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Optimizing Irrigation Infrastructure Management with Web-Based Technologies and OpenStreetMap Integration

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Abstract

Irrigation is essential for increasing agricultural productivity in Indonesia, directly impacting national food security and farmer welfare by ensuring the sustainability of irrigation systems. Despite its importance, significant challenges persist, including damage to 46% of the irrigation infrastructure across 7.1 million hectares, with responsibilities divided among central, provincial, and city governments. These challenges are compounded by issues such as inadequate information access, limitations in real-time monitoring, and poor stakeholder coordination. To address these issues, integrating technological tools such as Geographic Information Systems (GIS) and platforms such as OpenStreetMap (OSM) is essential. These technologies offer real-time information, facilitate land change tracking, and enable spatial mapping, which supports proactive management and planning while improving decision making through data-driven insights. The adoption of Rapid Application Development (RAD) and Decision Support Systems (DSS) further enhances the efficiency of irrigation system management. The RAD methodology ensures swift development cycles with user interaction, while DSS provides structured decision-making capabilities. This approach supports robust system design, user interface development, and geographic data visualization. In practice, efficient data collection and stakeholder participation enable the system to effectively report and track irrigation conditions, promoting public participation, and fostering long-term infrastructure sustainability. The developed online monitoring system demonstrates its effectiveness by providing interactive map features and transparent reporting platforms, verified through successful implementation of testing scenarios. This system not only improves infrastructure management in areas like Batu City, but also sets a precedent for scalable participatory irrigation solutions, creating a foundation for future enhancements.

Keywords : irrigation infrastructure, Openstreetmap, web technologies, decision support system, spatial data

1 Introduction

Irrigation plays a crucial role in increasing agricultural productivity in Indonesia [1]. It supports farm productivity to boost agricultural production in the context of national food security and community welfare, especially for farmers. This is achieved through the sustainability of irrigation systems [2]. Despite its vital role, some challenges must be addressed. Of the total surface irrigation area of 7.1 million hectares, approximately 46% or 3.3 million hectares of irrigation infrastructure is damaged. Of this figure, around 7.5% is under central government responsibility, 8.26% under provincial government responsibility, and around 30.4% under city government responsibility [1]. In addition, various constraints, such as the lack of access to information, the inability to monitor in real time, and the lack of coordination between the relevant stakeholders, often hinder irrigation system management.

The integration of current technology, such as Geographic Information Systems (GIS) and Rapid Application Development (RAD) methodology, is critical to improving irrigation and resource management efficiency [3, 4]. Systems are complicated arrangements of components that work together to achieve certain goals, and GIS is an essential tool for obtaining real-time pictures of irrigation infrastructure, tracking land changes, and supporting water resource management through spatial mapping [5, 6]. Platforms such as OpenStreetMap (OSM) provide the basic spatial data for mapping applications. Decision Support Systems provide objective data-driven insights that enable faster and smarter decision making and increase corporate value [7, 8]. RAD facilitates quick development cycles with active user interaction, ensuring solutions satisfy specified requirements [9]. These technological developments simplify the monitoring, maintenance, and administration of irrigation systems, enabling proactive resource management and supporting sustainable operations through increased operational planning.

The Rapid Application Development (RAD) technique organizes software development into four stages, analysis, planning, system design, development, and implementation [10, 11]. During Analysis and Planning, requirements are documented using a Software Requirement Specification (SRS) document [12], while System Design uses Figma for user interface design and feedback validation. The Development step develops and tests features such as geographic data visualization, while the Implementation stage makes the program available for usage. Efficient data collection and processing procedures ensure that all system needs are met, including geographic data analysis, user input, and literature reviews. The created method aims to improve irrigation monitoring by allowing stakeholders to report and track irrigation conditions more effectively. With an emphasis on community participation, the system supports open reporting and maintenance of irrigation infrastructure, using a Decision Support System. (DSS) enables data-driven decision-making [13]. System design and information management guarantee that data flows smoothly and is easily accessible to users, while use case and business process diagrams depict user interactions and reporting routines. The system, which includes advanced data processing, visualization, and decision support capabilities, promotes long-term infrastructure management and timely resolution of issues.

The online monitoring system and the decision support system for irrigation damage reports produced substantial results. The interactive map feature allows users to filter and display comprehensive irrigation management data, making it easier to monitor and manage infrastructure in Batu City. The website's home page provides broad access to irrigation channel information, hence increasing transparency and public participation. Detailed report interfaces give complete information on specific infrastructure concerns, making follow-ups easier with options for reading, amending, and finishing reports. The irrigation building page provides crucial data for each facility, allowing for more effective resource management. The system's dependability was shown by testing it with 23 black-box scenarios that focused on main functions such as login, map interaction, reporting, and account administration. All scenarios were successfully implemented. This demonstrates the system's ability to accomplish its objectives by providing accessible, accurate, and actionable data to stakeholders and the general public, while also highlighting areas for further improvement.

The rest of this article is organized as follows. Section 2 discusses several related theories to provide a more comprehensive and in-depth understanding of the topic. Section 3 covers the research strategy, monitoring and data representation techniques, and the system's website architecture. Section 4 discusses the results obtained from the implementation of the systems, including the website monitoring system and the decision support system for the irrigation damage report. Lastly, this article concludes with some future works in Section 5.

2 Literature Review

This section provides a review of the literature pertinent to this research, focusing on previous studies in irrigation management and web-based mapping applications. This review helps identify relevant methodologies and frameworks that inform the development of our system.

2.1 Geographic Information System

The system has the meaning of a set of interrelated components, both physical and non-physical, which work harmoniously with each other to achieve a certain goal, and the information is the result of data processing in a certain way so that it is easily understood by the recipient [14]. The application of alternative irrigation and the use of spatial mapping have been shown to improve the efficiency of the irrigation network and reservoir management [15]. The use of GIS (Geographic Information System) has been shown to monitor land changes and provide important information for the management of water resources [16]. GIS (Geographic Information System) can help capture images of irrigation infrastructure in real time and provide an overview of irrigation conditions [17, 18]. GIS can be developed on a web platform to present important information [19, 20]

2.2 Use of OpenStreetMap in Mapping

Referring to [21] on Geospatial Information, geospatial or earth space is a spatial aspect that shows the location, location, and position of an object or event below, on, or above the Earth's surface expressed in a certain coordinate system. One of the platforms used in mapping is OSM (OpenStreetMap) [22]. OSM can be used as a basis for more extensive mapping applications with spatial data management [23]. OSM is already quite accurate and can be used in areas that do not require very precise detail [24]. OSM can be extracted from the geodatabase format before being converted into shapefile format which includes points, polyline, polygon [25].

2.3 Decision Support System

Decision Support Systems help make faster and smarter decisions based on objective data, rather than subjective criteria or personal instincts [26]. Decision Support Systems are designed to help stakeholders make the right policy, which ultimately provides added value to the organization [27].

2.4 Rapid Application Development (RAD) Methodology

Rapid Application Development (RAD) methodology prioritizes the development phase over detailed planning. Moreover, it enables multiple development cycles to occur in parallel, allowing rapid prototyping and iterations based on user feedback [28]. In the application design process, the RAD approach actively involves end users to ensure that the resulting product meets their specific requirements and addresses their needs [29]. The flexibility and efficiency of the rad method for creating information system websites can be effective because it involves both developers and users [30]. The steps involved in the RAD method are illustrated in Figure 1.

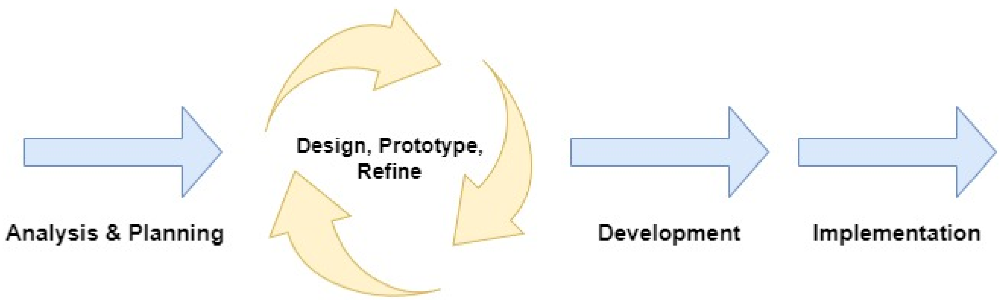


Figure 1: Rapid Application Development

2.5 Monitoring and Maintenance of Irrigation Areas

The acceleration of irrigation reporting can be improved in the form of software [31]. Using the app makes monitoring and maintenance of irrigation systems more efficient, enabling proactive management of resources, early detection of problems, and timely intervention. Management through a web-based system increases the effectiveness of monitoring projects in real time [32]. By utilizing technologies such as GIS and satellite imagery, detailed irrigation network maps can be created, which not only improve operational planning at the district level, but also enable decision makers to monitor and maintain irrigation systems more efficiently [33]. This improvement in irrigation monitoring and management highlights the importance of using modern technologies such as GIS and remote sensing to achieve more effective and sustainable irrigation systems [34].

3 Method

The methodology comprises the research strategy, monitoring and data representation techniques, and the system's website architecture. It also discusses how to integrate a decision support system (DSS) for informed decision making, as well as how to organize the system components geometrically for best performance. Each feature is intended to ensure reliable data collection and analysis.

3.1 Research Methodology

RAD (Rapid Application Development) is a methodology for software development. The RAD method is divided into 4 stages, Analysis and Planning, System Design, Development, and Implementation.

3.1.1 Development Method

In the context of developing this system, at the requirements analysis and planning stage, the Software Requirement Specification (SRS) document will be used as a guide to ensure that the system is developed correctly. In the system design stage, Figma will be used as a tool to generate the website interface and validate user feedback. In the development stage, the coding with the test documents will be referenced to ensure the quality and reliability of the system. Once the system is completed, a Technical Document will be prepared detailing the technical specifications and configuration of the system to support maintenance and further development.

In this development process, relevant data need to be collected and processed so that they can be clearly displayed. The methods used to collect data and information in this development include the following steps:

1. Analysis and Planning In the development of irrigation and reservoir area mapping applications, this phase will include collecting data on the needs of stakeholders is PUPR SDA Office of Batu City. This phase will focus on data mining, including extracting information about geospatial data and information on irrigation report criteria as recommendations for improvement. The design of the application system will be carried out in the next stage, based on the information and data obtained.
2. Design System In this phase, active users, such as related agencies or field officers, will be directly involved in designing an intuitive interface that provides a clear visualization of irrigation conditions. Initial prototypes will be used to illustrate user interaction with the application. User feedback will be used as evaluation material to improve the design at a later stage.
3. Development This phase will enter the stage where developers build applications based on prototypes that have been designed previously. Implementation of desired features, such as visualization of geospatial data, accurate reporting system, and data from the latest results of irrigation conditions.
4. Implementation This phase will involve the complete implementation of the irrigation and pond area mapping application to the production environment. This is the step in which the app is ready to be used by stakeholders and end-users, enabling more efficient monitoring and better collaboration on irrigation infrastructure improvements.

3.1.2 Data Collection Methods

The process of obtaining data for system development involves multiple approaches to ensure comprehensive and accurate information is gathered

1. Available geospatial data is used to identify new problems or test the validity of existing data. An in-depth analysis of the data was conducted to understand the condition of the irrigation infrastructure based on the current irrigation management system.
2. Data collection is done through interviews to get information about the needs of the data display and the flow of the developed system. This method aims to obtain more detailed and accurate information, which may not be available in secondary data.
3. Data collection methods are carried out by reading information or references related to geographic information system research. Literature study to support the methodology and technology used in system development.

3.2 Monitoring and Data Representation of Irrigation Infrastructure

The system requirements analysis aims to identify the features and functions required for irrigation. Functional requirements include the ability to efficiently report, monitor and improve irrigation conditions, including spatial and non-spatial data processing, and accurate visualization of geographic information. The system should enable users, including officials and the public, to access, report, and monitor irrigation status in a transparent manner.

The current process of irrigation maintenance carried out by the SDA Division PUPR Office with the system begins with officers reporting the condition of irrigation areas in Batu City every 10 days. The data from the report will then be reviewed to evaluate any damage. If the damage is identified but is mild, the repair process will be carried out. However, if the damage is classified as severe, a budget submission is required before making repairs.

In other parts of the current website system, the admin only has access to view reporting data sent by field officers without further processing. In addition, the addition of geographic information data is done manually, one by one, so that the geometry that appears is an irrigation point instead of a polyline or irrigation area line. The website display and maps available on the website are also still not responsive and not optimized.

Based on the results of the interviews, it was identified that challenges in the openness of reports and increasing community participation are problems in the process of reporting irrigation damage points. The general public is also expected to be able to report and see the progress of their reports transparently if they find damage points. This can encourage community participation in the maintenance of public infrastructure. By strengthening community participation in reporting irrigation damage points, it is expected to create synergy between related parties and the community to maintain the sustainability of irrigation systems and to accelerate the identification and management of problems that arise. From the system design process and planning requirements carried out, there are 3 data that will be displayed or processed on the website.

1. Primary channel is the main channel that transports water from the source to the distribution area.
2. Secondary channels that receive water from primary channels and distribute it to tertiary channels.
3. Tertiary channels that drain water from secondary channels directly to rice fields or fields.
4. Irrigation buildings are structures built to support, organize, and control the flow of water in the irrigation system. Examples of irrigation buildings include Dams, Sluice gates, Channel bridges, Pumps and pipes, Water dividers, Culverts, etc.
5. Irrigation Area is Information on the area served by the irrigation system.

3.3 Website Monitoring System Architecture

This section describes the overall architecture of the website monitoring system. The architecture outlines how different components of the system interact with each other, ensuring smooth data flow from the field to the system users. The first design for the development of the Web Mapping System is the development of a use case diagram that describes the interaction between users and the system. The three main actors in this system are Admin, Field Officers, and Communities. Admin has full access to manage irrigation building data, monitor reports, finalize reports, and manage user accounts and articles. Field Officers and the Public can report damage found, as well as view the status or progress of the report. This use case diagram is visually explained in Figure 2, which shows how each actor interacts with the features of the system.

Figure 3 explains that the irrigation condition reporting process involves the participation of the community and the officers in detecting and reporting damage to irrigation channels or buildings. To support better decision making, a Decision Support System (DSS) is used that can analyze and provide recommendations for improvement. In addition, transparency in the reporting process allows the community to monitor the progress of damage reports that have been submitted. Using mobile and internet technology, information related to irrigation area conditions can be collected in real time, processed, and presented to the community and related agencies quickly and accurately.

1. The public or officers can report damage to irrigation canals or buildings using the available applications.
2. The damage reports submitted by users will be processed by the Decision Support System (DSS) and displayed to the administrator.
3. The administrator can validate the reports.
4. The administrator can follow up on the reports and coordinate the necessary repairs.

Figure 2: Use Diagram System

3.3.1 Functional Requirement

Functional requirements describe the necessary features and processes that must be implemented in the system, covering actions performed by both the admin and the user, as well as the information displayed by the system.

3.3.2 Non Functional Requirement

1. The website must be accessible from any browser.
2. The system must efficiently process damage reports and update status changes in real time.
3. The user interface must be intuitive and easy to use, accommodating users from various backgrounds.
4. The display must be responsive when accessed from different devices (laptop, tablet, mobile phone).
5. Data access must be restricted to authorized users with valid API permissions.

3.3.3 Architecture System

In the system architecture shown in Figure 4, the focus of development is on creating a website system for report processing and interactive map visualization using geospatial data OSM, as well as the implementation of a Decision Support System (DSS) from the reporting results (represented by the red box with dashed lines).

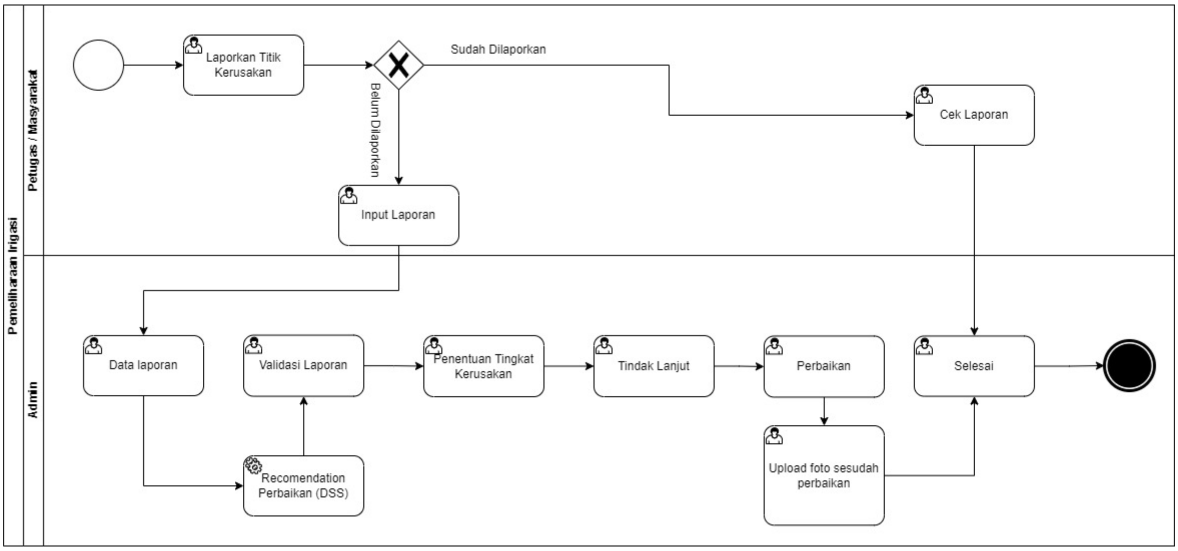


Figure 3: Business Process

3.3.4 Information Architecture

The information architecture is applied to websites to ensure that information management has a clear structure and is easily understood by various user groups. Information is organized into categories and subcategories with the goal of making relevant information accessible to users based on their needs[35]

3.3.5 Class Diagram

In the irrigation reporting and management system with spatial data, five main schemas are used to manage and group tables as needed. Each schema consists of several tables that are interconnected to support the overall functionality of the system, ensuring that spatial and non-spatial data can be processed efficiently. These schemas are designed to organize data related to irrigation infrastructure, user reports, geographic locations, and repair status, allowing seamless integration between the different modules of the system.

The structure and relationships between these schemas are illustrated in Figure 5, which provides a detailed overview of how the tables are organized and how they interact to deliver the system's functionalities. In the irrigation reporting and management system with spatial data, there are five main schemas used to manage and group tables as needed. Each schema consists of several tables that are interconnected to support the overall functionality of the system.

3.3.6 Topsis Calculation Metodology

Figure 6 illustrates the workflow of the designed Decision Support System (DSS) system. Data from various reports are collected and stored in the appropriate state. The accumulated data are then processed using the TOPSIS method to generate the most relevant recommendations based on predetermined criteria. The results of the TOPSIS method processing are displayed in the website interface in the form of the two latest recommendations from the report with the status "In Progress". When a report has been followed up, its status will be updated, so that the report is no longer used in the calculation of further recommendations. To access the latest recommendations, users simply refresh the web page and the system will automatically display the two latest recommendations based on the updated data. Users can view details and track the status of each recommended report.

3.3.7 Data Preparation and Classification

The first step is to identify and determine the criteria that will be used in the calculation. Since there are 2 data to be calculated, namely Irrigation Buildings and Irrigation Channels, the following example will provide an overview of the Irrigation Buildings data. Of the 14 available criteria, 9 criteria are selected to be used.

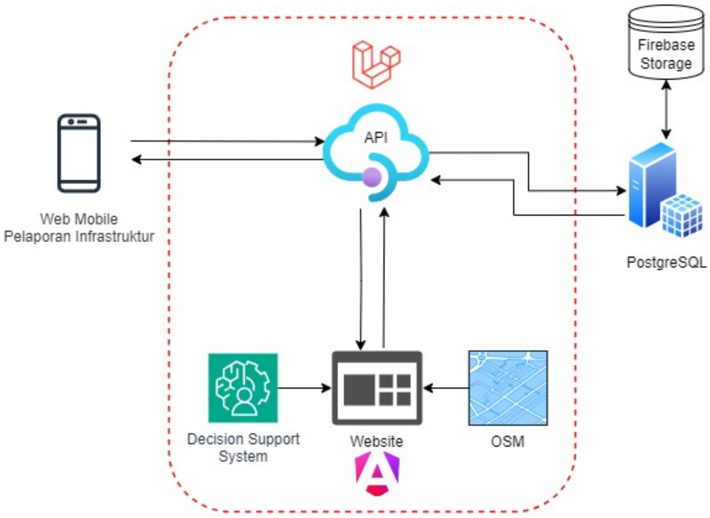


Figure 4: Architecture System Monitoring Website

A total of five criteria are not used because they are changeable or not always certain, making it difficult to predict the results or consequences of the decisions taken and can increase the risk of failure of the decisions taken and can increase the risk of failure. Table 1 shows the data used and not used in the attributes of the irrigation building. A criterion is classified as useful if a higher value indicates better results. Furthermore, determining the classification of each criterion as to whether it is included in the benefit or cost category is shown in Table 2. Then the classification of irrigation building types can be seen in Table 3 which is later associated with the level of damage as in table 4.

Table 1: Used and Unused Data Attributes

Used Data Attributes	**Unused Data Attributes**
1. Building Damage	1. Building Name
2. Channel Type	2. Outer Right Side
3. Distance	3. Outer Left Side
4. Channel Size	4. Right Channel
5. Right Boundary	5. Left Channel
6. Left Boundary	
7. Channel Area	
8. Right Channel Length	
9. Left Channel Length	

Table 2: Classification Criteria

Criteria	**Weight**
Building Damage	Benefit
Channel Type	Cost
Distance	Cost
Channel Size	Cost
Right Boundary	Cost
Left Boundary	Cost
Channel Area	Cost
Right Channel Length	Cost
Left Channel Length	Cost

Table 3: Weight and Importance Type Irrigation

Weight	**Importance**
1	Tertiary
2	Secondary
3	Primary

Table 4: Weight and Damage Severity

Weight	**Importance**
1	Minor Damage
2	Moderate Damage
3	Severe Damage

3.4 Implementation Geometry

Geometric data processing involves a series of steps to prepare, clean, validate, and integrate spatial data into a system that can be utilized for further analysis or web-based applications. This process ensures that the data are accurate, complete, and properly formatted to meet the needs of the application. The following steps outline the workflow from the initial data cleaning phase to the integration of the data into a web-based API for real-time access and visualization. The flow of the process is illustrated in Figure 7.

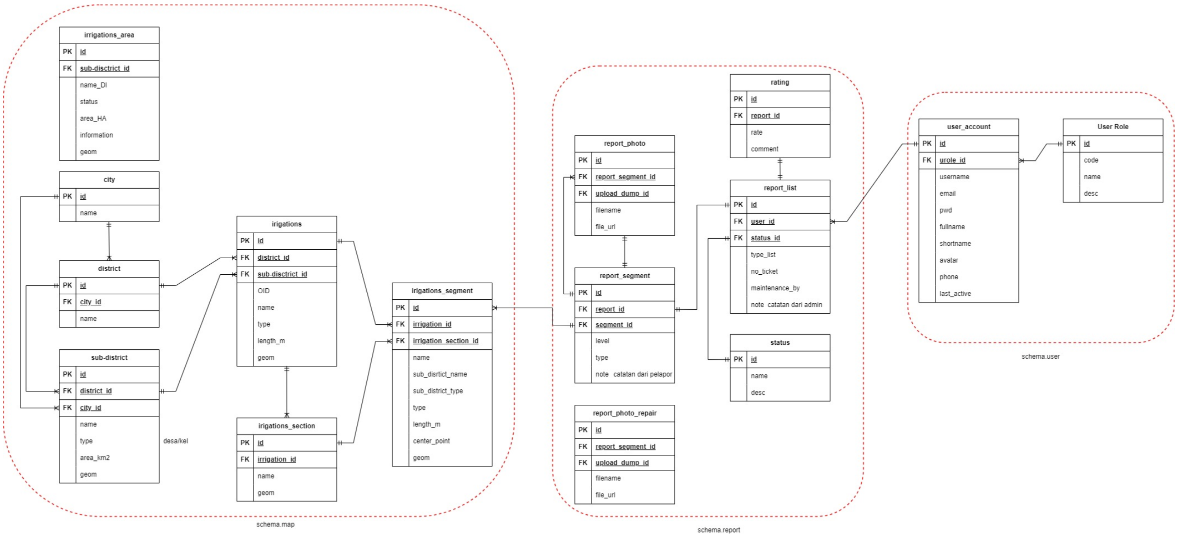


Figure 5: Class Diagram

1. The first step in this process is to clean the data obtained from various sources. This involves removing duplicates, correcting errors, and filling in missing data as shown in Figure 8.
2. Spatial data generated from QGIS is imported into schema public, which contains the original tables imported from QGIS. The public schema serves as the main set of tables that store all imported spatial data before it is further processed or merged with other relevant tables.
3. The required attributes or fields from the master table are merged with other relevant data according to the needs of the analysis or application. This process involves combining data from several sources, such as demographic data, and linking to provide more information.
4. The data that has been combined and processed is then transformed into GeoJSON format with the PHP programming language using the Laravel framework, the spatial data is converted into GeoJSON by using the `ST_AsGeoJSON` function.

   [colback=white, colframe=black, title=Query to retrieve GeoJSON from Database]

```
DB::selectOne('SELECT *, ST_AsGeoJSON(ST_Transform(geom, 4326)) as geojson
                    FROM map.irrigations
                    WHERE id = ?', [$this->id])->geojson
```

5. After the data are converted into GeoJSON, the website calls it through the API. Laravel provides API endpoints with HTTP calls to retrieve GeoJSON data according to application needs. This API serves as a bridge between the data on the website in retrieving data in the database with predefined logic and ensuring that the data can be accessed efficiently and safely. Each endpoint or data call will be validly authenticated using a token or x-api-key. The GeoJSON data can then be retrieved by the website and displayed as an interactive map according to the geometry data using the leaflet library.

4 Results and Discussions

This section presents and analyzes the results obtained from the implementation of the systems, including the website monitoring system and the decision support system for the irrigation damage report. The discussion will focus on how the system meets the desired objectives and how the system can be improved based on the observed results.

4.1 Results of the Website Monitoring System

The following subsection outlines the results of the website monitoring system architecture. The Interactive Map feature allows users to filter the map view as well as all data related to irrigation management, including

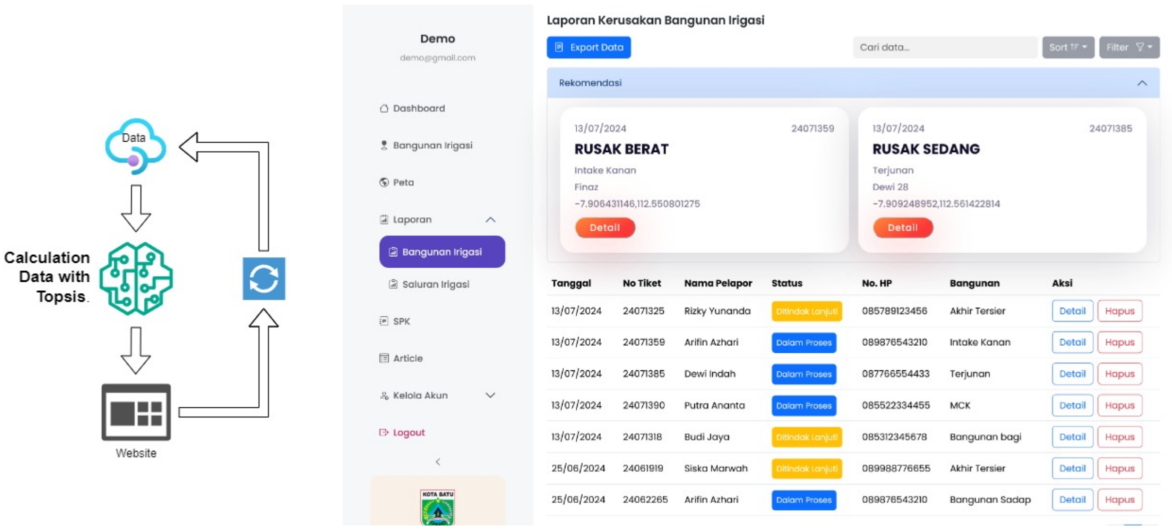


Figure 6: Flow Diagram of Data Processing with TOPSIS for Website

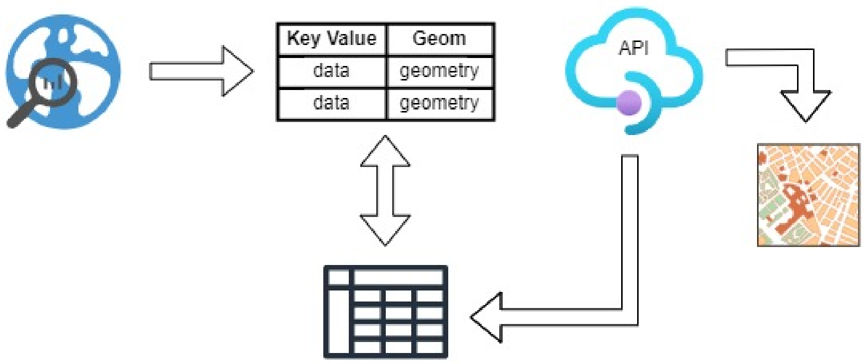


Figure 7: Geometry Data Processing

irrigation canals, irrigation structures, irrigation districts, and administrative boundaries. The image 9 displays the geographical location of these elements. The map helps users visually monitor and manage irrigation infrastructure, making it easier to understand the layout and situation on the ground.

Figure 10 the initial view of the website that displays general information on the distribution of irrigation channels in the Batu City area. The landing page provides access to the general public to view irrigation channel information without the need to log in.

Figure 11 displays the detailed report interface designed to monitor and follow up on irrigation infrastructure issues. This page provides comprehensive information on a particular report, including reporter details such as name, email, phone number, and current report status. In addition, the irrigation data section offers specific information about the infrastructure, such as channel type, distance, size, and location mapped for visual context. Key actions such as “Follow-up” or “Mark as Completed” are available, allowing the user or administrator to take the necessary steps to finalize the report. This interface ensures that all relevant data for the report is easily accessible.

ID-Test Case	Test Case	Pre-Condition	Test Steps	Expected Result	Actual Result
TC-LAPORAN-01	Admin melihat data laporan	User telah login dan berada pada laporan	User memilih sub-menu laporan bangunan irigasi atau saluran irigasi	Menampilkan data seluruh laporan	Berhasil menampilkan laporan sesuai dengan sub menu yang dipilih
	Melihat detail laporan bangunan irigasi	User telah login dan berada pada laporan	User click detail pada data	Menampilkan informasi status detail laporan.	Berhasil menampilkan detail laporan sesuai dengan id atau data yang dipilih beserta foto kerusakan
				Menampilkan Map dengan titik kerusakan sesuai jumlah pada laporan.	
TC-LAPORAN-02	Menanggapi laporan	User telah login dan terdapat laporan	Memilih detail pada salah satu laporan	Menampilkan detail laporan sesuai dengan id.	Berhasil merubah data menjadi 'Ditindak Lanjuti' dan memunculkan form untuk upload foto selesai perbaikan
			Mengedit kerusakan titik kerusakan	Muncul popup untuk admin mengedit titik kerusakan.	
			Click button 'Tindak Lanjuti'	Status berubah menjadi Ditindak Lanjuti	

Figure 8: Validation Data Geometry

4.2 Testing Procedures

Black-box testing is a test conducted to observe the input and output results of the software without knowing the code structure of the software.

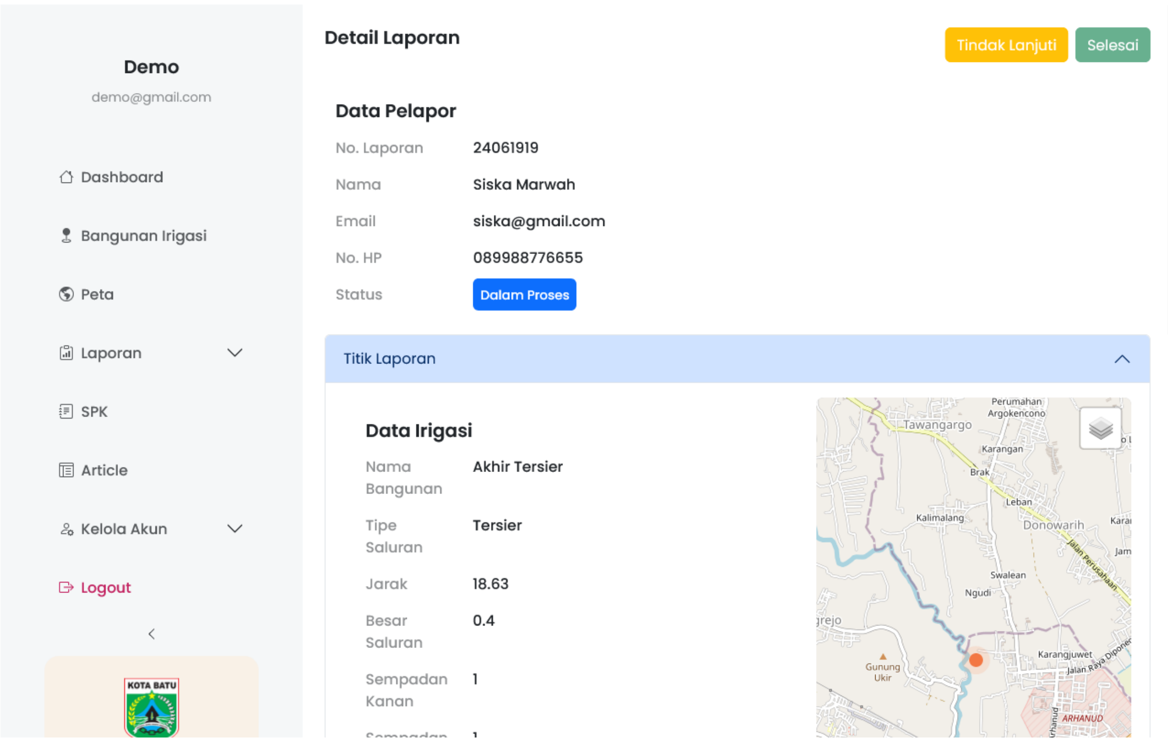
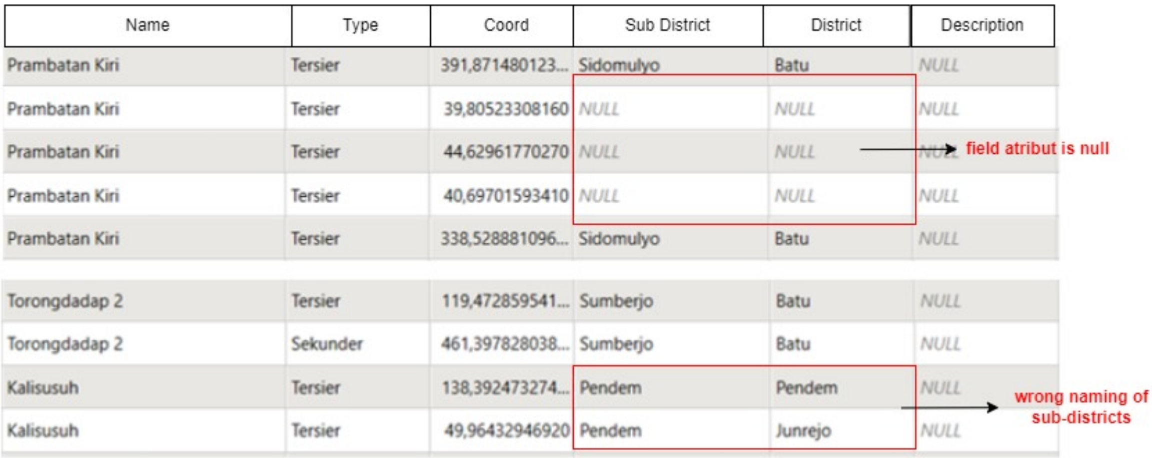


Figure 12: Example of Black Box Testing Scenario



Name	Type	Coord	Sub District	District	Description
Prambatan Kiri	Tersier	391,871480123...	Sidomulyo	Batu	NULL
Prambatan Kiri	Tersier	39,80523308160	NULL	NULL	NULL
Prambatan Kiri	Tersier	44,62961770270	NULL	NULL	NULL
Prambatan Kiri	Tersier	40,69701593410	NULL	NULL	NULL
Prambatan Kiri	Tersier	338,528881096...	Sidomulyo	Batu	NULL
Torongdadap 2	Tersier	119,472859541...	Sumberjo	Batu	NULL
Torongdadap 2	Sekunder	461,397828038...	Sumberjo	Batu	NULL
Kalisusuh	Tersier	138,392473274...	Pendem	Pendem	NULL
Kalisusuh	Tersier	49,96432946920	Pendem	Junrejo	NULL

Figure 9: Interactive Map Interface for Monitoring Irrigation Infrastructure

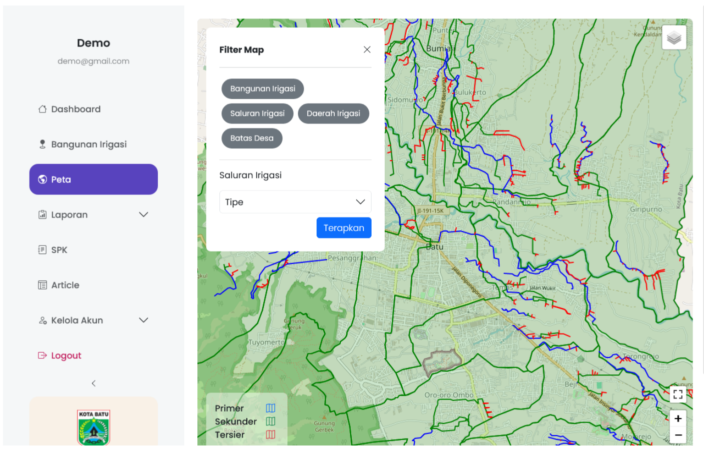


Figure 10: Website Home Page Information for the General Public

[36]. Figure 12 is an example of one of the test case scenarios, where the focus is on the user's ability to view and manage irrigation reports and respond to logged issues. This test includes various main modules in the application, namely, login, irrigation map, reporting, dss, and account management. Testing was also carried out on parameter scenarios to test sort, filter, and search. Of the total 23 test scenarios performed, all were carried out properly.

4.3 Discussions

The significance of the irrigation management system discussed in the literature review underscores the transformative impact of integrating Geographic Information Systems (GIS) and Remote Sensing technologies. By implementing a web-based platform for irrigation management, stakeholders can achieve real-time monitoring of irrigation conditions, significantly improving decision-making processes. The ability to visualize and analyze spatial data allows users to track changes in land and water resources effectively, which in turn enhances the management of irrigation systems. The incorporation of OpenStreetMap further enriches the data landscape, providing comprehensive mapping capabilities that are accurate and accessible, thus facilitating a more informed approach to irrigation management and resource allocation.

The implementation results indicate a successful integration of various technological components, particularly through the deployment of a Decision Support System (DSS) that automates the processing of the reports and facilitates stakeholder interaction. The system architecture, depicted through interactive maps and detailed reporting interfaces, demonstrates a user-friendly design that caters to both officials and the gen-

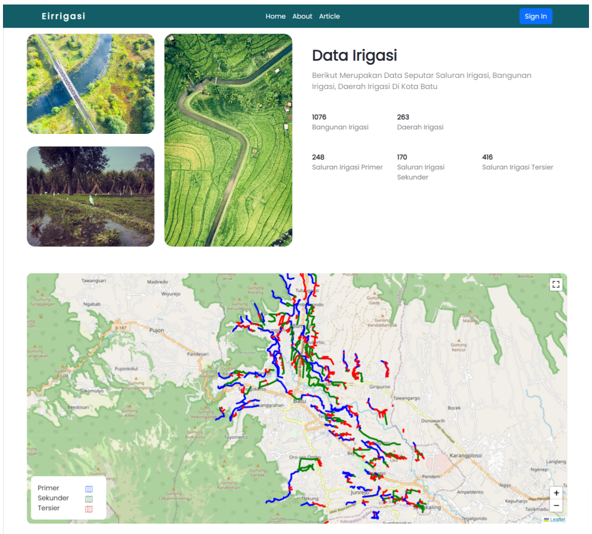


Figure 11: Detail Report to Process

eral public. With features such as real-time reporting and comprehensive mapping of irrigation infrastructure, the system not only improves operational efficiency, but also encourages community engagement and participation. The positive feedback from users on the intuitive interface and simplified functionalities supports the argument that the use of modern technologies can lead to substantial advancements in irrigation management practices.

Looking toward the future, several challenges remain for the continued development and sustainability of the irrigation management system. Ensuring data accuracy and seamless integration across various platforms is crucial as new technologies emerge. Moreover, maintaining user engagement and addressing the needs of various stakeholder groups will be vital to the long-term success of the system. These challenges may include enhancing user training and support, expanding the system's capabilities to adapt to changing environmental conditions, and fostering improved collaboration between governmental agencies and local communities. By actively addressing these future challenges, the system can evolve into an even more robust tool for sustainable irrigation management, ultimately benefiting a wider array of users and environmental stakeholders.

5 Conclusion

In this project, various aspects of the system were tested and validated to ensure its effectiveness and usability. The User Acceptance Testing (UAT) process played a crucial role in determining whether the developed system meets the needs and expectations of its users. Through this final stage of testing, early users were able to provide valuable feedback that helped refine the system further, ensuring both functionality and user satisfaction.

The UAT process involved a thorough evaluation of the system based on predefined criteria and several enhancements were tested to ensure that they contributed positively to the overall performance of the system. These improvements were designed to enhance the user experience and address specific user requirements. As a result, the following additional features were expected:

1. A new feature has been added to support the existing system, such as a Decision Support System (DSS) that helps partners determine suitable crops for agricultural lands in the irrigation areas of Batu City.
2. An extended and more detailed recap feature has been introduced to the website, enabling trend analysis of damages occurring over several weeks.
3. An automatic feature has been implemented for adding data into irrigation management, using geometry and spatial attributes directly. This eliminates the need for manual data conversion and integration from QGIS into the database.

In addition to these features, the developed app aims to significantly improve the collaboration between officers and communities, especially in terms of reporting and monitoring irrigation infrastructure. The app facilitates more efficient monitoring and reporting through direct delivery of photos of channel damage data and accurate information. In addition, the app provides an interactive map that displays comprehensive irrigation management data, making it easier for users to access information faster.

In terms of performance, the app demonstrates a high level of responsiveness, supported by Web technology that ensures fast access from a variety of devices without significant lag. Structured reporting features and comprehensive data analysis allow irrigation maintenance and repairs to be carried out more efficiently, with prioritization of critical points that require immediate attention. This supports optimal resource allocation based on the impact and extent of the damage.

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