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E-mail:ambidex@takaza.id

A Decision Support System for Prioritizing Lighting in Crime-Prone Areas Using GIS-Based AHP and Topsis Methods

Fakry alfarizi[1], Firahmi Rizky[2]
Program Studi Teknologi Informasi Fakultas Ilmu Komputer Dan Teknologi Informasi
Universitas Muhammadiyah Sumatera Utara
Corresponding Author e-mail : fakryalfarizi260903@gmail.com, firahmirizky@umsu.ac.id

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Abstract : *Inadequate lighting in crime-prone areas requires a decision support system to determine lighting installation priorities objectively and spatially. This study aims to develop a decision support system for prioritizing lighting in crime-prone areas in Medan City by integrating the Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Geographic Information System (GIS). This applied research employs a descriptive quantitative approach. The population consists of locations potentially vulnerable to crime in Medan City, while the sample consists of 25 location alternatives. Data were collected through literature reviews, observations, documentation, and interviews. AHP was used to determine criterion weights and assess consistency, while TOPSIS calculated preference scores and ranked the locations. The results indicate a Consistency Ratio of 0.0153, with Belawan I, Yos Sudarso Street, achieving the highest preference score of 0.861. The system presents the rankings through tables and digital maps using Leaflet Maps and OpenStreetMap. In conclusion, integrating AHP, TOPSIS, and GIS provides a structured approach to prioritizing lighting locations and supports decision-making for targeted lighting installation in crime-prone areas.*

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Introduction

Street lighting is an important public facility that contributes to public safety, comfort, and environmental visibility, particularly in areas with potential crime vulnerability. Adequate lighting improves visibility at night and supports environmental monitoring by allowing road users, residents, and security personnel to observe surrounding conditions more clearly. Conversely, inadequate lighting can create poorly illuminated spaces that limit visibility and reduce opportunities for monitoring activities. Therefore, lighting conditions should be considered as one of the environmental factors in

identifying locations that require greater attention to public safety. In addition to lighting conditions, crime rates, community activity density, road access, and distance from security posts may also provide relevant information for assessing the vulnerability of an area (Azis & Ridwan, 2025). Identifying locations that require lighting improvements consequently requires an assessment that considers both security-related and environmental characteristics.

The development of information technology, particularly Geographic Information Systems (GIS), provides opportunities to support the identification and analysis of crime-prone areas. GIS enables spatial data processing, location distribution mapping, and the presentation of geographic information to support decision-making (Isfahani & Paramudita, 2025). Previous studies have demonstrated the application of GIS in crime-related information management. Saputra et al. (2024), in their study of crime information in Central Java during 2019–2021, developed a geographic information system to map crime incidents based on their locations and types. Similarly, Kurniawan et al. (2024) developed a GIS-based system for mapping crime-prone areas. These studies demonstrate the usefulness of GIS in presenting the spatial distribution of criminal activities and identifying areas with potential crime risks. However, their primary focus is on crime information mapping and spatial visualization. Such approaches provide information about where crime incidents or vulnerable areas are located, but do not explicitly establish a multi-criteria decision-making process for determining which locations should receive priority for street lighting installation. Consequently, spatial mapping alone does not fully address the need to compare alternative locations according to different environmental and security-related criteria.

Another challenge concerns the process of determining street lighting installation priorities. When location selection relies primarily on manual assessment, differences in judgment and the absence of a structured comparison process may affect the consistency of decisions. A systematic approach is therefore required to assess alternative locations using measurable criteria, including crime rates, existing lighting conditions, community activity density, road access, and distance from security posts. These criteria represent different aspects of location vulnerability and lighting needs, so they require a method capable of determining their relative importance and evaluating each alternative consistently. The Analytical Hierarchy Process (AHP) can be used to determine criterion weights through pairwise comparisons, while the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) can rank alternatives based on their relative distances from positive and negative ideal solutions (Siagian, 2024). The combination of these methods provides a structured basis for evaluating locations, rather than relying solely on the visual identification of crime-prone areas.

Based on these considerations, integrating AHP, TOPSIS, and GIS offers an approach that connects multi-criteria evaluation with spatial information. AHP determines the relative importance of the assessment criteria, and the resulting weights are used in TOPSIS to calculate preference scores and rank alternative locations. GIS then presents the ranking results spatially, allowing users to identify the geographic distribution of locations according to their priority levels. This integration addresses a limitation of previous GIS-based crime mapping approaches by extending the system's function beyond mapping crime information to supporting decisions about street lighting installation priorities. The use of AHP and TOPSIS also makes the assessment process more structured because each alternative is evaluated using the same criteria and weighting framework, while GIS facilitates the interpretation of the resulting priorities in their geographic context.

This study aims to develop a web-based decision support system for prioritizing street lighting in crime-prone areas in Medan City by integrating AHP for criterion weighting, TOPSIS for alternative ranking, and GIS for spatial visualization using Leaflet Maps and OpenStreetMap. The urgency of this research lies in the need for a more objective, measurable, and transparent process to identify locations that require lighting improvements. The main contribution of this study is the development of an integrated decision support system that combines three complementary functions: determining the relative importance of assessment criteria, ranking alternative locations based on their preference scores, and visualizing the resulting priorities on a digital map. Unlike previous studies that primarily focused on mapping crime incidents or crime-prone areas, this research uses spatial information as part of a multi-criteria decision-making process to support the prioritization of street lighting installation in Medan City.

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Method

This research is an applied research with a descriptive quantitative approach that aims to build a decision support system to determine the priority of lighting in crime-prone areas in Medan City. The system was developed web-based by integrating the Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Geographic Information System (GIS) methods. AHP is used to determine the criteria weights, TOPSIS to rank the locations, while GIS is used to visualize the lighting priority results through Leaflet Maps and OpenStreetMap. This approach supports decision-making based on structured data and criteria (Harun & Aprilya, 2025).

The research instruments included location data, assessment criteria, alternative values, latitude and longitude coordinates, and documentation and information from observations and interviews. Data collection was conducted through literature studies, observations of crime-prone areas, location documentation, and interviews with local residents, security officers, and related parties. Assessment criteria included crime rates, lighting conditions, community activity density, road access, and distance to security posts.

Data analysis was performed using a combination of AHP and TOPSIS methods. AHP was used to calculate the priority weights of criteria through a pairwise comparison matrix and test the consistency of the assessment using the Consistency Ratio (CR), with the provision of $CR \leq 0.10$. Next, TOPSIS was used to compile the decision matrix, perform normalization, calculate the weighted normalization matrix, determine the positive and negative ideal solutions, calculate alternative distances, and obtain preference values to determine location rankings. The ranking results are presented in tables and GIS-based digital maps.

The study population included locations in Medan City that are potentially crime-prone and require priority lighting enhancements. The study sample consisted of alternative locations analyzed based on five predetermined assessment criteria. Based on the calculated data used in the system, 25 alternative locations were processed using the AHP and TOPSIS methods to determine the lighting priority order.

The research procedure was carried out through several stages. First, identifying the problem of determining lighting priorities and collecting location data through literature studies, observation, documentation, and interviews. Second, determining alternative locations and five assessment criteria. Third, weighting the criteria using AHP and testing the consistency of the comparison matrix. Fourth, applying TOPSIS to calculate preference values and determine the priority ranking of each location. Fifth, implementing the calculation results into a web-based system and displaying the distribution of locations through Leaflet Maps and OpenStreetMap. Finally, conducting system testing and compiling a research report based on the results of data processing and visualization of lighting priorities in crime-prone areas in Medan City.

Results and Discussion

Results View

1. Login Page

The login page is the first screen users see before accessing the application's main features. It contains the system ID, username fields, password fields, and a login button. The interface is designed to be simple to allow for straightforward authentication without displaying elements unrelated to the user's needs.

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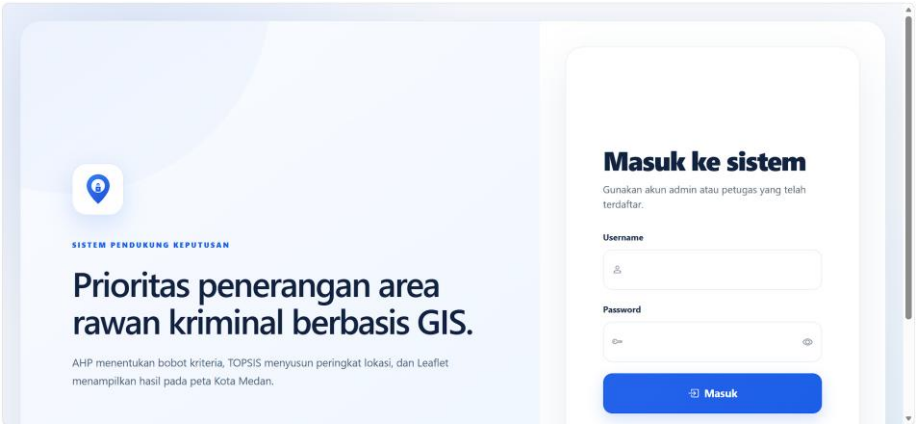


Figure 1. Login View

Based on Figure 1, the user enters their username and password in the provided fields, then presses the Login button. The system matches this data with the account stored in the database. If the data matches, a user session is created and the dashboard page is displayed. If the data does not match, access is denied, and the user remains on the authentication page with a redirecting error message.

The application differentiates between administrator and officer access rights. Administrators manage all data, users, calculations, reports, and settings. Officers focus on data management and analysis processes according to their assigned authority. Once a user exits the application, their session is terminated, preventing the protected page from being reopened via the browser's back button.

2. Dashboard Page

The dashboard page displays a summary of the system's status after successful authentication. Key information is organized into statistical cards and graphs to provide users with a quick overview of the number of alternatives, the criteria used, priority categories, and active accounts within the application.

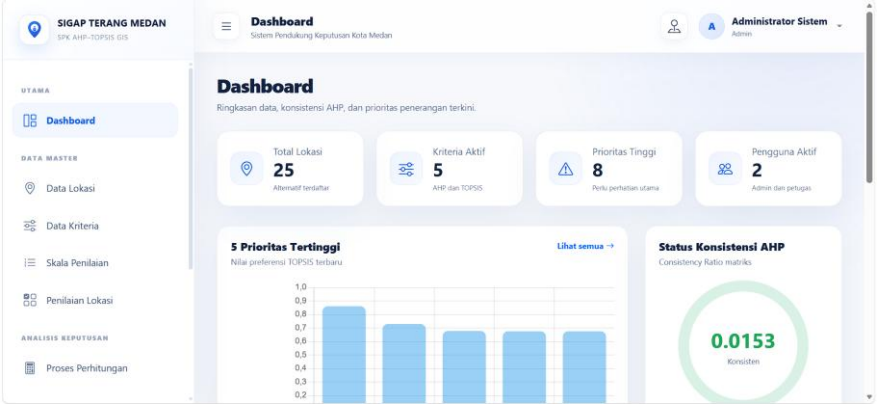


Figure 2. Dashboard page

In Figure 2, the Total Locations card shows 25 registered alternative locations. The Active Criteria card displays five AHP and TOPSIS criteria. The High Priority card lists eight locations requiring primary attention, while the Active Users card displays two accounts: an administrator and an officer. This summary helps users check data availability before executing the decision-making process. The five highest priority graph visually displays the order of TOPSIS preference values. The highest value is around 0.861, followed by 0.730, 0.678, and a value around 0.676. Preference values are not interpreted as a crime percentage, but rather as a relative score indicating a location's proximity to the positive ideal solution and its distance from the negative ideal solution. The AHP Consistency Status section displays a Consistency Ratio of 0.0153. This value is below the 0.10 threshold, so the pairwise comparison matrix is considered consistent. This condition indicates that the relationship between the levels of importance between criteria has met the requirements for use in the TOPSIS stage.

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3. Location Data Page

The Location Data page is used to manage alternatives analyzed by the system. Each alternative contains a location code, point name, address, sub-district, village, latitude and longitude coordinates, status, and criteria values. Users can add locations manually or import location data from an Excel file.

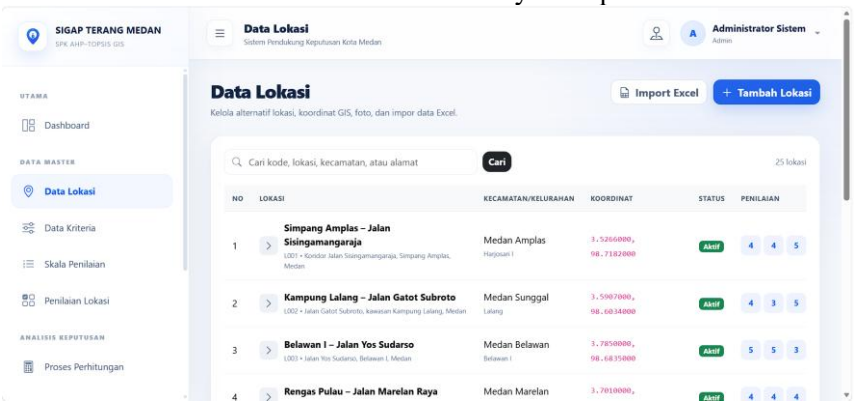


Figure 3. Location Data Page

Figure 3 shows the search feature, the Import Excel button, the Add Location button, and the alternative list table. The Number column displays the data sequence, not the primary identifier value in the database. The arrow buttons on each row function as a drill-down to expand location details without expanding the main table. The action buttons are arranged in parallel to maintain a streamlined data management process. The test location data uses area names and coordinates that refer to the Medan City area, including Simpang Amplas, Kampung Lalang, Belawan I, and Rengas Pulau. The criteria scores in this data are used as simulation data to test the AHP, TOPSIS, and GIS flows. The import feature checks the column structure before saving the data, so that inappropriate formats can be rejected without disrupting the existing data.

4. Criteria Data Page

The Criteria Data page is used to establish the basis for assessment in the AHP and TOPSIS processes. The five criteria used are crime rate, lighting conditions, community activity density, road access, and distance to security posts. Each criterion has a code, attributes, and description that explain the direction of the assessment.

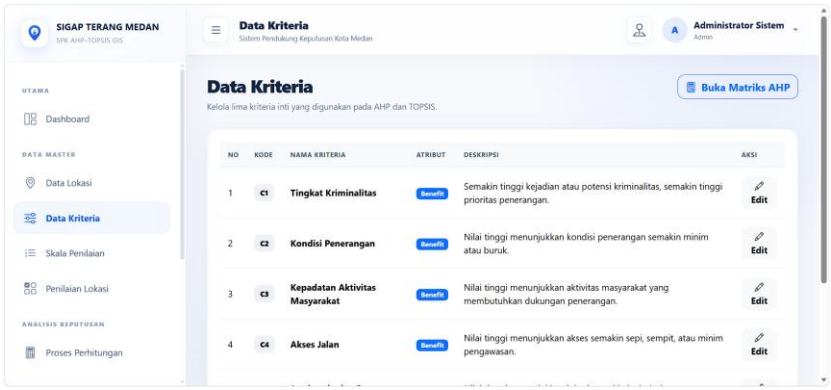


Figure 4. Criteria Data Page

In Figure 4, all criteria are assigned a benefit attribute because a higher value indicates a greater need for lighting. High crime rates increase priority. Poor lighting conditions are given a high score. High activity density requiring lighting, quiet road access, and distance from security posts also increase priority. The Open AHP Matrix button directs users to the pairwise comparison matrix. At this stage, each criterion is compared based on its level of importance. The Edit button is used to update the name, attribute, or description without changing the core code that serves as a reference for the assessment table and calculation process.

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5. Rating Scale Page

The Rating Scale page converts field conditions into numerical values from 1 to 5. The scale maintains uniformity in the input process because each value has a clear condition label and description. Users can filter data based on criteria, add scales, update descriptions, or delete unused data.

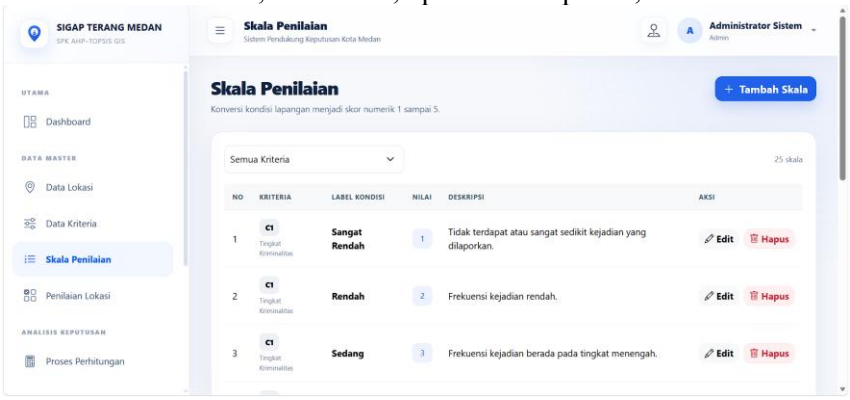


Figure 5. Rating Scale Page

Figure 5 shows an example of a scale for the crime rate criterion. A value of 1 is used for very low conditions, 2 for low, 3 for moderate, 4 for high, and 5 for very high. The same pattern is applied to other criteria, with descriptions adjusted for lighting conditions, community activity, road access, and distance to security posts. The use of condition labels reduces differences in interpretation when officers enter location values. System validation limits values to a range of 1 to 5. Data outside this range is not accepted because it can change the structure of the decision matrix and produce calculations that are inconsistent with the research design.

6. Location Assessment Page

The Location Assessment page is used to construct the TOPSIS decision matrix. Each row represents one alternative location, while each column represents a value from C1 to C5. Values are assigned based on observations, documentation, and field information, converted through a rating scale.

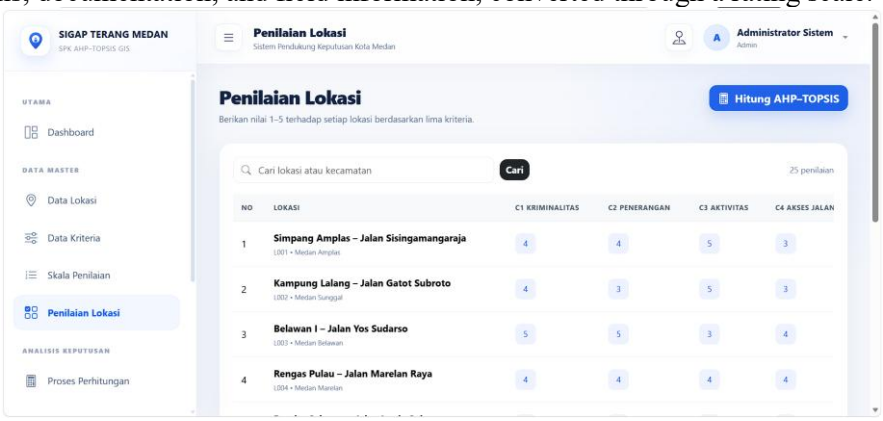


Figure 6. Location Assessment Page

Based on Figure 6, the table displays the location name and score for each criterion. For example, Simpang Amplas has a score of 4 for crime, 4 for lighting, 5 for community activity, and 3 for visible road access. These scores are still preliminary and do not yet indicate the final ranking. The search field is used to find locations by name or sub-district. The Calculate AHP-TOPSIS button directs the user to the analysis process after all scores are complete. The system checks for the presence of five scores for each alternative to prevent normalization and weighting from being performed on empty data.

7. Calculation Process Page

The Calculation Process page combines AHP, TOPSIS, and ranking results into a single flow. Users can navigate through the AHP, TOPSIS, and Ranking Results options. The Run and Save buttons run the calculation based on the most recent data and save the process history.

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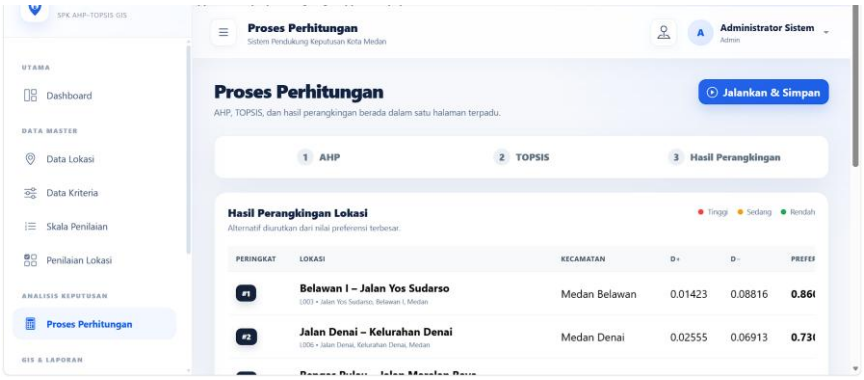


Figure 7. Calculation Process Page

The AHP stage generates the weights of each criterion from the pairwise comparison matrix. After normalization, the system calculates the priority vector, maximum eigenvalue, Consistency Index, and Consistency Ratio. The weights are only passed to TOPSIS if the consistency ratio value does not exceed 0.10. The TOPSIS stage forms a decision matrix, performs normalization, multiplies the normalized value by the AHP weights, determines the positive and negative ideal solutions, and calculates the D+ and D- distances. The preference value is obtained from the comparison of the distances to the two ideal solutions. The greater the preference value, the higher the alternative's position in the lighting priority order. The ranking results place Belawan I - Jalan Yos Sudarso in first place with a value of 0.861. Jalan Denai - Kelurahan Denai is in second place with a value of 0.730, followed by Rengas Pulau - Jalan Marelan Raya at 0.678. Simpang Amplas and Simpang Pos are in the range of 0.676. The difference in values between locations indicates the level of closeness of each alternative to the ideal conditions determined by the research criteria and weights.

8. GIS Map Page

The GIS Map page presents the ranking results in spatial form. The coordinates of each location are displayed on a Leaflet map sourced from OpenStreetMap. This visualization links preference values to geographic location, allowing users to understand the distribution of priorities within the city of Medan.

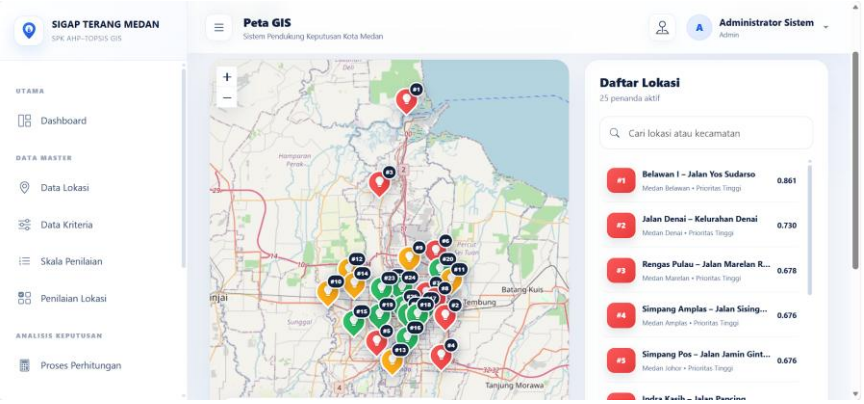


Figure 8. GIS Map Page

Figure 8 shows 25 location markers categorized. Red markers indicate high priority, orange markers indicate medium priority, and green markers indicate low priority. The marker number indicates its ranking position. The location list on the right displays the location name, district, category, and preference value, and provides a search feature to speed up the search for a specific point. Priority categories follow thresholds stored on the Settings page. A value of 0.6600 or higher is considered high. Values from 0.4500 to less than 0.6600 are considered medium, and values below 0.4500 are considered low. These categories reflect lighting priorities based on a multi-criteria analysis, not a single measure of crime rate.

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9. Report Page

The Reports page is used to export data and review the AHP-TOPSIS process history. The report type is selected from a drop-down list, and then the user clicks the Download button. This layout replaces multiple separate report cards, allowing for more efficient page space and a clearer export flow.

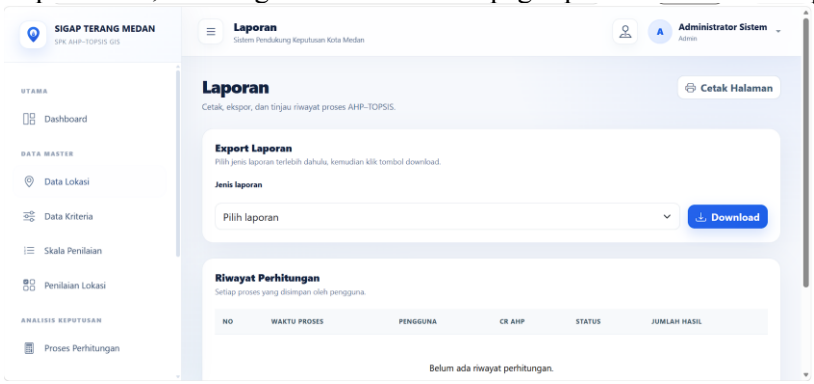


Figure 9. Report Page

In Figure 9, available report types include location reports, criteria reports, and priority reports. The Print Page button is used to generate a print view of the active page. The Calculation History section records the processing time, user, AHP consistency ratio value, status, and number of saved results. If no processes have been saved, the history table displays a note that the data is not yet available. After the Run and Save buttons are used on the calculation page, the history data will appear as evidence of the analysis process that has been carried out by the user.

10. User Data Page

The User Data page is used by administrators to manage which accounts can access the application. Stored information includes name, username, access rights, account status, and last login time. Add, edit, and delete features are provided according to system access rights rules.

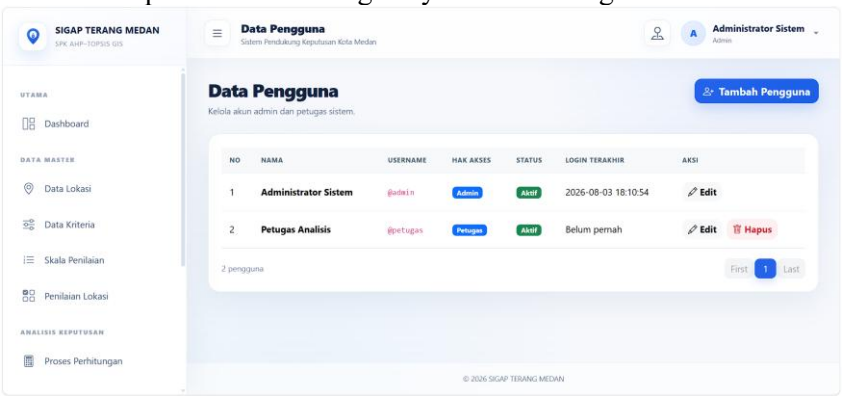


Figure 10. User Data Page

Figure 10 displays two active accounts: the System Administrator and the Analysis Officer. The administrator account has Admin privileges, while the officer account has Officer privileges. The last login time data helps administrators monitor account usage. The primary administrator account only provides Edit actions, while the officer account can be edited or deleted. The bottom of the table displays the First, page number, and Last navigation. The table's sequential numbers are arranged based on the data's position on the page, so they remain sequential even if data is added or deleted.

11. Settings Page

The Settings page is the central configuration for application identity, map starting point, zoom level, and priority category limits. Changes are made through the interface, allowing administrators to adjust operational parameters without directly modifying program files.

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Figure 11. Settings Page

Based on Figure 11, the application name is set as SIGAP TERANG MEDAN and the agency name is set as Medan City Decision Support System. The starting point of the map uses latitude 3.5951960 and longitude 98.6722260 with a zoom level of 12. These values place the initial view in the Medan City area. The high priority threshold is set at 0.6600 and the medium priority threshold at 0.4500. Changes to the thresholds affect the category labels and marker colors on the map, but do not change the order of the TOPSIS preference values. The Save Settings button applies the changes after the data is declared complete and in the correct format.

System Testing

System testing is conducted using the Black Box Testing method. Testing focuses on the relationship between input data, user actions, and system output without discussing the program code structure. Scenarios are created for valid and invalid data so that the application's response can be assessed under normal conditions and error conditions. The correct mark (✓) in the category column indicates the type of data used in the test scenario, while the cross (✗) indicates that the scenario does not fall into that category. The test result column is marked true if the system response matches the expected result. Invalid data testing is declared successful when the system rejects the data and displays a notification according to the validation rules.

Table 1. System Testing

No.	Tested Features	Testing Scenario	Valid Data	Invalid Data	Test Results
1	Login	Enter the correct username and password.	✓	✗	✓The dashboard appears and a user session is created.
2	Login	Entering an incorrect username or password.	✗	✓	✓Access is denied and an error message is displayed.
3	Access rights	Opens the dashboard page with an active session.	✓	✗	✓The page appears according to the user's access rights.
4	Access rights	Open protected page addresses without logging in.	✗	✓	✓The system directs the user to the login page.
5	Location Data	Import Excel files with the correct column structure.	✓	✗	✓Location data is saved and displayed in the table.
6	Location Data	Importing a file with the wrong format or columns.	✗	✓	✓The file is rejected and a validation notification appears.
7	Location Data	Add a location with full name, area and coordinates.	✓	✗	✓The new location is saved and the table number is updated.
8	Location Data	Add a location with empty or inappropriate coordinates.	✗	✓	✓The save is canceled and the problematic column is marked.
9	Location Data	Change and delete selected location data.	✓	✗	✓Changes are saved; data is deleted and the display order is tidied up.
10	Criteria Data	Change the name, attribute, or description of a criteria.	✓	✗	✓Criteria data is updated without changing the core code.

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11	Rating Scale	Saves a scale with values 1 to 5.	✓	✗	✓The scale is saved and displayed in the table.
12	Rating Scale	Stores values outside the range 1 to 5.	✗	✓	✓The system rejects the value and displays a notification.
13	Site Assessment	Fill in five criteria values for each location.	✓	✗	✓The decision matrix is stored in full.
14	Site Assessment	Execute the process while one of the values is still empty.	✗	✓	✓The process is stopped until all values are completed.
15	AHP	Using a comparison matrix with CR ≤ 0.10.	✓	✗	✓The weights are accepted and the TOPSIS stage can be run.
16	AHP	Using a comparison matrix with CR > 0.10.	✗	✓	✓The system gives an inconsistent status and requests a fix.
17	TOPSIS	Perform normalization, weighting, and preference values.	✓	✗	✓Grades D+, D-, preference, and ranking are displayed.
18	Calculation Process	Press the Run and Save button after the data is complete.	✓	✗	✓Results are updated and process history is saved.
19	GIS Map	Open the map and select one of the location markers.	✓	✗	✓Position, rank, category and location value are displayed.
20	GIS Map	Searching for a location name that is not available.	✗	✓	✓An empty results list is displayed without stopping the page.
21	Report	Select the report type and then press the Download button.	✓	✗	✓Report files are created according to your choice.
22	Report	Press the Download button without selecting a report type.	✗	✓	✓The system asks the user to select a report first.
23	User Data	Add an account with an unused username.	✓	✗	✓The account is saved and can be used according to access rights.
24	User Data	Add an account with an already registered username.	✗	✓	✓The system rejects duplicate usernames.
25	Arrangement	Saves the correct identity, coordinates, zoom and threshold.	✓	✗	✓The configuration is saved and applied to the system.
26	Arrangement	Filling coordinates or thresholds with an incorrect format.	✗	✓	✓The system rejects the data and displays a notification.
27	Pagination	Select First, page number, and Last in the table.	✓	✗	✓Data moves according to the selected page.
28	Logout	Press logout and try to go back to the previous page.	✓	✗	✓The session expires and the protected page cannot be reopened.

Discussion of Implementation Results

The system workflow begins with recording alternative locations and assigning scores based on five criteria. AHP is used to obtain criteria weights through pairwise comparisons, while TOPSIS processes these weights along with a decision matrix to generate preference scores. The final results are not limited to a numerical table but are forwarded to a GIS map so that the relationship between priority order and geographic location can be read in a single view. A Consistency Ratio value of 0.0153 indicates that the inter-criteria assessment has met the consistency limit. At the TOPSIS stage, Belawan I - Jalan Yos Sudarso obtained the highest preference score of 0.861, followed by Jalan Denai - Kelurahan Denai with 0.730 and Rengas Pulau - Jalan Marelan Raya with 0.678. This order indicates that the locations in the top ranking have characteristics closer to the ideal lighting priority conditions based on the weights and criteria values used. The high, medium, and low groupings help users quickly interpret the results.

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However, the system's values still need to be compared with field inspections, electricity network conditions, pole availability, budget, and agency policies. In this way, the AHP-TOPSIS results serve as a measurable analytical basis in compiling decisions on installing or adding lighting in crime-prone areas in Medan City.

Conclusion

This study produces a web-based decision support system to determine the priority of lighting in crime-prone areas in Medan City by integrating the Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and Geographic Information System (GIS) methods. The results of the AHP calculation show a Consistency Ratio (CR) value of 0.0153, which meets the consistency limit of ≤ 0.10. Based on the TOPSIS calculation of 25 alternative locations, Belawan I, Jalan Yos Sudarso, obtained the highest preference value of 0.861, followed by Jalan Denai, Kelurahan Denai, at 0.730, and Rengas Pulau, Jalan Marelan Raya, at 0.678. The ranking results are displayed through tables and digital maps using Leaflet Maps and OpenStreetMap so that priority locations can be identified based on their geographical position and preference value. These findings indicate that the integration of AHP, TOPSIS, and GIS can support the process of determining lighting priorities in a more structured and measurable manner.

This study's limitations lie in the use of 25 alternative locations and five assessment criteria, so the results still depend on the completeness, accuracy, and representativeness of the data used. Preference scores are also relative scores based on the research criteria, not a direct measure of crime rates or a guarantee of crime prevention effectiveness. Future research is recommended to expand the coverage of locations, increase the quantity and quality of field data, and evaluate the suitability of the ranking results to actual conditions and lighting needs. Practically, this system can be used as a tool for local governments and related parties in setting priorities for installing or adding lighting. However, final decisions still need to take into account field verification, infrastructure availability, budget, and applicable policies to ensure the system's recommendations are implemented effectively.

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