Design of a Client-Side Based WebGIS System for Health Service Distribution Analysis (Case Study of Sukabumi Regency)

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Abstract

Equitable healthcare services require the support of information systems capable of presenting data spatially and being easily accessible to decision-makers. However, most of the geographic information systems currently in use still rely on server-based architecture and centralized databases, which demand technical resources and infrastructure that are not always available at the regional level. This research aims to design a client-side WebGIS system to analyze the distribution of healthcare services in Sukabumi Regency. The system was developed using HTML, CSS, and JavaScript technologies with the use of LeafletJS and OpenStreetMap as the base map, as well as GeoJSON and Google Sheets as sources of dynamic spatial and non-spatial data. The client-side processing approach allows the entire process of visualization and spatial analysis to be carried out on the client side without reliance on the database server. The implementation results show that the system is capable of presenting interactive maps, facility distribution analysis, and identifying areas with unmet healthcare service needs. The novelty of this research lies in the implementation of a lightweight, flexible, and easily replicable client-side WebGIS architecture, making it suitable for institutions with limited technical resources in the development of spatial information systems.

Keywords*: WebGIS, Client-Side Processing, Geographic Information System, Software Engineering, Spatial Analysis.*

INTRODUCTION

The utilization of information technology in the public service sector continues to evolve along with the increasing need for accurate, integrated, and easily accessible information. One of the technologies widely used to support location-based decision-making is Geographic Information Systems (GIS). GIS enables the integrated management and analysis of spatial and non-spatial data, allowing for the presentation of more contextual and visual information in various fields, including regional planning and healthcare services (Peterson, 2020).

In the context of healthcare services, the uneven distribution of facilities and healthcare personnel remains a problem in many areas. This disparity can affect the community's access to adequate healthcare services and impact the overall quality of service. The use of GIS is considered effective in identifying the distribution patterns of healthcare facilities and supporting the analysis of spatially-based service accessibility (Fradelos et al., 2021; Tanser et al., 2020).

The development of web technology has driven the implementation of GIS in the form of WebGIS, which allows for the presentation and utilization of spatial data online and interactively thru web browsers. WebGIS provides easy access to information for various stakeholders without requiring specialized GIS software, making it more flexible and easier to adopt in organizational environments with limited technical resources (Peterson, 2020; Kessler & Slocum, 2020).

Most WebGIS development generally still relies on server-based architecture with centralized database support. This approach requires server infrastructure and relatively complex system management. As an alternative, the client-side processing approach allows data processing to be carried out directly on the user's side by utilizing JavaScript and open data formats such as GeoJSON. This approach is considered lighter, more flexible, and capable of reducing dependence on server database infrastructure (Zhao et al., 2021).

Based on these issues, this research develops a client-side processing-based WebGIS system to support the analysis of the distribution and access to healthcare services in Sukabumi Regency. The developed system, SIGKES, utilizes modern web technology and open spatial data to present information on the distribution of facilities and healthcare personnel interactively. It is hoped that this system can become an easily replicable applicative solution and support spatially-based decision-making in the context of regional healthcare services.

LITERATUR REVIEW

2.1 Geographic Information System

Geographic Information System (GIS) is a computer-based system used to manage, analyze, and present data with geographic references. GIS allows the integration of spatial and non-spatial data, thereby supporting location-based analysis processes in various fields, including regional planning and public services. The use of GIS is considered effective in aiding decision-making because it can present information visually and contextually (Peterson, 2020).

2.2 WebGIS in Public Services

The development of web technology has driven the implementation of GIS in the form of WebGIS, which allows access and utilization of spatial data online and interactively thru web browsers. WebGIS has been widely implemented in the public service sector, including the mapping of healthcare facilities, to help identify disparities in service distribution and support spatial-based planning. The use of WebGIS provides easy access to information for various stakeholders without the need for specialized GIS software (Peterson, 2020; Kessler & Slocum, 2020). WebGIS has been widely implemented in the public service sector, including the mapping of facilities and analysis of healthcare service access, to help identify disparities in service distribution and support spatial-based planning (Fradelos et al., 2021; Tanser et al., 2020).

2.3 Client Side Processing in Web Applications

The client-side processing approach in WebGIS application development allows data processing to be carried out directly on the user's side by utilizing JavaScript and modern web technologies. This approach is considered lighter and more flexible compared to server-based architecture because it can reduce server load and dependence on centralized databases. In the context of WebGIS, the use of open data formats such as GeoJSON allows for the visualization and manipulation of spatial data directly on the client side, making it suitable for system development with limited technical infrastructure (Zhao et al., 2021).

2.4 Related Research

Several previous studies have examined the implementation of WebGIS for mapping public service facilities. The research results show that WebGIS is capable of enhancing the understanding of facility distribution patterns and supporting the presentation of spatial information that is easily accessible to users. However, most studies still use a server-based architecture with support from conventional databases. Therefore, this research focuses on the development of a client-side processing-based WebGIS system as a simpler, more flexible, and easily replicable architectural alternative, particularly to support health service analysis at the regional level (Putra & Suryanto, 2022). Several previous studies have shown that the implementation of WebGIS in the health service sector is effective in supporting spatial analysis of facility distribution and service access, although most still use server-based architecture (Tanser et al., 2020).

2.5 Information System Testing Model

System testing is an important stage in software development to ensure that the functions built operate according to user needs. One of the commonly used testing methods in the development of web-based information systems is black-box testing, which focuses on testing the system's functionality without considering the internal structure of the program code. This approach is suitable for evaluating the alignment between user needs and system outputs. In software engineering research, functional testing is often associated with the aspect of functional suitability as described in the ISO/IEC 25010 software quality standard (ISO/IEC, 2020).

METHOD

3.1. Type and Approach of Research

This research uses a software engineering approach with a WebGIS-based information system development method. This approach was chosen to design and implement a system capable of supporting the analysis of the distribution and access to healthcare services spatially. The research is descriptive and applicative in nature, focusing on the utilization of WebGIS technology to present spatial information interactively as a basis for decision-making.

3.2. Research Stages

The research stages are carried out in a gradual and systematic manner, including:

1. System Requirements Analysis This stage includes identifying user needs, the types of data used, and the main functions of the system. The system requirements focus on mapping health facilities, analyzing the distribution of healthcare workers, and presenting information based on sub-district and community health center areas.
2. System Design The design is carried out by structuring the architecture of the WebGIS system based on client-side processing. At this stage, the system components, data flow, and user interaction mechanisms with the presented maps and data are determined.
3. System Implementation The system is implemented using standard web technologies consisting of HTML, CSS, and JavaScript. LeafletJS is used as the mapping library, OpenStreetMap as the base map, spatial data in GeoJSON format, and Google Sheets as the source of non-spatial data accessed via API.
4. Testing and Validation Testing is conducted to ensure that all system functions operate according to requirements, including map loading tests, display of health facility markers, data filtering, and analysis of healthcare workforce needs at each community health center.
5. Final Stage Analysis in the form of mapping results analysis and data visualization to identify areas with adequate, insufficient, or critical healthcare service conditions.

3.3. System Architecture

The developed system architecture applies the client-side based WebGIS concept, where all data processing, map visualization, and user interaction processes are carried out on the client side (browser). The system does not use a centralized database server, making it lighter and easier to replicate.

The web application utilizes LeafletJS as a mapping library to display interactive maps. Spatial data is presented in GeoJSON format, while non-spatial data such as the number of healthcare workers is dynamically obtained from Google Sheets via API. OpenStreetMap is used as the base map provider. The overall system architecture is shown in Figure 1.

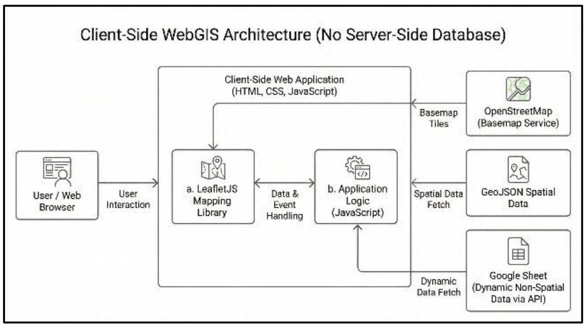

Figure 1. Client-Side Based WebGIS System Architecture

Figure 1 shows the architecture of the WebGIS system developed with a client-side processing approach, where the entire process of visualization, data processing, and user interaction is carried out entirely on the client side (browser). The web application is built using HTML, CSS, and JavaScript with LeafletJS as the mapping library and OpenStreetMap as the base map provider. Spatial data is presented in GeoJSON format, while non-spatial data is dynamically obtained from Google Sheets via API, allowing the system to operate without reliance on a centralized database server.

3.4. Data Collection Techniques

1. The data used in this research consists of: Spatial data, in the form of the locations of community health centers and the boundaries of sub-districts in Sukabumi Regency in GeoJSON format.

2. Non-spatial data, in the form of data on facilities and healthcare personnel (doctors, nurses, midwives, nutritionists, and others) obtained from relevant agencies and stored in Google Sheets.

3.5. Data Analysis Techniques

Data analysis is conducted descriptively and spatially. Health worker data is analyzed to determine the status of healthcare service needs at each community health center, classified into adequate, insufficient, and crisis categories. The analysis results are visualized in the form of thematic maps and concise tables to facilitate interpretation and decision-making.

RESULTS AND DISCUSSION

4.1 Results of WebGIS System Implementation SIGKES

The main result of this research is the development of the SIGKES system, a client-side processing-based WebGIS application capable of presenting spatial information on the distribution and access to health services in Sukabumi Regency. This system displays an interactive map that includes the locations of community health centers along with supporting information related to the availability of facilities and healthcare personnel. The implementation of the system is carried out entirely using standard web technology without involving a database server. Spatial data is displayed in GeoJSON format, while non-spatial data is dynamically obtained from Google Sheets via API. This approach allows for flexible and efficient data updates without changes to the core application code. Functionally, the system is capable of loading the OpenStreetMap base map, displaying markers for health center locations, and presenting attribute information thru interactive popups. Users can access health service information based on sub-district and community health center areas directly thru a web browser The Health Geographic Information System (SIGKES) has been successfully implemented as a client-side processing-based WebGIS application that can be accessed thru a web browser. The implementation of this system allows users to visualize the distribution of healthcare facilities and healthcare personnel spatially, equipped with search features, data filtering, and the presentation of statistical information in a concise and interactive manner.

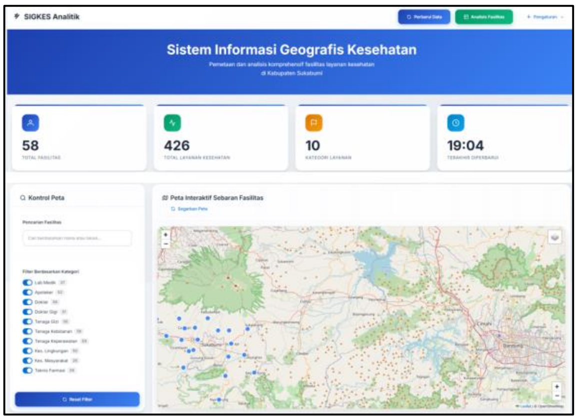

Figure 2. Interface Display of the SIGKES WebGIS Application Based on Client-Side Processing

Figure 2 shows the main interface of the SIGKES application, which consists of a data summary panel, mapping controls, and an interactive map based on LeafletJS and OpenStreetMap. The entire process of loading spatial and non-spatial data is done on the client side using JavaScript, including dynamic data retrieval thru Google Sheets and GeoJSON data processing. This approach allows the system to run lightly without relying on a server database, while also supporting real-time spatial analysis for healthcare planning and evaluation needs.

4.2. Analysis of Distribution and Status of Health Services by Sub district

Based on the spatial visualization results produced by the SIGKES system, it is evident that the distribution of healthcare services in Sukabumi Regency is not yet fully equitable. Some areas show a relatively adequate density of facilities and healthcare personnel, while other areas still experience service limitations. Spatial analysis was conducted by comparing the availability of healthcare personnel at each community health center (puskesmas) against the service needs standards. The results of this analysis are then classified into three categories: adequate, insufficient, and crisis. This classification is visualized in the form of thematic maps so that the differences in conditions between regions can be observed more clearly. From the mapping results, the SIGKES system is able to identify areas that require further attention, particularly sub-districts categorized as crisis and less. This information is important as a starting point in planning the equitable distribution of healthcare needs. To obtain a more comprehensive picture of the health service conditions in Sukabumi Regency, an analysis of the distribution of healthcare personnel across all sub-districts was conducted. This analysis includes several categories of healthcare workers. main, namely doctors, dentists, nursing staff, midwifery staff, nutritionists, pharmacists, public health, environmental health, and medical laboratory staff. The distribution of healthcare workers was analyzed quantitatively by sub-district to identify disparities in service availability, as well as to serve as a basis for determining the health service status in each region.

The visualization of the distribution of healthcare workers per sub-district is presented in the form of a stacked bar graph as shown in Figure 3.

distribution of healthcare human resources, especially in areas with limitations of facilities and access to services. The results of this analysis serve as the basis for determining the status of healthcare services per sub-district, which are subsequently classified into adequate, insufficient, and crisis categories. These classifications are used as an initial reference in formulating policy recommendations for the equitable distribution and strengthening of healthcare services at the regional level. To clarify the results of the healthcare workforce distribution analysis, a summary table has been prepared that illustrates the status of healthcare service needs at the sub-district level. This table summarizes the system's interpretation of the healthcare service conditions based on the availability of primary healthcare personnel, thereby facilitating the understanding of regions that require priority attention.

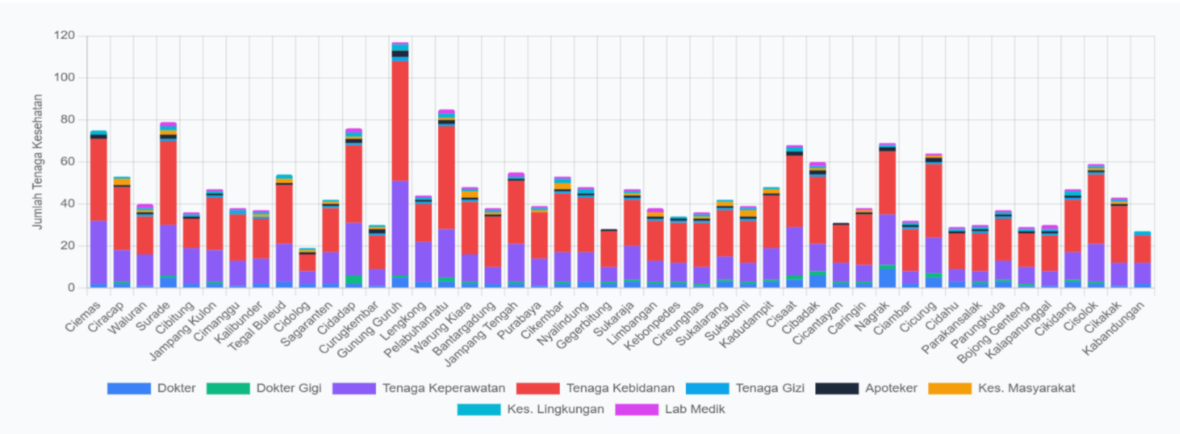

Figure 3. Distribution of healthcare workers by sub-district in Sukabumi Regency

Based on Figure 3, it can be seen that the distribution of healthcare workers among sub-districts in Sukabumi Regency shows a quite significant variation. Some sub-districts have a relatively adequate composition of healthcare workers, marked by a balance between the number of medical and paramedical staff, while other sub-districts still experience shortages of certain types of healthcare workers. Sub-districts with a low number of nursing and midwifery personnel relative to the basic service needs tend to be categorized as having a status ranging from insufficient to crisis. This condition indicates an imbalance in the

To clarify the condition of healthcare services at the sub-district level, the results of the analysis of healthcare workforce distribution are summarized in the form of service status and initial recommendations as presented in Table 1. Based on Table 1, it can be seen that not all sub-districts have adequate levels of healthcare services. Several sub-districts are classified in the less and crisis categories, indicating the need for efforts to equalize and strengthen healthcare services, especially in areas with limited medical and paramedical personnel. This information serves as the initial basis for formulating spatial data-based policy recommendations.

Table 1. Summary Table of Health Workforce Needs Status by Subdistric

No	**District**	**Total Facilities**	**Dominant Indicaktor**	**Service Status**	**Initial Recommendation**
1	Ciemas	2	Shortage of doctors	Less	Addition of general practitioners
2	Ciracap	1	Shortage of doctors and nurses	Less	Placement of doctors and nurses
3	Waluran	1	Shortage of doctors and nurses	Less	Redistribution of healthcare human resources
4	Surade	2	The composition of energy is relatively balanced	Sufficient	Periodic monitoring
5	Cibitung	1	Shortage of doctors and nurses	Less	Adjustment of human resource needs
6	Jampang Kulon	1	Shortage of doctors and nurses	Less	Strengthening basic services
7	Cimanggu	1	Shortage of doctors and nurses	Less	Additional service staff
8	Kalibunder	1	Shortage of doctors and nurses	Less	Reorganization of human resource distribution
9	Tegal Buleud	2	Shortage of nurses	Less	Addition of nursing staff
10	Cidolog	1	Shortage of nurses	Crisis	Priority for adding nurses

4.3 System Testing

System testing is conducted to ensure that all main functions of the SIGKES application operate according to user needs and the designed system specifications. The testing method used is black-box testing, which focuses on validating the system's functionality without considering the internal structure of the program's code. This testing aims to evaluate the conformity between the input provided by users and the output generated by the system, particularly on key features such as health facility mapping, data search, service category filtering, and dynamic data updating.

4.3.1 Testing Scenario

Testing was conducted on several main usage scenarios that represent user interactions with the SIGKES system. Each scenario was tested by providing specific inputs and then matching the system's output with the expected results. Testing was conducted on several main usage scenarios that represent user interactions with the SIGKES system. Each scenario was tested by providing specific inputs and then matching the system's output with the expected results.

4.3.2 Black-Box Testing Results

The results of the black-box testing on the main functions of the SIGKES system are presented in Table 2. This testing was conducted to ensure that each main feature of the SIGKES system can operate according to the functional needs of the users without considering the internal structure of the program code. The focus of the testing is directed toward validating the system's output based on the given input, including data loading functions, map interactions, facility searches, filtering health service categories, and dynamic data updates. The black-box testing approach was chosen because it aligns with the characteristics of the WebGIS-based system, which is user interaction-oriented, thus the system's success is measured by the alignment of the system's behavior with the predetermined usage scenarios. A summary of the functional testing results is presented systematically in Table 2.

Table 2. Black-Box Testing Results of the SIGKES System

No	Tested Feature	Testing Scenario	Expected Results	Test Results	Status
1	Map loading	The system loads the map when the application is run.	Map displayed with OpenStreetMap basemap	Suitable	Valid
2	Facility marker display	Facility markers are displayed on the map	Markers appear according to the facility location.	Suitable	Valid
3	Facility search	Users search for facilities by name	The system displays the location of the searched facility.	Suitable	Valid
4	Service category filter	Users select the category of healthcare workers	The map displays markers according to category.	Suitable	Valid
5	Detailed information display	User selects facility marker	Detailed facility information is displayed	Suitable	Valid
6	Data analysis per sub-district	User opens analysis menu	Graphs and data summaries are displayed.	Suitable	Valid
7	Data update	User presses Update Data button	Data updated from Google Sheet	Suitable	Valid
8	Interface responsiveness	Access across multiple screen sizes	Display adjusts to screen size	Suitable	Valid

4.3.3 Discussion of Test Results

Based on the results of black-box testing, all main functions of the SIGKES system functioned well and met user needs. No functional errors were found in the mapping, search, data filtering, or dynamic data updates. The success of the data update feature demonstrates that the integration between the client-side application and external data sources (Google Sheets and GeoJSON) can function effectively without the need for a server database. This reinforces the advantages of the SIGKES system as a lightweight, flexible, and easily implemented WebGIS application in environments with limited infrastructure.

4.3.4 Implications of Testing on System Feasibility

The test results indicate that the SIGKES system meets the functional correctness and usability requirements as a spatial-based healthcare service analysis support system. Therefore, this system is suitable for use as an analytical tool and initial decision-making tool in planning equitable healthcare services at the regional level.

4.4 Discussion of Results and Implications Software Engineering

From a software Engineering perspective, the research results demonstrate that a client-side WebGIS approach can be effectively implemented to support spatial analysis of healthcare services. The use of a serverless database architecture makes the system lighter, more accessible, and less reliant on complex server infrastructure. Data integration through the GeoJSON format and Google Sheets as dynamic data sources provides flexibility in data management. This approach differs from conventional WebGIS research, which typically utilizes more complex database servers and spatial web services. Thus, the SIGKES system offers a simpler yet functional alternative solution, particularly for institutions with limited IT resources. Furthermore, the use of the LeafletJS and OpenStreetMap libraries allows for the development of an open-source system that is easily developed. This strengthens the research contribution in Informatics, particularly in the development of applicable and replicable web-based geographic information systems.

4.5 System provisions

Although the SIGKES system is capable of providing interactive spatial analysis, this research has several limitations. The analysis conducted is still descriptive and has not yet included planning for the equitable distribution of healthcare services, such as predictive modeling or optimization of healthcare service distribution. In addition, dependence on internet connectivity becomes a factor that affects the real-time accessibility of the system. These limitations open up opportunities for further development, such as the integration of advanced analysis based on data mining or the utilization of backend technology for larger-scale system needs.

CONCLUSION

This research resulted in the SIGKES application, a client-side processing-based WebGIS system to support the mapping and analysis of healthcare service distribution at the sub-district level in Sukabumi Regency. The system implementation uses standard web technologies (HTML, CSS, JavaScript) with LeafletJS and OpenStreetMap as mapping components, GeoJSON as spatial data representation, and Google Sheets (API) as a non-spatial data source that is dynamically updated without reliance on a server database. This approach demonstrates that a lightweight and easily replicable WebGIS system can still provide relevant spatial analytical functions for decision-making needs.

Based on the analysis results, SIGKES is able to display variations in the distribution of healthcare workers between sub-districts and help classify the status of healthcare service needs into adequate, insufficient, and crisis categories. The presentation of information thru maps/graphs and summary tables clarifies the areas that require priority service strengthening. The results of functional testing using black-box testing show that the main features of the system include map loading, marker display, search, category filtering, detail view, data analysis, and data updates, all of which operate according to requirements, making the system deemed suitable for use as a spatial analysis tool. From the perspective of Software Engineering, the main contribution of this research lies in the design of a WebGIS architecture without a backend and without a server-side database, which enhances the simplicity of implementation, portability, and ease of system maintenance. The integration of spatial and non-spatial data thru GeoJSON and Google Sheets provides an efficient update mechanism and opens up opportunities for the adoption of similar systems in institutions with limited Information Technology infrastructure.

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