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Geographic Information System for Mapping Accommodation Locations in Lhokseumawe City Using the AHP Method and Dijkstra's Algorithm

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ABSTRACT

This study aims to develop a web-based Geographic Information System (GIS) to provide recommendations for the best accommodation and the fastest route to the accommodation location in Lhokseumawe City. The Analytical Hierarchy Process (AHP) method is used to determine the priority of accommodation based on five main criteria, namely price, public facilities, cleanliness, security, and year founded. The Dijkstra algorithm is applied to calculate the shortest path from the user's position to the selected accommodation. This study involved 21 accommodations as study objects. The results of the analysis showed that Hotel Diana obtained the highest value of 0.08873, so it was recommended as the main accommodation. The shortest distance from the Faculty of Engineering, Malikussaleh University to Hotel Diana is 11.53857 km. These results indicate that the combination of the AHP method and the Dijkstra algorithm is effective in supporting location-based decision making, as well as making it easier for users to determine appropriate accommodation and the fastest route efficiently.

I. Introduction

Computers play an important role in processing data and producing accurate information, thus supporting the ease of data management and storage in the era of ever-growing information technology [1]. Geographic Information Systems (GIS) is a computer technology used to manage, store, analyze, and access data that is related to geographic location, which is currently experiencing significant progress [2]. Geographic Information Systems can be developed using decision-making methods that can provide recommendations for accommodation in Lhokseumawe City and the Dijkstra algorithm for determining the optimal road route to the accommodation.

Lhokseumawe City has various accommodations ranging from hotels, guesthouses, and homestays with various facilities ranging from standard facilities to complete facilities. However, information about accommodation in this city is still limited. Lack of information regarding the best accommodation and the location of accommodation is an obstacle for those who are visiting Lhokseumawe for the first time.

The Analytical Hierarchy Process (AHP) method is the method used in this study to recommend accommodation in Lhokseumawe City. The Analytical Hierarchy Process (AHP) method is a decision-making approach that discusses complex complexity into a hierarchical form, by assessing each element based on predetermined criteria and sub-criteria [3]. This method was chosen in the study because AHP is able to provide a systematic and objective structure in emitting various criteria comprehensively [4]. Accommodation recommendations in this study are based on predetermined criteria such as price criteria, public facilities, cleanliness, security, and length of operation of the accommodation.

Dijkstra's algorithm is also used in this study which allows users to determine the fastest route to the desired accommodation and helps reduce travel time [5]. Dijkstra's algorithm is effective in finding the shortest path, because in the process, each graph is selected based on the minimum weight connecting a selected node with another node that has not been selected [6]. This algorithm makes it easier to determine the shortest route from the starting point to the destination point efficiently, making it very useful for researchers in identifying the optimal route in a practical way [7].

In previous research conducted by [8] this study used a geographic information system and the Analytical Hierarchy Process (AHP) method to collect the locations of final disposal sites (TPA) in Butuan City, Philippines [8]. The difference between this study and previous studies is the addition of the Dijkstra Algorithm for optimizing the shortest route on a weighted graph.

The implementation of geographic information systems and AHP in determining and providing accommodation recommendations can help people find the desired accommodation [9]. The implementation of Dijkstra and Geographic Information Systems can also help people find the shortest route to the desired accommodation [10].

The purpose of this study is to develop a geographic information system by applying the Analytical Hierarchy Process (AHP) method as a lodging recommendation system and the Dijkstra Algorithm as the fastest route finder. Not only that, this study also aims to make it easier for visitors to find lodging that suits their desires based on their needs.

II. METHOD

This study uses a waterfall model that is sequential and systematic. The process begins with a literature study as a theoretical basis, followed by a needs analysis to determine system specifications. The next stage is the design of the interface and database, then the implementation of the system into an application form. Finally, testing is carried out to ensure that the system's functionality runs according to the design.

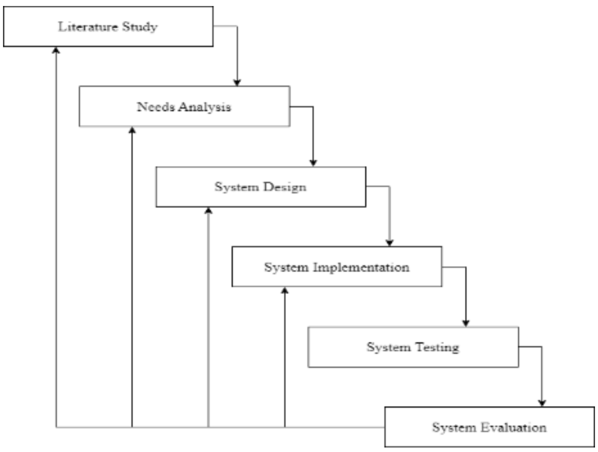


Figure 1. Research flow diagram

A. System Schematic

The developed system schema explains the workflow sequentially, starting from the process of inputting criteria and alternative data by the user. Furthermore, the system performs calculations using the Analytical Hierarchy Process (AHP) method to determine the weight of each predetermined criterion. The results of this calculation are used to generate accommodation recommendations that best suit the user's preferences. After that, the user can select one of the recommended accommodations, and the system will display a map containing the location points of the selected accommodation and the user's current position. To help users reach the location, the system will calculate the fastest route using the Dijkstra algorithm. Finally, the system displays the closest distance that the user must travel to the selected accommodation.

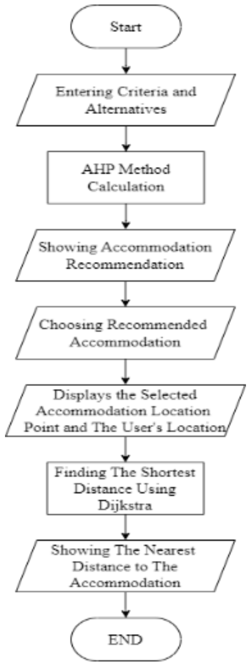


Figure 2. System Schematic

B. Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) method is a method developed by Thomas L. Saaty, allowing measurements between criteria by calculating the relative weight of each relevant criterion [11]. The Analytic Hierarchy Process (AHP) is one method used to assist the decision-making process and support the achievement of goals, planning, and business operations [12]. The Analytic Hierarchy Process (AHP) method has a number of advantages, including providing a structured framework for handling complex problems, allowing the conversion of qualitative assessments to quantitative ones, and helping to maintain assessment consistency by calculating consistency ratios [13]. In general, the decision-making process using the AHP method includes the following stages [14].

- The first step of the AHP method is to define the problem and arrange it in a hierarchy.
- After the hierarchical structure is complete, the next step is to create a pairwise comparison matrix to compare the

elements in each level of the hierarchy. Elements are compared based on the following importance intensity scale.

TABLE I
INTENSITY OF INTEREST

Intensity of Interest	Information
1	The second element is equally important
3	One element is slightly more important than the other elements.
5	One element is more important than the other elements
7	One element is clearly more absolutely important than the other elements
9	One element is absolutely more important than the other elements
2,4,6,8	Values between two adjacent consideration values
the opposite	If activity i gets one number compared to activity j, then j has the opposite value compared to i.

- Once the comparison matrix is complete, the next step is normalization by dividing the number of rows
- After the matrix is normalized, the priority weight calculation is carried out, which is the average value of each row of the normalized matrix by adding each row and calculating the weight value that can be obtained using the vector/n matrix priority method.
- After the priority weights are calculated, the next step is to calculate the eigenvalues and lambda max (λ_{maks}). Multiply the priority weights w_i by the total elements in the corresponding comparison matrix column. Then add up the results from all the columns to get λ_{maks}.
- Calculating CI, Consistency index (CI) is used to assess the level of consistency of the matrix with the formula.

$$CI = \frac{\lambda\, maks\, -\, n}{n\, -\, 1}$$

- Calculating CR, Consistency ratio (CR) is the ratio between CI and random value (RI). If Consistency ratio (CR) is more than 0.1 indicates inconsistency and requires calculation improvement. If CR ≤ 0.1, the results are considered consistent.

$$CR = \frac{CI}{RI}$$

Random Index (RI) is a measure used to assess the level of inconsistency of the importance weights given by decision makers. The following is a table of random indices.

TABLE II
RANDOM INDEX

Number of Criteria	IR Value
1	0.00
2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

- Calculating Alternative Rankings. Alternative rankings are calculated by multiplying the criteria weights by the local alternative weights.

C. Dijkstra's Algorithm

Dijkstra's algorithm is a systematic and logical procedure used to solve the problem of finding the shortest path in a weighted graph [15]. Dijkstra's algorithm is often the focus of research to be applied in the system. This algorithm was introduced by Edsger Dijkstra, a Dutch computer scientist [16]. The main objectives of the Dijkstra algorithm include designing an efficient way to find the shortest path based on the lowest weight value, as well as optimizing the use of time and resources in its application in various real situations [17]. The Dijkstra algorithm works by determining the optimal path to one node at each step. At the nth step, there are at least n nodes whose shortest path is known. The following are the steps to run the Dijkstra algorithm [18].

- Set the starting node as the starting node, then assign the distance weight from the starting node to each nearest node one by one. The algorithm will develop the search gradually from one node to another.
- Set the distance weight for each node with a value of 0 for the initial node and a value of infinity (∞) for other nodes that do not yet have a definite distance.
- All unprocessed nodes are considered as "untraversed nodes", while the starting node acts as the "departure node".
- Calculate the distance from the departure node to each neighbor node that has not been passed. If the new distance is smaller than the previously recorded distance, update it to a smaller value.
- After calculating all distances to neighboring nodes, set the processed nodes as "skipped nodes". Skipped nodes will not be reprocessed, and the stored distance is the shortest distance with the minimum weight
- Select the node with the smallest distance from the departure node as the next "departure node", then repeat steps 4 to 6 until all nodes have been processed.

The principle of Dijkstra's algorithm is to find the path with the shortest distance or the smallest weight in a certain directed and weighted graph [19]. The shortest distance between two or more points in the graph is calculated, and the result obtained is the smallest total value. For example, if G is a directed graph with a set of points V(G) = {v1, v2, ..., vn}, then the shortest path sought is from v1 to vn [20].

III. RESULTS AND DISCUSSION

Based on the results of the analysis and testing, the Geographic Information System for mapping lodging locations in Lhokseumawe City designed with the AHP method and Dijkstra algorithm is able to provide lodging recommendations by sorting alternatives based on the highest preference value. In addition, the system can also determine the fastest lodging route chosen, making it easier for users to make decisions and reach their destination efficiently.

A. Analytical Hierarchy Process (AHP) Calculation

The first step in the AHP method is to determine the criteria that will be used to perform the calculation. The criteria in this study were selected based on user questions and user needs when choosing accommodation.

TABLE III
CRITERIA

Criteria	Code
Price	Cr1
Public Facilities	Cr2
Cleanliness	Cr3
Security	Cr4
year founded	Cr5

After determining the criteria, the next step is to conduct a pairwise comparison between the criteria to obtain the value of each criterion. In this study, the criteria value is given based on the results of the questionnaire that has been filled out by the community in Lhokseumawe City.

TABLE IV
PAIRWISE COMPARISON

Criteria	Cr1	Cr2	Cr3	Cr4	Cr5
Cr1	1	4	3	3	4
Cr2	1/4	1	1/2	2	2
Cr3	1/3	2	1	3	4
Cr4	1/3	1/2	1/3	1	3
Cr5	1/4	1/2	1/4	1/3	1
Amount	2.16667	8	5.08333	9.33333	14

The next step is to normalize by dividing the value of each column by the total value that has been added together.

TABLE V
NORMALIZATION OF COMPARISON MATRICES

	Cr1	Cr2	Cr3	Cr4	Cr5
Cr1	0.46154	0.5	0.59016	0.32143	0.28571
Cr2	0.12	0.125	0.10	0.21429	0.14286
Cr3	0.15	0.25	0.19672	0.32143	0.28571
Cr4	0.15	0.0625	0.06557	0.10714	0.21429
Cr5	0.12	0.06	0.05	0.04	0.07143

Next, find the priority value of the vector by calculating the value of each row. To find the weight value, you can divide the priority value of the vector by the number of criteria. After finding the weight value, then multiply the weight value by the number of columns of the comparison table to find the eigenvalue value, add up the eigenvalue values to get the lambda max value.

TABLE VI
PRIORITAS VEKTOR, WEIGHT, EIGEN VALUE, LAMDA MAX

	P. Vektor	Weight	Eigen Value
Cr1	2.15885	0.43177	0.93550
Cr2	0.70	0.13918	1.11342
Cr3	1.20771	0.24154	1.22784
Cr4	0.60335	0.12067	1.12625
Cr5	0.33	0.06684	0.93578
Lamda Max			5.33879

After getting the eigenvalue, the next step is to find the Consistency Index (CI) and Consistency Ratio (CR) values.

CI = (5.33879-5) / (5-1) = 0.08470

CR = 0.08470/ 1,12 = 0.07562

A matrix in the AHP method is declared consistent if the Consistency Ratio (CR) value is less than or equal to 0.1. Conversely, if the CR value exceeds 0.1, the matrix is considered inconsistent and its assessment needs to be reviewed. After being declared consistent, the next calculation can be continued, namely the alternative calculation like the previous calculation. The alternative or lodging that is compared is lodging in the city of Lhokseumawe, this lodging does not include annual lodging such as boarding houses. The following are the alternatives or lodgings that are compared.

TABLE VII
ALTERNATIVE

Alternative	Code	Coordinate
Alsafwa	P1	5.210689129808432, 97.07169685116656
AlFajri	P2	5.188742241012939, 97.11950628002923
Selat malaka	P3	5.175171281964783, 97.12857892235715
Sartika	P4	5.177083336492076, 97.13411873952477
Diana	P5	5.17781452583625, 97.1347482913757
Singapore	P6	5.180061080574272, 97.13306588095473
Kuta karang Baru	P7	5.17653084722149, 97.14352582235716
Pase	P8	5.175202611746252, 97.14790992235713ss
Winton	P9	5.177890576411046, 97.15000822235719
Vina Vira	P10	5.180520897368444, 97.15162498298147
Kuta Karang	P11	5.18201993404553, 97.14557364903035
Kanaya	P12	5.185555193338937, 97.13752582235715

Sydney	P13	5.176706785873663, 97.15242599537329
Jiddah	P14	5.190073200920859, 97.14870150886523
Harida	P15	5.175895671157301, 97.14666769352111
Rifana	P16	5.1686681286346685, 97.13423142235716
Lilawangsa	P17	5.180177321854013, 97.15139805533472
Koeta Radja	P18	5.176971391771659, 97.14718539722546
Lido Graha	P19	5.1689705285425624, 97.13342403955342
Yana	P20	5.177193196175332, 97.14931382235714
DV	P21	5.187535943321724, 97.14407056882693

After getting the alternative weight value, the next step is to multiply the criteria weight value by the alternative weight based on the criteria, which will produce the following value.

TABLE VIII
THE RESULT OF MULTIPLYING THE WEIGHTS OF THE CRITERIA AND ALTERNATIVES

	Cr1	**Cr2**	**Cr3**	**Cr4**	**Cr5**
P1	0.01240	0.00276	0.00919	0.00480	0.00065
P2	0.03350	0.00321	0.00397	0.00273	0.00106
P3	0.03066	0.00351	0.00548	0.00556	0.00688
P4	0.02418	0.00153	0.00891	0.00160	0.00377
P5	0.00608	0.02077	0.03867	0.02049	0.00271
P6	0.01025	0.01332	0.02098	0.01107	0.00137
P7	0.01867	0.00252	0.00454	0.00361	0.00863
P8	0.02519	0.00255	0.00826	0.00140	0.00267
P9	0.00698	0.01897	0.02751	0.01266	0.00159
P10	0.03168	0.00677	0.01581	0.00391	0.00267
P11	0.01414	0.00739	0.01324	0.00502	0.01185
P12	0.01727	0.00175	0.00499	0.00144	0.00077
P13	0.00667	0.01644	0.02728	0.01959	0.00077
P14	0.01308	0.00333	0.00633	0.00401	0.00105
P15	0.03860	0.00134	0.00554	0.00161	0.00190
P16	0.03423	0.00458	0.01209	0.00354	0.00112
P17	0.03006	0.00535	0.00573	0.00405	0.00442
P18	0.04079	0.00214	0.00388	0.00163	0.00371
P19	0.00519	0.01490	0.00349	0.00231	0.00809
P20	0.02085	0.00460	0.00971	0.00785	0.00054
P21	0.01129	0.00142	0.00592	0.00177	0.00063

Next, add up each row in the table of the results of multiplying the weights and alternatives and produce the value of each alternative.

TABLE IX
ALTERNATIVE VALUES AND RANKING

	Value	**Ranking**
P1	0.02980	18
P2	0.04447	12
P3	0.05209	8
P4	0.03998	15
P5	0.08873	1
P6	0.05698	5
P7	0.03797	16
P8	0.04007	14
P9	0.06772	3
P10	0.06085	4
P11	0.05164	9
P12	0.02622	20
P13	0.07075	2
P14	0.02780	19
P15	0.04900	11
P16	0.05557	6
P17	0.04962	10
P18	0.05216	7
P19	0.03398	17
P20	0.04356	13
P21	0.02103	21

B. Dijkstra's Algorithm Calculation

After using the AHP method calculation, the most recommended accommodation is Hotel Diana with coordinates 5.17781452583625, 97.1347482913757. The next stage is to find the fastest or shortest route to get to the accommodation location using the Dijkstra Algorithm from the user's starting point to the recommended accommodation. The following is a picture of the intersection points that will be passed where the user's starting point is the Faculty of Engineering, Malikussaleh University.

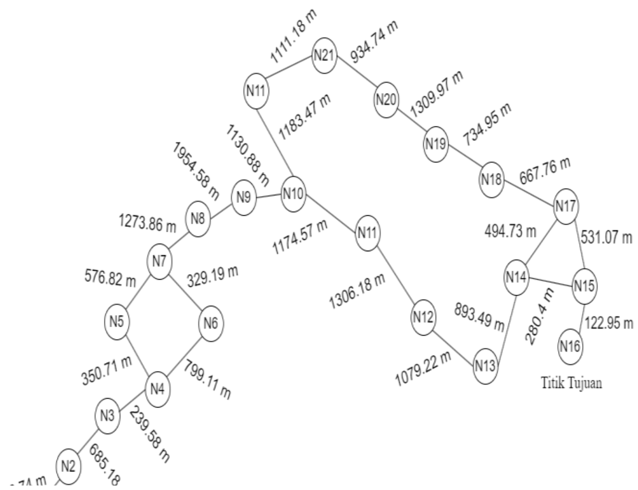
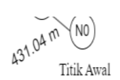


Figure 3. Intersection Poin



The route from the Faculty of Engineering, Malikussaleh University to the Diana Hotel has several alternatives with varying distances, where the shortest route is N0-N4-N5-N7-N10-N14-N15-N16 for 11.53857 km, and the longest route is N0-N4-N6-N7-N10-N17-N15-N16 for 13.97388 km. The analysis shows that the route passing through node N5 is more efficient than N6, and the addition of node N17 tends to extend the distance. The maximum difference between routes reaches 2.43 km, which is significant enough to affect time and fuel efficiency. Therefore, route selection should consider the shortest path as a priority, but still adjusted to actual conditions in the field such as traffic density or road accessibility. The optimal route is not only determined by distance, but also by the smoothness and safety of the trip as a whole, so that periodic mapping and evaluation are still needed to support the right decision making in daily transportation or mobility planning.

The following is a list of routes that will be taken along with the distance from the user's location (Faculty of Engineering, Malikussaleh University) to the Diana Hotel.

TABLE X
PATH LIST

Path List	Distance (km)
N0-N4-N6-N7-N10-N14-N15-N16	11.98697
N0-N4-N6-N7-N10-N14-N17-N15-N16	12.48170
N0-N4-N5-N7-N10-N14-N15-N16	11.53857
N0-N4-N5-N7-N10-N14-N17-N15-N16	12.03330
N0-N4-N6-N7-N10-N17-N15-N16	13.97388
N0-N4-N5-N7-N10-N17-N15-N16	13.52548

TABLE XI
INTERSECTION DISTANCE CALCULATION

	N0	N4	N5	N6	N7	N10	N17	N14	N15	N16
N0	0	$1{,}6_{N0}$	∞	∞	∞	∞	∞	∞	∞	∞
N4		$1{,}6_{N0}$	$1{,}9_{N4}$	$2{,}3_{N4}$	∞	∞	∞	∞	∞	∞
N5			$1{,}9_{N4}$	$2{,}3_{N4}$	$2{,}4_{N5}$	∞	∞	∞	∞	∞
N6				$2{,}3_{N4}$	$2{,}4_{N5}$	∞	∞	∞	∞	∞
N7					$2{,}4_{N5}$	$4{,}3_{N7}$	∞	∞	∞	∞
N10						$4{,}3_{N7}$	$10{,}2_{N10}$	$8{,}6_{N10}$	∞	∞
N14							$10{,}2_{N10}$	$8{,}6_{N10}$	$9{,}1_{N14}$	∞
N15							$10{,}2_{N10}$		$9{,}1_{N14}$	$9{,}2_{N15}$
N17							$10{,}2_{n10}$			

The following table is an adjacency matrix which calculates the distance from one point to another adjacent point, non-adjacent points will be given ∞.

By calculating each intersection point, we get the points N0-N4-N5-N7-N10-N14-N15-N16 which is the shortest distance or N0-N1-N2-N3-N4-N5-N7-N8-N9-N10-N11-N12-N13-N14-N15-N16.

C. Website implementation

The purpose of website implementation is to present a visual representation of the system that has been designed, making it easier for users to understand the workflow and function of the system as a whole.

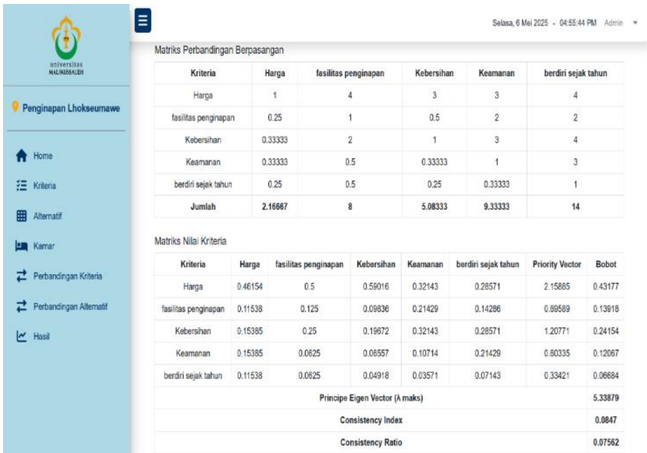
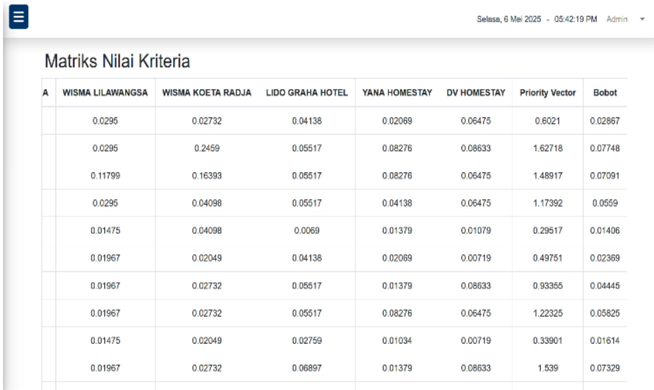


Figure 4. Criteria Weight

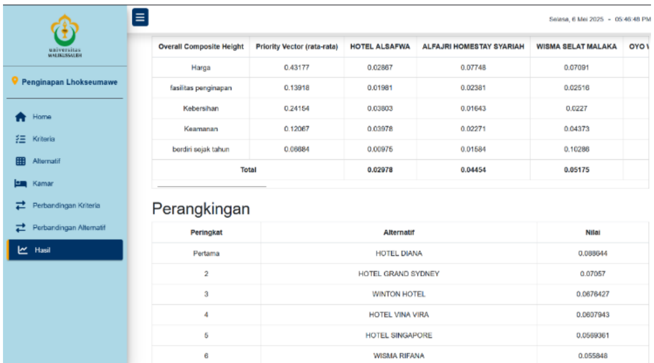
This page will display the results of the calculation of the comparison of accommodation criteria whose values have been determined by the admin. This value is the result of the calculation of the AHP method.



A	WISMA LILAWANGSA	WISMA KOETA RADJA	LIDO GRAHA HOTEL	YANA HOMESTAY	DV HOMESTAY	Priority Vector	Bobot
	0.0295	0.02732	0.04138	0.02069	0.06475	0.6021	0.02867
	0.0295	0.2459	0.05517	0.08276	0.08633	1.62718	0.07748
	0.11799	0.16393	0.05517	0.08276	0.06475	1.48917	0.07091
	0.0295	0.04098	0.05517	0.04138	0.06475	1.17392	0.0559
	0.01475	0.04098	0.0069	0.01379	0.01079	0.29517	0.01406
	0.01967	0.02049	0.04138	0.02069	0.00719	0.49751	0.02369
	0.01967	0.02732	0.05517	0.01379	0.08633	0.93355	0.04445
	0.01967	0.02732	0.05517	0.08276	0.06475	1.22325	0.05825
	0.01475	0.02049	0.02759	0.01034	0.00719	0.33901	0.01614
	0.01967	0.02732	0.06897	0.01379	0.08633	1.539	0.07329

Figure 5. Alternative Comparison Matrix

This page will display the results of the calculation of alternative sub-criteria. The weight value in this calculation has been determined by the admin and this result is a calculation with the AHP Method.



Overall Composite Height	Priority Vector (rata-rata)	HOTEL ALSAFWA	ALFAJRI HOMESTAY SYARIAH	WISMA SELAT MALAKA	OYO \
Harga	0.43177	0.02867	0.07748	0.07091	
fasilitas penginapan	0.13918	0.01981	0.02381	0.02516	
Kebersihan	0.24154	0.03803	0.01643	0.0227	
Keamanan	0.12067	0.03978	0.02271	0.04373	
berdiri sejak tahun	0.06684	0.00975	0.01584	0.10286	
Total		0.02978	0.04454	0.05175	

Perangkingan

Peringkat	Alternatif	Nilai
Pertama	HOTEL DIANA	0.088644
2	HOTEL GRAND SYDNEY	0.07057
3	WINTON HOTEL	0.0676427
4	HOTEL VINA VIRA	0.0607943
5	HOTEL SINGAPORE	0.0569361
6	WISMA RIFANA	0.055848

Figure 6. Rang

This page will show the order of suggested lodging values as well as the outcomes of the AHP calculation. If the administrator enters the criterion weight value on the criteria weighting page and the alternative sub-criteria weight value on the alternative weighting page, the AHP calculation can be performed. The ranking's outcomes will be used to suggest accommodations to users.

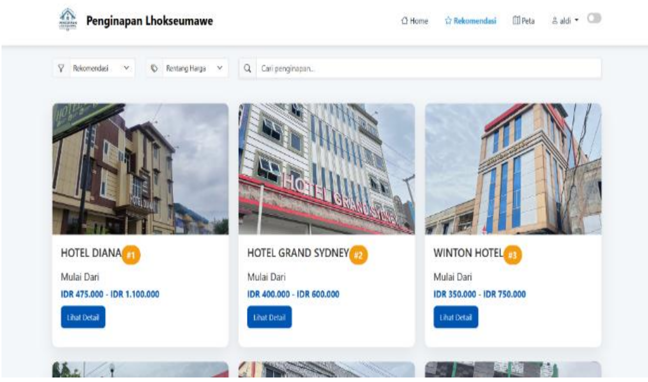


Figure 7. Lodging Recommendations

Users can select the suggested lodging by viewing recommendations that have been determined using the AHP approach on this page. Additionally, users can select the type of room, the amenities offered at the lodging, and the pricing range of the room.

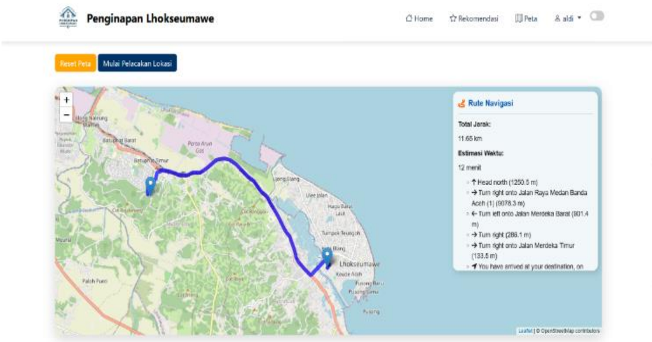


Figure 8. Shortest Route

Using the Dijkstra algorithm, this page will show the quickest path from the user's starting place to the lodging they have chosen. The route and the total distance to be covered will also be shown on this page.

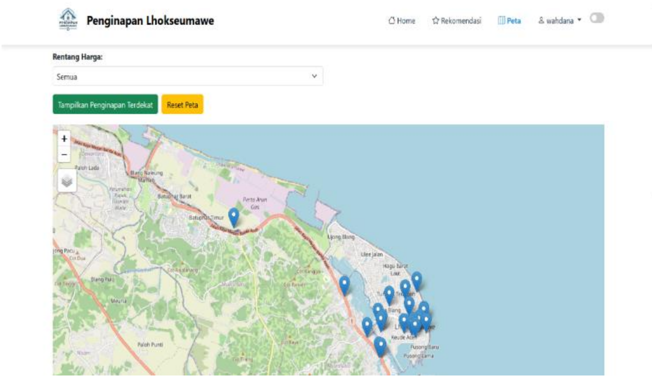


Figure 9. Mapping Accomodation

This page is a mapping page for accommodation locations in Lhokseumawe City, this page can also filter based on the desired price and on this page there are several map layers such as satellite, terrain, etc.

IV. Conclusion

The results of this study indicate that Geographic Information Systems (GIS) utilizing the Analytic Hierarchy Process (AHP) method and the Dijkstra algorithm are able to provide accommodation recommendations and the fastest routes based on user locations, especially in the Lhokseumawe City area. By considering five main criteria, namely price, public facilities, cleanliness, security, and length of establishment, Hotel Diana emerged as the most recommended accommodation with a priority value of 0.08873. Meanwhile, the shortest route from the user's initial location (Faculty of Engineering, Malikussaleh University) to the recommended hotel (Hotel Diana) was recorded as

11.53857 km. The application of the AHP method and the Dijkstra algorithm to GIS has proven effective in facilitating users to obtain accurate accommodation information and efficient travel routes. However, this system still has limitations, one of which is the dynamic nature of accommodation data that can change at any time. Therefore, it is recommended for further research to develop a system that allows accommodation owners to input information directly and update it, so that data accuracy and system functionality can be maintained sustainably. This system uses leaflet.js as the map API on the website. Leaflet.js also uses several map layers such as satellite layers, terrain layers and so on to see the map structure.

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