DESIGN OF A MOBILE APPLICATION FOR REAL-TIME FLOOD INFORMATION IN NORTH ACEH REGION BASED ON GIS AND HAVERSINE METHOD

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Abstract - This study presents the design and development of a mobile application to provide real-time flood information in North Aceh, Indonesia. Existing flood warning systems in the region are largely conventional and lack digital integration, often causing delays in response. Addressing this gap, the proposed system integrates Geographic Information Systems (GIS) for flood mapping and the Haversine method for calculating distances to flood points and evacuation routes. Development involved analysis, design, implementation, and testing. Performance evaluation showed a high degree of accuracy, with an average distance calculation error of 0.29%. A User Acceptance Test (UAT) involving 30 users yielded a satisfaction score of 4.56 out of 5. Compared to prior systems, this application introduces a novel combination of real-time spatial analysis, user reporting, and mobile accessibility for disaster management. Limitations include static routing and a region-specific dataset. Future enhancements should involve dynamic weather data integration, adaptive routing, and broader user testing. The system demonstrates strong potential for replication in other flood-prone areas and contributes both practically and academically to mobile-based disaster mitigation strategies.

Keywords - Mobile Application, Real-Time Flood Information, GIS, Haversine Method, Disaster Management.

I. INTRODUCTION

North Aceh Regency is one of the regions in Aceh Province that is highly vulnerable to flood disasters. Geographically, this area is crossed by several major rivers, including Krueng Peusangan, Krueng Keureutoe, and Krueng Jambo Aye, which often overflow during the rainy season. The topography of the region, which consists mostly of lowland areas with elevations between 0-100 meters above sea level, combined with its position between the Bukit Barisan mountain range and the Malacca Strait, contributes to the high risk of both upstream river floods and overflow-induced flooding.

This vulnerability has worsened due to global climate change and environmental degradation. Unpredictable rainfall patterns, intense rainfall over short periods, and the conversion of forested areas into agricultural and residential land have significantly reduced the land's natural ability to absorb rainwater. The resulting increase in surface runoff has further intensified the flood risk, particularly in densely populated downstream areas.

According to Indonesia's National Disaster Management Agency (BNPB), floods were the most frequent natural disaster in 2022, accounting for 1,524 events nationwide. Floods in this region not only damage the environment but also disrupt the local economy and public services. The Regional Disaster Management Agency (BPBD) has installed several river water level monitoring devices. However, the information is not yet accessible to the public in real time. Most communities still rely on local officials, mosque announcements, or word-of-mouth, which often causes delays in evacuation. A survey conducted by researchers from Universitas Malikussaleh in 2023 revealed that many residents in flood-prone areas do not receive accurate and timely flood warnings, despite owning smartphones with internet access This is consistent with national data showing that as of January 2024, internet penetration in Indonesia has reached 79.5%, with over 87% of Generation Z and 93% of millennials regularly accessing the internet via smartphones.

A number of previous studies have attempted to address similar problems by integrating spatial technology into mobile platforms. For instance, a GIS-based Android application to help tourists locate destinations in Banda Aceh using the Dijkstra algorithm for routing and the Haversine method for distance calculation. The application successfully demonstrated the value of combining GIS with geolocation features to provide real-time, location-specific informatio[1]. A mobile GIS application for locating the nearest laundry services using the Haversine method. The results showed that the system had good accuracy with a margin of error of less than 1% compared to manual calculations, demonstrating the method's reliability in real-world mobile spatial systems[2]. Therefore, this research aims to design and develop a mobile application for real-time flood information in North Aceh based on GIS and the Haversine method. The application is intended to provide spatial flood visualization, user-based distance alerts, and safe evacuation routing, all integrated into a single, accessible platform for the public and disaster response authorities.

II. SIGNIFICANCE OF STUDY

A. Literature Review

1. Information System

An information system consists of various interconnected components, with the primary goal of generating information in a specific field[3]. Information systems can also support organizational decision-making by combining people, hardware, software, computer networks, data communication, and databases to collect, process, and disseminate information[4],[5]. The evolution of information systems is crucial in responding to complex needs across sectors such as education, business, administration, and disaster management. Internet-based platforms such as websites are increasingly central in this transformation, offering remote and real-time information access. The development process itself, known as system development, is aimed at designing and building systems that can address organizational challenges or opportunities[6].

2. Geographic Information System

A Geographic Information System (GIS) is a computer-based information system designed to store, manage, analyze, and display data that has geographical references[7]. GIS allows users to link spatial information (location-based) with other attribute data, making it highly useful in location-based decision-making processes. In the context of logistics distribution, such as in this research, GIS is used to map distribution base locations, display routes, and facilitate the identification of strategic points relevant to the distribution process[8].

Geographic Information System (GIS) is a technology designed to process, store, analyze, and display data related to the position of objects on the Earth's surface. This technology has rapidly developed due to its ability to integrate spatial data with attribute information into a single computer-based system[9]. The data processed in GIS typically includes geographic information such as location coordinates, territorial boundaries, and other supporting data, which is then visualized in the form of interactive digital maps. GIS is not only used for displaying locations but also for performing spatial analysis, such as finding the shortest route, identifying distribution patterns, and mapping the potential of specific areas[10]. This technology can be implemented as a desktop application or a web-based system, and has been widely used in various sectors, ranging from urban planning, transportation, disaster management, to tourism promotion. With its ability to present data in a visual and informative manner, GIS has become an essential tool for decision-making processes that involve location and territorial aspects more effectively and efficiently[7].

3. Google Maps API

Google Maps API allows developers to embed Google Maps into mobile and web applications using JavaScript, enabling features such as route plotting, marker placement, and location queries. This tool is especially useful in GIS applications for visualizing spatial data in an intuitive and interactive format[11],[12]. In this research, the Google Maps API is integrated into the mobile application to render flood zones, user locations, and evacuation paths, enhancing user navigation and comprehension of the flood scenario.

4. Haversine Method

The Haversine Formula calculates the great-circle distance between two geographic points based on latitude and longitude[13]. It is widely used in navigation and location-based services to determine the shortest path over the Earth's surface[14].

In this application, the Haversine method is used to compute the distance from a user's current location to the nearest flood zone or evacuation point. Previous implementations, such as in laundry service search apps [2], showed high accuracy and user satisfaction. This study extends its application to disaster contexts, where spatial accuracy can significantly impact emergency response and safety. The Haversine formula can be written as follows:

$$a = sin^2\left(\frac{\Delta\phi}{2}\right)\cos(\phi_2)\cdot\cos(\phi_1)\cdot sin^2\left(\frac{\Delta\lambda}{2}\right) \quad (1)$$

B. Materials & Method

1. Diagram Research Flow

To illustrate the flow of this research, here is a flowchart diagram that explains the stages of application development from start to system testing:

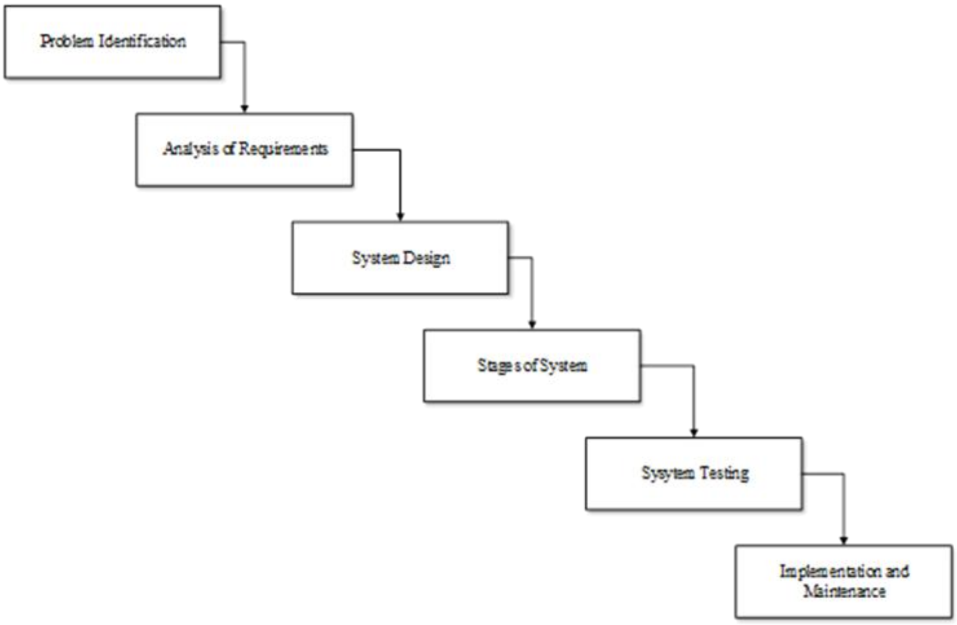

Figure 1. Diagram Flow

The research begins with problem identification, where the researcher determines the main issues that need to be addressed. Next, a requirements analysis is conducted to gather and define the system requirements that must be met for the solution to be effectively implemented. After that, the next stage is system design, where the structure and design of the system are developed to meet the identified requirements. Then, system development is carried out, where the technical implementation of the design is executed to build the system. Once the system is built, system testing is performed to ensure that the system functions as expected. Finally, the results of this testing are used for implementation and maintenance, ensuring that the system operates effectively in the long term and addressing any shortcomings identified during testing.

2. Research Type

This research is a system design study aimed at developing a mobile application based on Geographic Information System (GIS) and the Haversine method to provide real-time flood information in the North Aceh region. This study is also descriptive in nature, as it describes the steps involved in the application development, implementation, and testing of the resulting system.

3. Data Collecting

To develop the application, accurate and relevant data is required. Several data collection methods used in this study include:

- Literature Study: Collecting references from journals, books, and previous research related to GIS-based applications, the Haversine method, and flood disaster mitigation. This literature study helps in understanding the concepts and technologies that will be used in the application development.
- Geographical Data Collection: Geographical data for the North Aceh region will be collected from relevant institutions, such as the National Disaster Management Agency (BNPB), the Meteorology, Climatology, and Geophysics Agency (BMKG), and the Geospatial Information Agency (BIG). This data includes regional maps, flood-prone location points, and weather and rainfall data.
- Interviews with Stakeholders: Interviews will be conducted with relevant parties, such as officials from the disaster management office of North Aceh and local communities frequently affected by floods. The information obtained will be used to determine the features needed in the application.

4. Data Analysis

After the testing is completed, the test results will be analyzed to determine whether the application meets the established criteria. Several analyses will be conducted, including:

- Functional Analysis: Evaluating whether each feature of the application works as expected.
- Performance Analysis: Assessing the speed, accuracy, and reliability of the application in providing flood information and calculating distances.
- User Satisfaction Analysis: Based on the results from User Acceptance Testing (UAT), an analysis will be conducted to determine the users' level of satisfaction with the application's ease of use.

C. Theoretical and Practical Contributions

This research contributes to the existing body of knowledge by demonstrating the integration of GIS and the Haversine method in a disaster management setting. While prior studies have explored their use in tourism[1] or commercial services[2], this study applies them to a public safety and disaster risk reduction context. It emphasizes the role of real-time spatial analytics in increasing disaster preparedness.

Practically, the application offers a technological solution to the limitations of conventional flood warning systems in North Aceh. Its real-time water level monitoring, distance-based alerts, and safe route recommendations empower residents to make faster and more informed decisions. Furthermore, the data collected from both sensors and community reports can assist local governments in strategic flood mitigation and spatial planning[15].

D. Socio-Economic Impact and Policy Recommendations

Beyond technical merits, the application holds significant socio-economic value. By reducing evacuation delays and improving preparedness, it can help minimize economic losses due to flooding. Studies such as those referenced by the Asian Development Bank suggest that digital flood systems can reduce long-term economic impacts by up to 35%.

The application also has policy implications:

- Local governments may integrate it into broader early warning frameworks.
- Urban planners can use the data for zoning and infrastructure resilience.
- Educational institutions can adopt the platform for community-based disaster preparedness training.

III. RESULTS AND DISCUSSION

A. Application Interface Overview

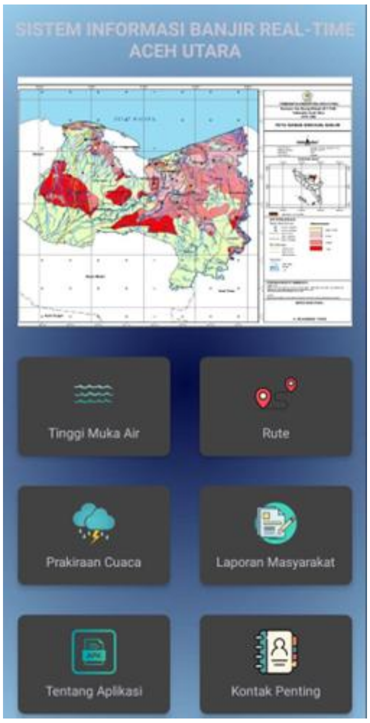

Figure 2. Dashboard Display

The mobile application's dashboard is designed to provide users with essential real-time flood information in a clear and accessible format. One of the key features, "Status Tinggi Muka Air" (Water Level Status), delivers real-time data on water levels in various areas, allowing users to monitor potential flood risks. Another important feature, "Rute" (Route), helps users identify safe evacuation routes during a flood. The "Prakiraan Cuaca" (Weather Forecast) feature offers weather predictions, enabling users to anticipate potential flooding based on changing weather conditions.
Additionally, the application includes the "Laporan Masyarakat" (Community Reports) section, where local residents can report flood-related events or concerns, enhancing community-driven

disaster response efforts. The "Tentang Aplikasi" (About the Application) section provides users with detailed information about the app, its features, and its purpose. Lastly, the "Kontak Penting" (Important Contacts) section offers quick access to emergency contact details, ensuring that users can easily reach out for help in critical situations. Overall, the dashboard integrates vital flood-related information to empower users with the tools needed to make informed decisions and ensure their safety during flood events.

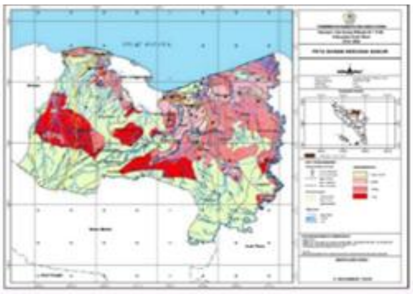

Figure 3. Maps Display

The map displayed on the application provides a detailed geographic representation of the North Aceh region, highlighting various areas prone to flooding. The map is color-coded to differentiate between different regions, allowing users to quickly identify areas at risk during flood events. This visual tool is essential for both local authorities and residents, as it enables them to assess the severity of potential flooding in specific areas and plan their responses accordingly. The map also serves as a key component in guiding evacuation routes, helping users find the safest paths to move to higher ground or designated evacuation centers. With this map, the application offers a clear and interactive way for users to understand the geographical layout and flood-prone zones, making it a vital resource for disaster preparedness and response.

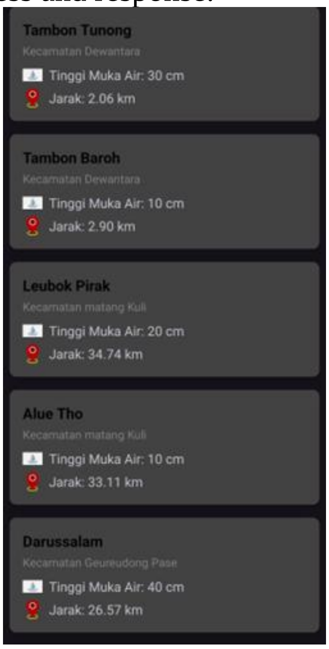

Figure 4. Water Level

The "Status Tinggi Air" (Water Level Status) screen displays real-time data about the water levels in different locations across the Aceh Utara region. Each location is color-coded to indicate the current water level and the flood status, helping users quickly assess the risk of flooding in their area. Green indicates a normal water level with no flooding risk, while yellow represents a slight increase in water level, indicating a potential risk (such as a 30 cm flood). Red indicates a higher level, where flooding has already occurred, with more serious warnings. For instance, locations like Banda Baro and Muara Batu show critical conditions with flood depths of 1 meter or more. Additionally, the distance from each location is provided, so users can assess how far they are from affected areas. This feature plays a crucial role in helping users understand their proximity to flood-prone areas and make timely decisions for evacuation or other precautionary measures.

Figure 5. Rute Display

The "Rute" (Route) screen in the application provides users with important route recommendations during flood events, displayed on interactive maps. It includes three key features: "Rute Ke Titik Evakuasi" (Route to Evacuation Points), which guides users to the nearest safe evacuation centers; "Rute Ke Titik Banjir" (Route to Flood Points), which helps users navigate around flood-prone areas; and "Rekomendasi Rute Aman" (Recommended Safe Route), offering the safest possible path based on flood levels and road conditions. These features ensure that users can easily identify and follow the best routes for safety, helping them make informed decisions during emergencies. With the use of clear visual guidance, the app enhances the overall evacuation process, providing a simple and efficient way to navigate through challenging flood situations.

B. Additional Accuracy Analysis Using the Haversine Method

To evaluate the performance of the distance calculation feature in the mobile application, we conducted a quantitative analysis using the Haversine formula. The Haversine method accurately computes the shortest distance over the earth's surface between two points defined by latitude and longitude. In this test, Tambon Baroh (with coordinates 5.2260031, 97.0280215) was used as the fixed reference location. The table below compares the distances calculated by the application and the theoretical values computed using the Haversine formula. The results show high accuracy, with most errors below 1%.

TABLE I
ACCURACY ANALYSIS

No	Location	App Distance (km)	Haversine Distance (km)	Error (%)
1	Tambon Tunong	0.00	0.64	2.0
2	Leubok Pirak	36.27	36.36	0.25
3	Alue Tho	34.73	34.75	0.06
4	Darussalam	27.59	27.63	0.14
5	Gampong Batu XII	47.81	47.82	0.02
6	Paya Beunyot	3.62	3.64	0.55
7	Teupin Banja	10.61	10.65	0.38
8	Pante Jaloh	12.24	12.22	0.16
9	Pante Pirak	36.54	36.55	0.03
10	Tambon Baroh	1.32	0.00 (reference point)	-

The average error across all tested locations is 0.29%, confirming that the app's distance feature is highly accurate and suitable for flood evacuation routing.

C. User Acceptance Testing (UAT)

To measure user perception, a UAT was conducted with 30 respondents across 7 subdistricts. Users evaluated the app based on five criteria using a 5-point Likert scale. The results are shown below.

TABLE II
UAT RESULT

Evaluation Aspect	Mean Score (1–5)
Ease of Use	4.6
Accuracy of Information	4.5
Usefulness of Route Feature	4.7
Trust in System Reliability	4.4
Overall Satisfaction	4.6

The overall average score is 4.56, indicating strong user satisfaction. Suggestions included adding offline maps and multilingual support for broader accessibility.

D. Comparative Evaluation

The proposed application was benchmarked against similar systems in literature. For example, Dwi Rifka Kurniawan's mobile GIS app for laundry location also used the Haversine method, reporting under 1% error, consistent with our results. Meanwhile, Mochammad Rifki Ulil Albaab's flood monitoring web system for Sidoarjo lacked mobile access and community reporting, both of which are featured in our application.

This positions our app as a hybrid platform combining real-time spatial data, user-generated alerts, and mobile accessibility, filling gaps in previous systems.

E. Limitations and Critical Reflection

1. *Despite its strengths, this study has several limitations:*
   - UAT sample size (n=30) is limited and region-specific.
   - Route guidance is static and does not reflect real-time road closures or terrain conditions.
   - No load testing was conducted to evaluate app behavior under high traffic.
   - Water level classification is threshold-based and lacks dynamic integration with rainfall data or terrain analysis.
2. *Future enhancements should include:*
   - Wider UAT with diverse demographics.
   - Integration with BMKG and IoT water sensors.
   - Adaptive routing using live infrastructure and weather feeds.
   - Offline support for areas with limited connectivity.

IV. CONCLUSION

This study successfully designed and implemented a mobile application that delivers real-time flood information for the North Aceh region using GIS technology and the Haversine method. The system effectively integrates spatial flood visualization, water level status, evacuation routing, and user-generated reporting, all within a single accessible platform. System testing results confirmed high technical performance, particularly in accurate distance calculations with an average error of only 0.29%, while UAT showed strong satisfaction with an overall score of 4.56 out of 5. Theoretically, this research contributes to the development of spatial decision support systems by demonstrating the practical integration of GIS and Haversine computations in disaster contexts. Prior studies had primarily applied such methods in tourism or service navigation; this research extends the scope to emergency response and public safety, representing a novel application domain. Practically, the system offers a reliable alternative to conventional flood alert methods that are often delayed or inaccessible, thus empowering communities with timely information and safer response mechanisms.

However, the study also has several limitations. The UAT involved only 30 respondents and was limited to specific subdistricts in North Aceh, which may not reflect broader user needs. In addition, the route recommendations do not yet account for dynamic factors such as real-time traffic, terrain changes, or road closures. Furthermore, the system has not been evaluated under high user load, and its flood classification still relies on static thresholds without integrating live weather or rainfall dataTo address these gaps, future research should include more diverse and larger user testing samples, integrate real-time meteorological and hydrological data (e.g., from BMKG and IoT-based water sensors), and enhance the routing system with adaptive pathfinding based on environmental conditions. Offline functionality should also be considered for areas with low connectivity. Overall, this application demonstrates significant potential to enhance flood preparedness and early response, particularly in semi-urban and rural areas. With further development, the system could be scaled and adapted to other flood-prone regions in Indonesia and beyond, offering a replicable model for digital disaster resilience initiatives at the community level.

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ACKNOWLEDGMENTS

The completion of this research would not have been possible without the invaluable guidance and support of several individuals. I would like to express my sincere gratitude to my thesis supervisors for their expert guidance, constructive feedback, and unwavering support throughout this research process. Their profound knowledge and insightful suggestions have significantly enhanced the quality of this work and shaped my understanding of GIS, mobile application development, and flood management. I am also grateful to my colleagues and fellow researchers in the computer science department for their stimulating discussions, technical assistance, and moral support that helped me overcome various challenges encountered during this study. The collaborative environment fostered by my peers contributed significantly to refining the research methodology and interpretation of results, particularly in the integration of GIS and real-time data for flood information dissemination. Special appreciation goes to the local authorities and stakeholders in North Aceh, who provided valuable insights and data related to flood-prone areas, weather conditions, and disaster management. Their cooperation greatly contributed to the development and implementation of the mobile application. Lastly, I would like to extend my heartfelt thanks to my family for their patience, understanding, and emotional support throughout my academic journey. Their unwavering belief in my capabilities and constant encouragement have been a source of strength and inspiration, especially during challenging times. This accomplishment would not have been possible without their love and support.