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# Development of a Web-Based Geographic Information System for Mapping and Monitoring the Spatial Distribution of Dengue Hemorrhagic Fever (DHF) Cases in Manado City

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Dengue Hemorrhagic Fever (DHF) remains a major public health concern in many regions of Indonesia, including Manado City. The spatial distribution of dengue cases is strongly influenced by environmental and geographical factors, highlighting the need for an information system capable of providing timely and accurate spatial data to support disease surveillance and control. This study aims to design and develop a web-based Geographic Information System (GIS) for mapping the spatial distribution of DHF cases in Manado City. The system was developed using the Waterfall software development model, which consists of the sequential phases of requirements analysis, system design, implementation, testing, and maintenance. The application was implemented using PHP as the programming language and MySQL as the database management system, while Leaflet.js and OpenStreetMap were utilized to provide interactive geospatial visualization based on GeoJSON data. The developed system enables users to visualize the spatial distribution of dengue cases through an interactive digital map, manage epidemiological data, and access statistical summaries via a web-based dashboard. Functional evaluation using Black Box Testing demonstrated that all major system functions operated correctly and fulfilled the specified requirements. The proposed GIS application provides an effective platform for spatial disease surveillance and supports evidence-based decision-making by public health authorities in planning and implementing dengue prevention and control strategies.
**Keywords:** Geographic Information System (GIS), Dengue Hemorrhagic Fever (DHF), Web-Based Application, Spatial Mapping, Waterfall Model, Disease Surveillance.



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## 1. Introduction

Dengue Hemorrhagic Fever (DHF) remains one of the most significant public health challenges in Indonesia. According to the Indonesian Ministry of Health, the incidence of DHF fluctuates annually, with a substantial mortality burden, particularly among children and adolescents [1]. The transmission dynamics of the disease are closely associated with environmental and geographical factors, including population density, rainfall patterns, and the availability of breeding habitats for Aedes aegypti mosquitoes [2]. Consequently, the adoption of Geographic Information Systems (GIS) has become increasingly important for mapping, monitoring, and controlling the spatial distribution of dengue cases, thereby supporting more effective public health interventions and evidence-based decision-making [3], [4] .

Previous studies have demonstrated that GIS provides a powerful platform for visualizing epidemiological data in a spatial context, enabling health authorities to better understand disease distribution and transmission patterns [5]. GIS is a computer-based system designed to acquire, store, manage, analyze, and visualize spatial and attribute data associated with geographic locations [6], [7]. In the context of DHF

ISSN 2797-7889


surveillance, GIS facilitates the mapping of disease incidence across administrative regions, such as villages, subdistricts, or districts, allowing public health agencies to identify endemic areas, detect transmission clusters, and prioritize vector control strategies [8]. Compared with conventional tabular reporting, spatial visualization provides a more comprehensive understanding of the relationship between environmental determinants and the geographical distribution of dengue cases, thereby improving the effectiveness of disease surveillance and intervention planning [9].

Despite these advantages, many existing GIS-based dengue surveillance systems remain limited in functionality. Most available systems are relatively static, provide minimal user interaction, and lack integration with a structured software engineering methodology [10]. These limitations reduce their capacity to support timely spatial analysis and rapid decision-making, particularly during outbreaks when real-time access to accurate geospatial information is essential [11]. Furthermore, inadequate system architecture and documentation often hinder future maintenance, scalability, and integration with other public health information systems [12].

To address these challenges, this study develops a web-based Geographic Information System for dengue surveillance using the Waterfall software development model. The Waterfall model adopts a systematic and sequential approach in which each development phase including requirements analysis, system design, implementation, testing, deployment, and maintenance is completed before proceeding to the next stage. This methodology was selected because the system requirements and research scope were clearly defined at the outset, making the Waterfall model more appropriate than iterative approaches such as Agile, which are better suited to rapidly evolving requirements. Moreover, the Waterfall model emphasizes comprehensive documentation throughout the development lifecycle, facilitating system evaluation, maintenance, and future enhancements. Previous studies in health information systems have also reported that the Waterfall approach is effective for developing small- to medium-scale web-based applications with stable functional requirements, making it an appropriate methodological choice for this research.

## 2. Literature Review And Problem Statement

Geographic Information Systems (GIS) have been widely adopted in public health research as an effective tool for analyzing, visualizing, and monitoring the spatial distribution of infectious diseases [13]. Previous studies have demonstrated that GIS-based applications can support dengue surveillance by identifying high-risk areas, detecting disease clusters, and assisting health authorities in prioritizing vector control interventions. The integration of spatial data with epidemiological information enables decision-makers to better understand the relationship between environmental factors, population characteristics, and disease transmission dynamics [14]. In addition, web-based GIS platforms have further improved the accessibility and dissemination of geospatial information by providing real-time visualization and interactive mapping capabilities for multiple stakeholders [15].

From a software engineering perspective, the success of a GIS application depends not only on its analytical capabilities but also on the robustness of its development methodology. Several software development models have been employed in developing health information systems, including Agile, Rapid Application Development (RAD), and Waterfall. Among these, the Waterfall model remains a suitable approach for projects with clearly defined functional requirements and stable system specifications [16]. Its structured and sequential development process facilitates comprehensive documentation, systematic testing, quality assurance, and long-term system maintenance. Previous studies have reported that the Waterfall model provides reliable outcomes for small- to medium-scale

 ISSN 2797-7889 

web-based information systems, particularly in healthcare environments where data accuracy, system reliability, and process traceability are essential.

Despite the growing adoption of GIS for dengue surveillance, several research gaps remain. Many existing systems primarily focus on spatial visualization while offering limited interactivity, inadequate decision-support features, and insufficient integration with systematic software engineering practices. Consequently, these limitations reduce the effectiveness of spatial data utilization for timely disease monitoring and public health decision-making. Based on these gaps, this study aims to develop an interactive web-based Geographic Information System for Dengue Hemorrhagic Fever (DHF) surveillance using the Waterfall software development model. The proposed system is expected to provide accurate spatial visualization of dengue cases, improve data management and monitoring capabilities, and support evidence-based decision-making for more effective dengue prevention and control strategies.

## 3. Method

This study employed a research and development (R&D) approach to design and implement a web-based Geographic Information System (GIS) for mapping and monitoring the spatial distribution of Dengue Hemorrhagic Fever (DHF). The research was conducted within the service area of Bahu Public Health Center (Puskesmas Bahu) in Manado City, North Sulawesi, Indonesia, a region characterized by relatively high population density and recurring dengue cases. The selection of the study area was based on the availability of documented DHF surveillance data, the diversity of environmental characteristics associated with dengue transmission, and the need for an interactive spatial information system to support disease surveillance and control. Both primary and secondary data were utilized in this study. Primary data were collected through interviews with surveillance officers and administrative staff, as well as direct observations of the existing case reporting and management processes to identify system requirements. Secondary data consisted of recorded DHF case data, including temporal and spatial information obtained from Bahu Public Health Center, complemented by official reports from the Manado City Health Office and relevant scientific literature on GIS, dengue epidemiology, and web-based information systems.

The proposed GIS application was developed using the Waterfall software development model, which consists of sequential phases including requirements analysis, system design, implementation, testing, deployment, and maintenance [17]. Data collection techniques included literature review, semi-structured interviews, field observations, and document analysis to ensure comprehensive understanding of user requirements and system functionality [18]. Spatial and epidemiological data were integrated into a web-based platform to enable interactive visualization of dengue case distribution and facilitate location-based analysis. System validation was performed through functional testing to verify that all modules operated according to the specified requirements, while user-oriented evaluation was conducted to assess the usability and effectiveness of the application in supporting dengue surveillance and decision-making [19]. This methodological framework ensured that the developed system was technically reliable, functionally appropriate, and capable of providing accurate geospatial information for public health management.

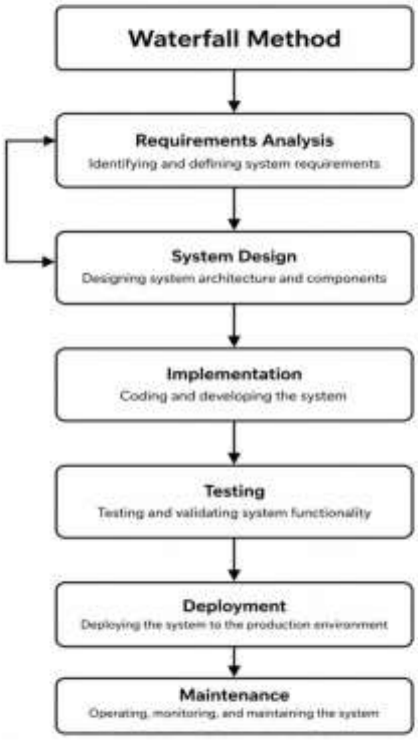


**Fig. 1.** Waterfall Method [20]

The development of the proposed web-based Geographic Information System (GIS) followed the Waterfall software development model, a structured and sequential methodology in which each phase must be completed before progressing to the next. This model was selected because the system requirements were clearly defined at the beginning of the study and were not expected to undergo significant changes during development. The Waterfall model provides a systematic framework that facilitates project planning, comprehensive documentation, quality assurance, and effective management of the software development lifecycle. As illustrated in Figure X, the development process consists of five major phases: requirements analysis, system design, implementation, testing, and maintenance [21].

The first phase, requirements analysis, involved collecting and analyzing user requirements through literature review, interviews, observations, and document analysis to identify both functional and non-functional system requirements. The resulting Software Requirements Specification (SRS) served as the foundation for the subsequent development stages. In the system design phase, the overall system architecture, database schema, user interface, and system workflows were designed using software modeling techniques such as UML diagrams and Entity Relationship Diagrams (ERD). The implementation phase translated these designs into executable code, including database development, module integration, and the implementation of web-based GIS functionalities for spatial visualization and dengue case management.

Following implementation, the system underwent a comprehensive testing phase to verify that all functional components operated according to the predefined requirements. Functional, integration, and system testing were performed to identify and correct potential defects before deployment. Finally, the maintenance phase focused on ensuring the long-term reliability and sustainability of the application through error correction, performance optimization, and future feature enhancements. Overall, the Waterfall model provided a disciplined and well-documented software engineering process, making it particularly suitable for developing health information systems with stable requirements, high reliability, and clear development objectives.

ISSN 2797-7889


## 4. Results And Discussion

The initial phase of this study involved data collection at Bahu Public Health Center (Puskesmas Bahu), Manado City, to understand the existing dengue surveillance process and identify system requirements. Data collected included the number of Dengue Hemorrhagic Fever (DHF) cases over specific periods, patient location data based on villages or geographic coordinates, and monthly and annual case summaries. In addition, interviews were conducted with surveillance officers to examine the current workflow for recording and reporting dengue cases. The findings revealed that dengue surveillance data were primarily maintained in tabular formats (Microsoft Excel and manual records) without integration into a digital mapping platform. Consequently, spatial patterns of disease distribution could not be effectively visualized, making it difficult for health personnel to identify high-risk areas and support evidence-based decision-making.

Based on these findings, a comprehensive requirements analysis was conducted to define both functional and non-functional system requirements. The proposed system was designed to enable administrators to create, update, and delete dengue case records, store geographic information based on administrative areas or geographic coordinates, visualize case locations using interactive map markers, generate regional case summaries, and display detailed information for each reported case. Non-functional requirements included web-based accessibility through standard browsers, a user-friendly and responsive interface, secure administrator authentication, and compatibility across multiple devices. The requirements analysis ensured that the developed GIS application addressed the actual operational needs of the public health center rather than assumptions made by the development team, thereby improving system usability and practical applicability.

Following the requirements analysis, the development process proceeded with planning and iteration initialization. Development priorities were organized into sequential iterations, beginning with database construction and case data management, followed by integration of interactive digital maps, implementation of statistical reporting features, and final user interface refinement and system testing. Prior to implementation, the development environment was established using XAMPP as the local web server environment, integrating Apache, PHP, and MySQL into a unified platform. Apache and MySQL services were configured through the XAMPP Control Panel and validated by successfully accessing the local server via http://localhost. This preparation provided a stable and integrated development environment, ensuring that the subsequent implementation and testing phases could be conducted efficiently and consistently.

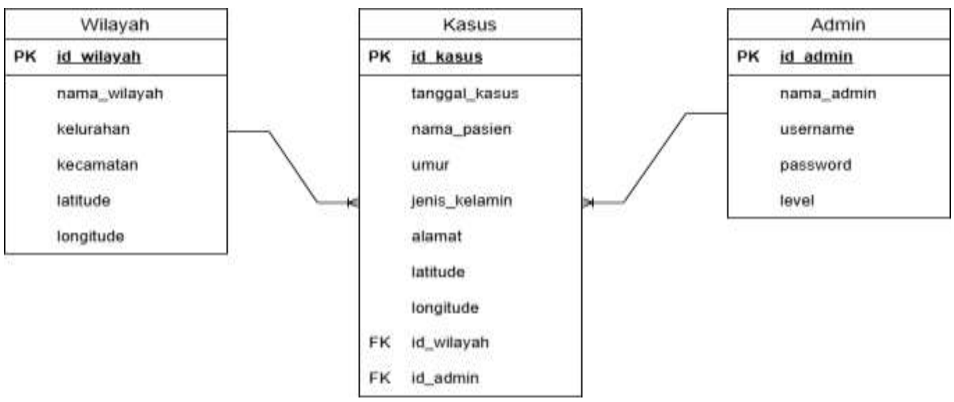


**Fig. 2**. Entity Relationship Diagram

ISSN 2797-7889


Figure 2 illustrates the Entity Relationship Diagram (ERD) of the proposed web-based Geographic Information System (GIS) for Dengue Hemorrhagic Fever (DHF) surveillance. The database consists of three main entities: Region (Wilayah), Case (Kasus), and Administrator (Admin). The Region entity stores geographic information, including region name, village, district, latitude, and longitude, which serves as the spatial reference for dengue case mapping. The Case entity contains epidemiological information, such as the date of diagnosis, patient name, age, gender, address, geographic coordinates, and foreign keys linking each case to its corresponding region and administrator. Meanwhile, the Administrator entity manages user authentication and system access through administrator information, including username, password, and access level. The relationships among these entities ensure data integrity by allowing multiple dengue case records to be associated with a specific geographic region and managed by an authorized administrator, thereby supporting efficient data management, spatial visualization, and decision-making for dengue surveillance.

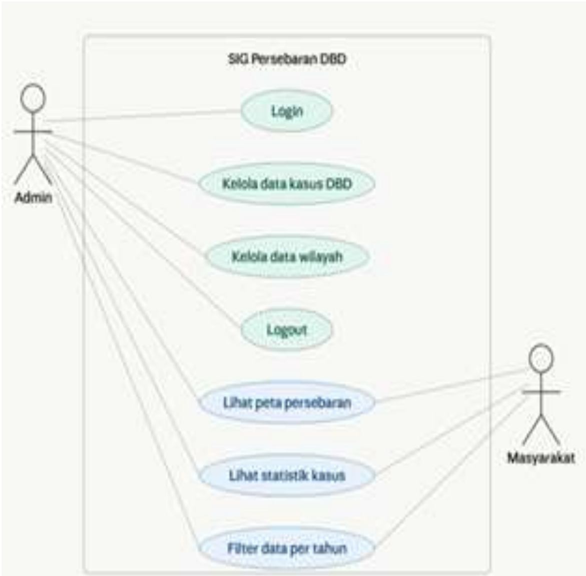


**Fig. 3.** Use Case Diagram

Figure 3 presents the Use Case Diagram of the proposed web-based Geographic Information System (GIS) for Dengue Hemorrhagic Fever (DHF) surveillance, illustrating the interactions between the system and its users. The system involves two primary actors: Administrator and Public User (Community). The Administrator is responsible for authenticating through the login process and managing the system by performing operations such as adding, updating, and deleting dengue case data, maintaining regional information, filtering case data by year, viewing disease distribution maps and statistical reports, and securely logging out of the system. In contrast, the Public User has read-only access, enabling them to view the interactive dengue distribution map, access statistical summaries of reported cases, and filter case information by year without requiring authentication. This use case design clearly defines user roles and access privileges, ensuring secure data management while providing the public with transparent and accessible spatial information to support dengue awareness and prevention efforts.

ISSN 2797-7889



**Fig. 4.** Landing Page Implementation

Figure 4 presents the implementation of the landing page of the proposed web-based Geographic Information System (GIS) for Dengue Hemorrhagic Fever (DHF) surveillance. The landing page serves as the primary interface that provides users with an overview of the current dengue situation through an intuitive and interactive dashboard. The system displays key statistical indicators, including the total number of reported DHF cases, the number of affected areas, and the reporting year. In addition, an interactive digital map visualizes the spatial distribution of dengue cases using location markers, enabling users to identify affected areas more effectively. A statistical chart complements the map by presenting the temporal distribution of reported cases, thereby facilitating trend analysis and supporting evidence-based public health decision-making. The clean and responsive interface enhances usability while providing quick access to essential spatial and epidemiological information for both administrators and the general public.


**Fig. 5**. Dashboard Implementation for Dengue Case Data

Figure 5 illustrates the implementation of the DHF Case Data Dashboard, which serves as the main administrative interface for managing the web-based Geographic Information System (GIS). After successful authentication, administrators are presented with a dashboard that provides a concise overview of key surveillance information, including the total number of reported Dengue Hemorrhagic Fever (DHF) cases and the total number of monitored regions. The dashboard also offers direct access to the system's core functionalities through navigation buttons for managing regional data, managing dengue case records, and viewing the interactive distribution map. This centralized interface enables

 ISSN 2797-7889


administrators to efficiently monitor epidemiological data, perform data management tasks, and access spatial information, thereby improving the effectiveness of dengue surveillance and supporting timely public health decision-making.


**Fig. 6.** Interactive Map Integration Page

Figure 6 illustrates the Interactive Map Integration Page of the proposed web-based Geographic Information System (GIS) for Dengue Hemorrhagic Fever (DHF) surveillance. The page provides an interactive digital map that visualizes the spatial distribution of reported dengue cases within the Bahu Public Health Center service area using geographic markers and coverage boundaries. In addition to the map, the interface displays a list of monitored regions and detailed information on reported dengue cases, enabling users to identify affected locations and examine case-specific information efficiently. By integrating spatial visualization with epidemiological data, the system enhances situational awareness, facilitates the identification of disease clusters, and supports timely, evidence-based decision-making for dengue surveillance and vector control activities.

## 5. Conclusion

This study successfully designed, developed, and implemented a web-based Geographic Information System (GIS) for mapping and monitoring the spatial distribution of Dengue Hemorrhagic Fever (DHF) cases in Manado City using the Waterfall software development model. The proposed system effectively integrates spatial and epidemiological data through interactive digital maps powered by Leaflet and OpenStreetMap, enabling users to visualize the geographic distribution of dengue cases and supporting more efficient disease surveillance. In addition, the system provides comprehensive administrative functionalities, including case data management, regional data management, and a dashboard displaying key statistical indicators to facilitate real-time monitoring and data-driven decision-making. Functional evaluation using Black Box Testing demonstrated that all major system features operated correctly and satisfied the predefined functional requirements without significant errors. Therefore, the developed GIS application can serve as an effective decision-support tool for public health authorities by improving the monitoring, analysis, and management of dengue cases through accurate, interactive, and location-based information, thereby contributing to more efficient dengue prevention and control strategies.

## 6. Referensi

[1] S. P. Latowa, H. Jusuf, and T. S. Maksum, “Spatial Patterns of Dengue Hemorrhagic Fever (DHF) Cases in Boalemo Regency, 2021-2024,” *Int. J. Heal. Econ. Soc. Sci.*, vol. 8, no. 1, pp. 222–226, 2026.

[2] G. Fu, “Seasonal Dynamics and Habitat Characteristics of Mosquito Populations in a Tropical Environment,” *J. Mosq. Res.*, vol. 16, 2026.

[3] U. Mehmood, U. Ujang, and S. Azri, “Urban GIS and digital platforms for sustainable high-density

ISSN 2797-7889


development," in *Digital Platforms for Sustainable Business*, Elsevier, 2026, pp. 265–280.

[4] R. A. Purba, "Application design to help predict market demand using the waterfall method," *Matrix J. Manaj. Teknol. dan Inform.*, vol. 11, no. 3, pp. 140–149, 2021.

[5] B. S. Widodo *et al.*, "Integration of geospatial data in education management systems: A multiple study in eastern Java regions, Indonesia," *Geo J. Tour. Geosites*, vol. 62, no. 4, pp. 2240–2248, 2025.

[6] U. Ujang and R. N. Yadava, "Geospatial Technology in the Smart City Paradigm," in *Innovations in Geospatial Technology for Sustainable Smart City Development*, Springer, 2026, pp. 3–38.

[7] R. A. Purba, "PENDETEKSIAN SISI TEPI OBJEK CITRA DIGITAL MENGGUNAKAN OPERATOR LAPLACE DENGAN TEKNIK KONVOLUSI UNTUK MENGHASILKAN BAHAN DASAR MENGGAMBAR ANAK," *SEMNASTEKNOMEDIA ONLINE*, vol. 5, no. 1, pp. 2–4, 2017.

[8] A. R. Crispin, E. Edbert, V. T. Hulu, P. B. Kamble, and A. Dharma, "Trends and Potential of Geographic Information Systems in Dengue Management: Bibliometric Analysis," *J. Eng. Sci. Appl.*, vol. 2, no. 2, pp. 13–20, 2025.

[9] A. C. Okafor, O. Imarhiagbe, and M. C. Ogwu, "Dengue fever: Integrated approaches for sustainable disease management," in *Sustainable health practices for emerging tropical diseases*, Springer, 2026, pp. 53–86.

[10] J. Chaiyarit and P. Intarasaksit, "Environmental Health Factors and Dengue Risk Mapping Using Spatial-AHP: A Case Study in Nakhon Nayok Province, Thailand," *Spat. Spatiotemporal. Epidemiol.*, p. 100808, 2026.

[11] R. A. Purba and S. Sondang, "Design and Build Monitoring System for Pregnant Mothers and Newborns using the Waterfall Model," *INTENSIF J. Ilm. Penelit. dan Penerapan Teknol. Sist. Inf.*, vol. 6, no. 1, pp. 29–42, 2022.

[12] R. Purba, "DSS Determines the Best Urban Village in handling COVID-19 Using AHP Method," *J. Sist. Komput. dan Inform.*, vol. 7, pp. 742–751, Dec. 2025, doi: 10.30865/json.v7i2.9384.

[13] L. Warlina and A. Afredi, "Geographic Information System (GIS) Application to Identify the Distribution of Tourist Attractions and Supporting Facilities Related to the Sustainable Development Goals (SDGs)," *Indones. J. Sci. Technol.*, vol. 11, no. 2, pp. 525–540, 2026.

[14] M. Billah, M. E. Shaik, M. S. Hossain, S. E. Jahan Sakib, and L. Rahman, "Identification and Analysis of Road Traffic Crash Hotspots Using Geographic Information System (GIS): A Study on Dhaka–Mawa Expressway (N804), Bangladesh," *J. Sensors*, vol. 2026, no. 1, p. 5619948, 2026.

[15] R. A. Purba, "The Effectiveness Combination of Blended Learning and Flipped Classroom with Edmodo as a Digital Media Innovation for Learning From Home," *J. Educ. Technol.*, vol. 5, no. 3, 2021.

[16] M. F. G. Matondang, M. S. Harefa, E. Yuniastuti, M. Putra, R. Mahmuda, and T. A. Azis, "Integration of Geographic Information Systems in Determining Flood Risk Evacuation Routes in Medan City," *Indones. J. Earth Sci.*, vol. 6, no. 1, pp. A1607–A1607, 2026.

[17] R. A. Purba, D. J. M. Sembiring, S. M. B. Perangin-Angin, and R. Buaton, "Implementasi Metode Promethee Untuk Rekomendasi Destinasi Objek Wisata Unggulan Provinsi Sumatera Utara," *JST (Jurnal Sains dan Teknol.*, vol. 13, no. 1, pp. 181–189, 2024.

[18] R. A. Purba, "SMART NETWORK REFERENCE DICTIONARY DEVELOPMENT USING WATERFALL FRAMEWORK MODEL TO IMPROVE LEARNING OUTCOMES," *J. Inov. Pendidik. dan Teknol. Inf.*, vol. 7, no. 1, pp. 65–78, 2026.

[19] R. A. Purba, "Integration of Machine Learning and GAP Analysis for a Data Driven Lecturer Performance Evaluation System," *International Journal of Advances in Data and Information Systems*, vol. 7, no. 1 SE-Articles. pp. 52–61, 2026, doi: 10.59395/ijadis.v7i1.1481.

ISSN 2797-7889


[20] R. A. Purba and U. Verawardina, “Deteksi Mahasiswa Yang Dapat Menyusun Tugas Akhir dengan Metode Visekriterijumsko Kompromisno Rangiranje (VIKOR),” *Techno. Com*, vol. 20, no. 2, pp. 210–220, 2021.
[21] S. Sugiyono, “Metode penelitian kuantitatif dan kualitatif dan R&D,” *Alf. Bandung*, 2010.