates for each streetlight. These coordinates were obtained by locating each streetlight using Google Earth and the Street View feature.

The process of marking streetlight locations was carried out using Google Earth as a digital mapping platform. Each streetlight location was identified and represented as a geographic marker (placemark). The locations were manually marked on a digital map, and attribute information, such as location names or identification numbers, was added. The marked data was then saved in KML format, which is an XML-based standard for geospatial data representation. This format allows for easy data interoperability, making it simple to integrate into GIS or WebGIS applications for more advanced spatial analysis. This approach is not only effective in documenting the distribution of streetlights but also ensures high geographical accuracy in the resulting data.

The digitization process was carried out using the QGIS application, which displays maps from all over the world by selecting "OpenStreetMap" in the XYZ Tiles menu in the QGIS browser. OpenStreetMap serves as a basemap, providing a fundamental reference layer that is essential for the digitization process. Once the basemap layer appears, the digitization process can begin. Data in XML format is imported into QGIS but is only used for displaying the streetlight tracking points and cannot be edited. Therefore, the data is then converted into SHP format, allowing it to be processed and adjusted according to project needs. The conversion process is illustrated in Figure 4.

The streetlight data, including specifications for each light, was obtained from the Padang City Transportation Agency and then entered into each corresponding point on the basemap. When a point is clicked, a table appears displaying the required attributes, such as sub-district, village, construction, power, type, and category, which define the streetlight specifications.

This data entry process is conducted using QGIS software. Once all the necessary data has been filled in, it is saved again in SHP format. The processed SHP file is then stored in PostgreSQL and PostGIS databases for further management and analysis.

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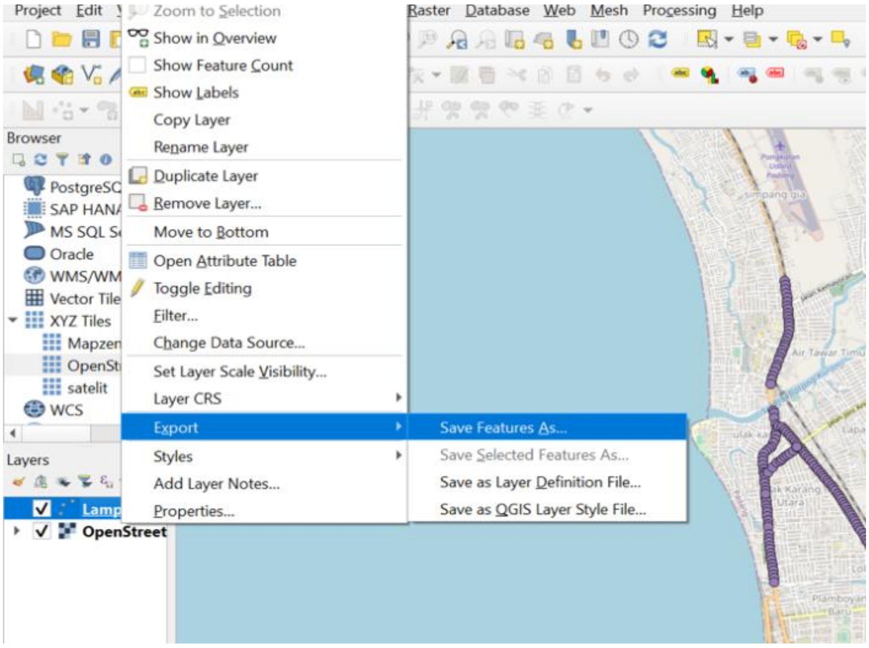

Figure 3. Save Layer

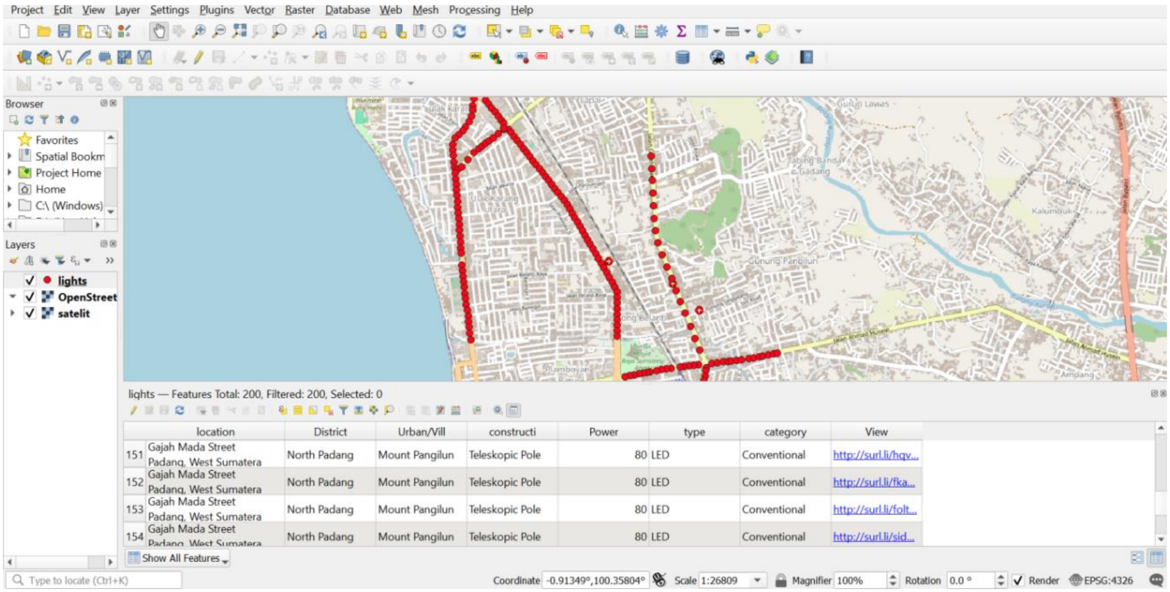

Figure 4. Open Attribute Table

3.3. Data Storage

The processed data, which results in an SHP file, will be uploaded to PostgreSQL using PostGIS. PostGIS enables the processing and storage of geospatial data within the PostgreSQL database, allowing the SHP file to be imported and managed efficiently. This process facilitates easier access, querying, and manipulation of stored geospatial data in PostgreSQL [42] .

The first step in storing SHP data in PostgreSQL is activating pgAdmin, a management tool for PostgreSQL. pgAdmin is used to design, maintain, and administer PostgreSQL databases. Using pgAdmin, a database can be created and configured, and SHP data can be imported into PostgreSQL through built-in PostGIS features that support geospatial data processing.

PostGIS is a spatial database extension for PostgreSQL that enables the storage and processing of geospatial data [43]. In Figure 6, the features of PostGIS supporting SHP data upload are illustrated. Before

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using PostGIS, users must connect an existing PostgreSQL database with PostGIS. This step is crucial to ensure that SHP format data is successfully imported into the targeted database and managed using PostGIS.

During this process, it is essential to enter correct and accurate information, including username, password, and database name, to ensure a smooth connection. Once PostGIS is successfully connected to PostgreSQL, the "Add File" feature can be used to upload and store SHP files within the PostgreSQL database integrated with PostGIS. This step is critical for importing geospatial data in SHP format into the PostgreSQL database system, where it can be further managed and processed. Additionally, the SRID (Spatial Reference Identifier) field must be filled in. SRID is a distinctive identifier assigned to a particular coordinate system, defining its tolerance and resolution [39]. The SRID value varies depending on the database used. For example, if using the EPSG:4326 coordinate system, entering 4326 is sufficient as its encoding.

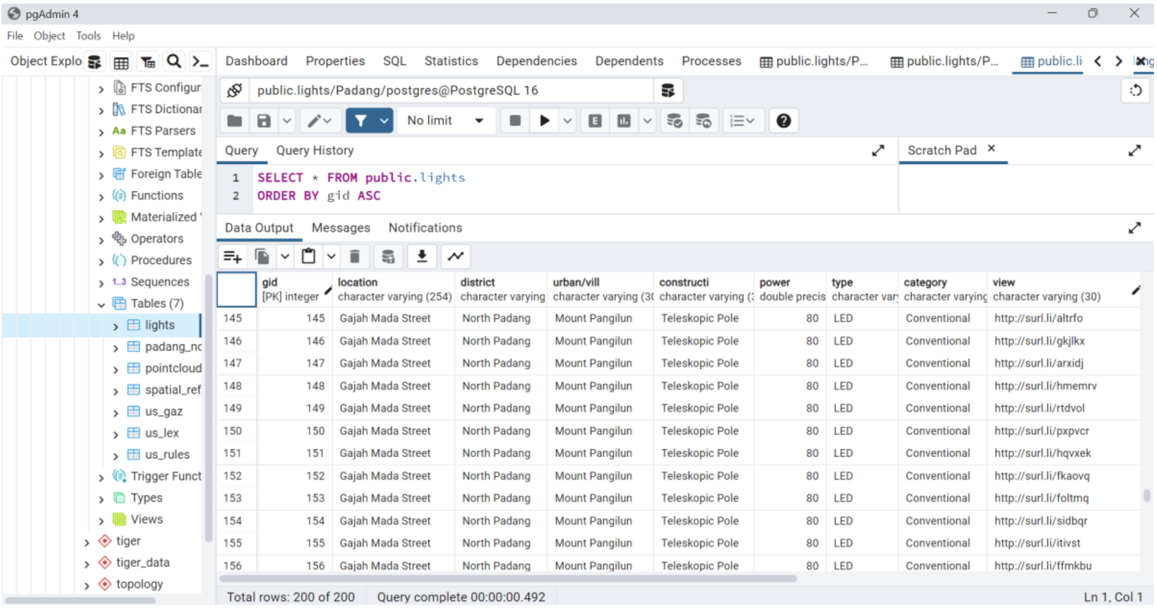

Figure 5. SHP Data Table

3.4. Webgis Development with Geoserver

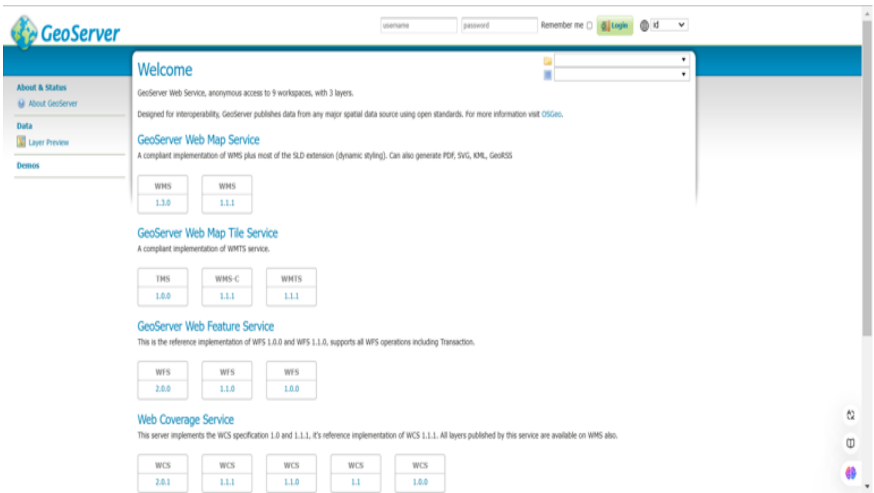

Figure 6. Geoserver

The necessary steps involve publishing the data layer stored in the database using GeoServer. GeoServer functions as a GIS server that allows users to access and share geospatial data via the web.

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Figure 7 shows the initial page of GeoServer. On this page, we can see the version of the Open Geospatial Consortium (OGC) protocols included in our GeoServer configuration. In GeoServer, we configure the connection between GeoServer and the PostGIS database so that layers containing point data for streetlight locations and attributes can be accessed and displayed properly in the WebGIS application. With proper configuration, the data can be dynamically displayed on the map in the WebGIS application, facilitating easy monitoring and analysis of streetlight distribution in Padang City.

Furthermore, to publish our layers, we must prepare data sources and storage space. Storage space is added by selecting a new data source type. In this case, PostGIS is chosen because, in addition to functioning as a database, it also ensures secure data management. To connect GeoServer to PostGIS, the connection parameters must be provided, including the server, port, database, schema, username, and password. Once the connection is successfully established, the database contents can be accessed and used for publishing layers. The published layers will appear in the layer list on GeoServer, as shown in Figure 8. Users can manage these layers, including removing or disabling layers if needed. This feature ensures that only relevant and active layers are displayed in the WebGIS application.

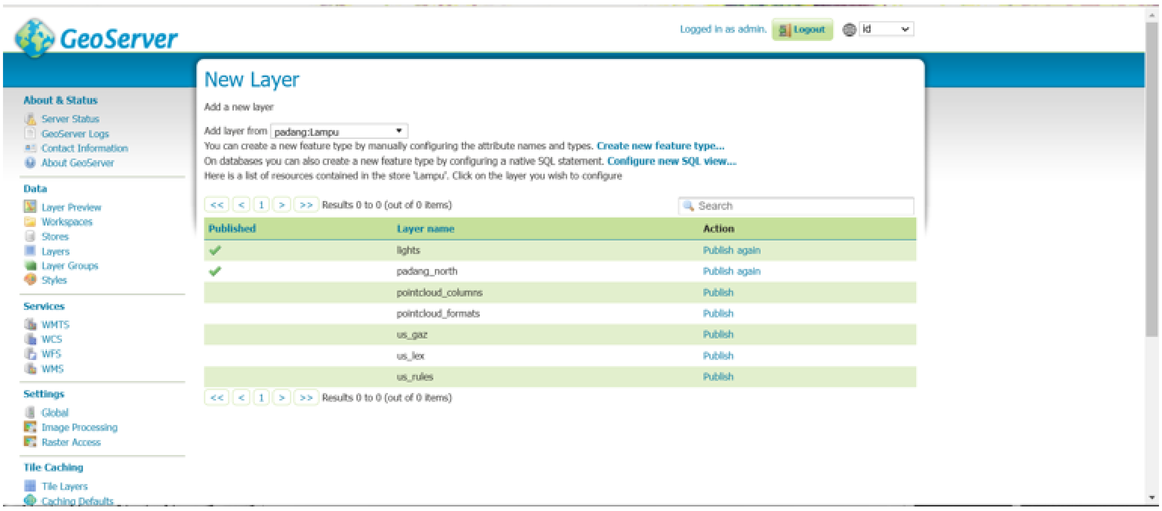

Figure 7. Adding Light Layers

The layers that have been published can be viewed using the 'Layer Preview' feature in GeoServer. This feature allows users to display a preview of the published layer to check the accuracy of the uploaded data. This includes verifying that the streetlight locations are correct and that the map is displayed as expected. This step is essential to ensure that the data is ready for use before the layer is integrated into the WebGIS application.

On the home page as shown in Figure 9, there are elements such as images that can change dynamically in a slideshow format, as well as information about the benefits and functions of WebGIS. This page also provides a special button that allows users to navigate directly to the streetlight map. When the button is pressed, users will be directed to the streetlight map page, where they can access information related to the distribution of streetlights.

The streetlight point map on WebGIS provides a visualization of the distribution of streetlights in the North Padang area. As shown in Figure 10, each streetlight point is displayed as an overlay on an OpenStreetMap (OSM)-based map, allowing users to clearly see the locations of the lights. This display enables visitors to easily identify the position of each mapped streetlight.

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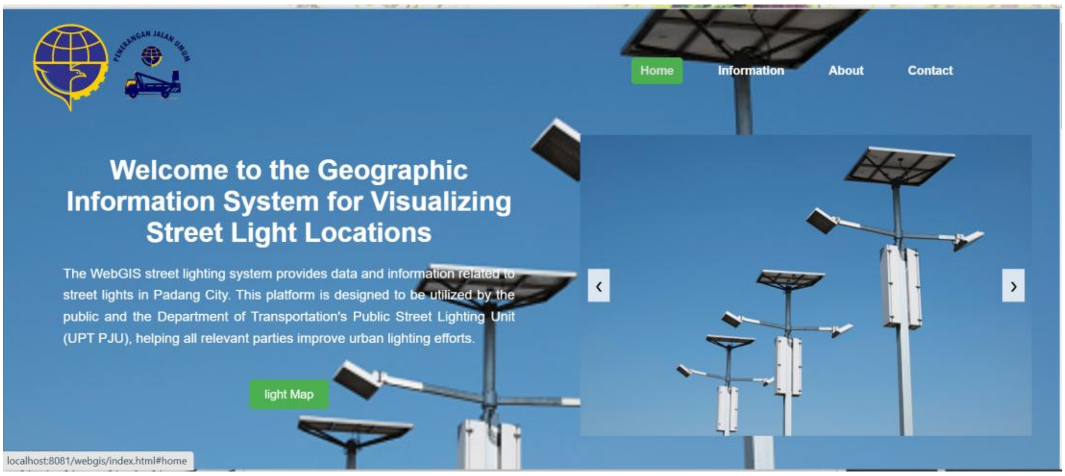

Figure 8. Home WebGIS

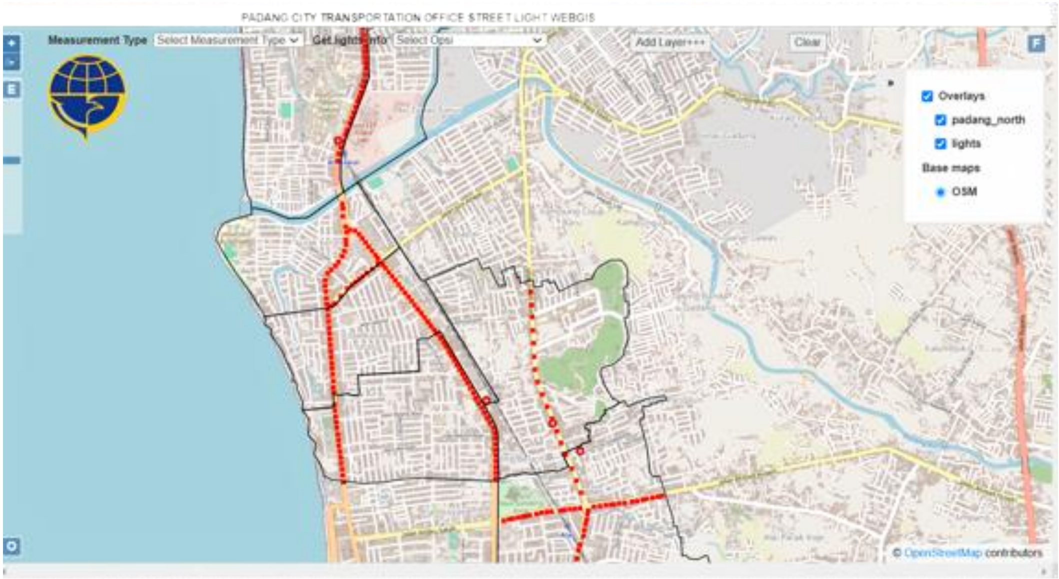

Figure 9. Light Map WebGIS

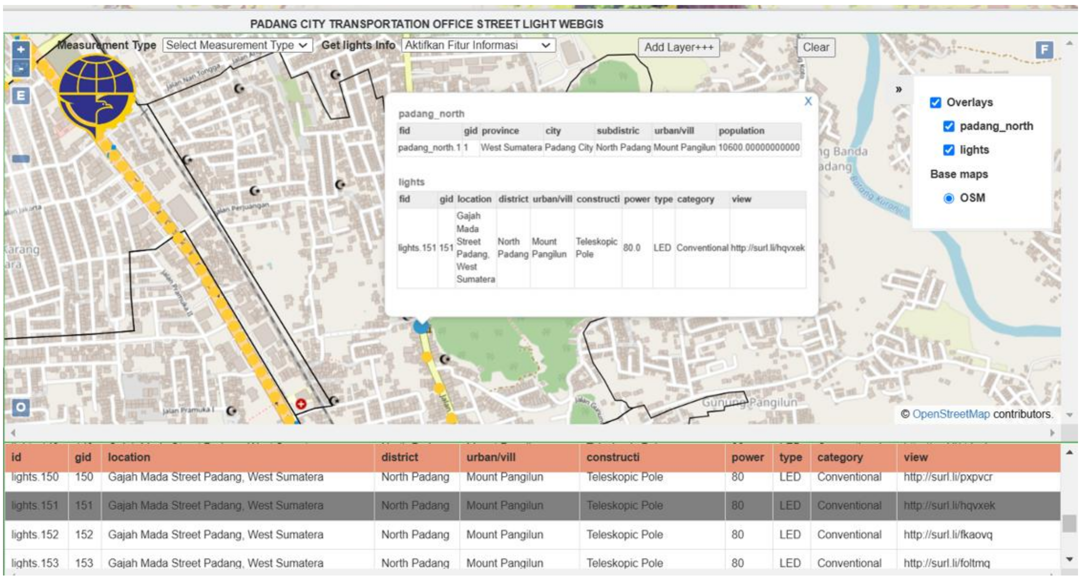

Figure 10 Information Features

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The Information feature on WebGIS allows visitors to view detailed information about a specific streetlight. When a light is clicked, its related information is displayed in a table format, including data such as location, type, power, and other relevant attributes. In Figure 12, Lamp 151 is shown to be located on Gajah Mada Street, North Padang District, Mount Pangilun Village. The pole construction at this location is a telescopic pole with a power of 80 Watts. The lamp type is LED, and it is categorized as a Smart System. In the last column, a link is provided that directs users to a real image of the lamp's location.

3.5. System Performance Evaluation

To ensure the practicality and responsiveness of the developed WebGIS system for streetlight management, a series of performance evaluations were conducted focusing on load time, concurrent user support, database responsiveness, and system resource consumption.

Table 1. System Performance Evaluation

No	Evaluation Indicator	Test Result	Description
1	Streetlight point layer loading time	0.8 seconds (GeoJSON, 0.5 MB)	Measured using Chrome browser, cache disabled
2	Main road layer loading time	1.3 seconds (converted Shapefile to PostGIS, 3.2 MB)	Served via GeoServer and visualized with Leaflet
3	Maximum concurrent users supported	25 active users without significant degradation	Simulated using Apache JMeter
4	Average database query time	18–50 milliseconds for streetlight table (820 records)	Tested on PostgreSQL with PostGIS extension
5	Server resource usage	CPU: 65%, RAM: 1.2 GB (under 20 active users)	Server, 8 GB RAM, Windows 11
6	Real-time data availability	Available immediately after field input	Data synchronized via input form and auto-refreshed map layer

Table 1 shows the average layer loading time was measured to be 0.8 seconds for the streetlight point data layer (in GeoJSON format) and 1.3 seconds for the main road network layer served via GeoServer. These results demonstrate that the system is capable of rendering spatial layers in near real-time, which is crucial for an application intended for interactive use by technical staff and decision-makers. A concurrent user load test was performed using Apache JMeter, simulating active usage by multiple users. The system remained responsive up to 25 simultaneous users, with only minor latency (less than 2 seconds) observed under peak conditions. This is considered sufficient for the current operational needs of local government stakeholders.

In terms of database performance, the PostgreSQL database integrated with PostGIS returned streetlight queries with an average response time of 18 to 50 milliseconds, even with over 800 data entries. This indicates that spatial queries are efficiently handled, supporting both monitoring and analytical tasks. Regarding system scalability, testing was performed on a server with 8 GB of RAM. During active usage by 20 users, resource usage remained within acceptable limits, with CPU utilization peaking at 65% and RAM usage around 1.2 GB. These findings suggest that the system is stable and scalable for small to medium-scale deployment without significant infrastructure investment.

Furthermore, the application supports real-time data updates, where new information submitted from the field is automatically reflected in the WebGIS interface through data synchronization and dynamic layer refreshing. Overall, the performance results confirm that the system is technically viable, responsive, and ready for operational use in supporting the spatial management of street lighting infrastructure in Padang City.

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4. DISCUSSIONS

The implementation of a WebGIS-based streetlight monitoring system in North Padang District provides significant improvements in infrastructure management, especially in the context of digital transformation in urban areas. Based on the spatial visualization produced, users can clearly identify the position, type, and category of each streetlight, which supports better decision-making in terms of asset maintenance and planning.

Compared to the manual methods traditionally used by the Department of Transportation, this system significantly reduces time and effort in locating and verifying field data. This finding is aligned with previous studies, such as the one conducted by Carli et al. [24], which emphasized the efficiency gained from using WebGIS for managing urban lighting systems. Moreover, the use of PostgreSQL and PostGIS in this study ensures scalable and efficient data management, which has also been reported as a best practice in other GIS-based studies [36], [40]. The addition of OpenLayers and GeoServer as visualization tools further strengthens the accessibility and interactivity of the system.

Despite its advantages, the current WebGIS system lacks real-time status updates or public interaction mechanisms. In future research, it is recommended to integrate sensor-based IoT systems to monitor streetlight functionality and allow automatic updates of streetlight conditions. Such integration would enhance the system's responsiveness and maintenance prioritization, especially in critical public areas. Additionally, future development could involve a citizen-reporting module that enables the public to submit complaints about malfunctioning streetlights directly through the WebGIS interface. This feature has been suggested in previous smart city frameworks [15], as it supports participatory governance and increases transparency in public service delivery.

Therefore, this research not only contributes technically by providing a functional prototype but also opens opportunities for further innovation in smart infrastructure management for urban environments. In terms of scientific contribution, this research advances the field of Information Technology by demonstrating the application of open-source geospatial technologies in building scalable, web-based infrastructure monitoring systems. It highlights the practical integration of spatial databases, web mapping services, and geoinformatics tools as a comprehensive framework for developing responsive digital platforms in urban infrastructure management.

5. CONCLUSION

The research results on the visualization of street light locations using WebGIS (Case Study: North Padang District) provide comprehensive information on the distribution of streetlights in the area. The study identified a total of 200 streetlights along major roads, from Prof. Dr. Hamka to Teuku Umar street over a distance of 7 km.

The WebGIS system for visualizing streetlight locations in North Padang offers users a clear representation of streetlight positions. It enables users to visually locate streetlights and access detailed specifications for each one. The system provides seven key pieces of information for each light: location, district, village, pole construction, power, type, and category. Additionally, a filtering feature allows users to search based on specific attributes. The information is presented in a tabular format, making it easy to understand.

By utilizing WebGIS technology, the Padang City Transportation Agency can efficiently map and monitor streetlight locations in real time. This enhances planning and asset maintenance processes. Furthermore, WebGIS facilitates maintenance teams by providing accurate information about the number and location of streetlights in their respective work areas - information that was previously difficult to obtain in detail.

A potential improvement to this system would be the addition of a streetlight damage complaint feature for the Department of Transportation, allowing the public to report faulty streetlights directly through the WebGIS application. Implementing this feature could accelerate the response time for repairs and maintenance. By incorporating this suggestion, it is hoped that this study can contribute to a more useful and efficient system in the future.

CONFLICT OF INTEREST

Anisya and other authors that there is no conflict of interest between the authors or with research object in this paper.

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