

Implementation of Geographic Information System (GIS) And Multi-Criteria Decision Analysis (MCDA) In Determining Tourist Attractions In Samosir Regency

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ABSTRACT

Tourism in Samosir Regency has significant potential as a key sector in North Sumatra Province; however, there is an imbalance in the number of visitors across various tourist sites. This study aims to develop a decision support system for identifying and prioritizing tourist destinations based on accessibility and traveler preferences by integrating Geographic Information System (GIS) and Multi-Criteria Decision Analysis (MCDA) using the Analytical Network Process (ANP) approach. The system utilizes both spatial and non-spatial data to map tourist locations and determine priorities based on relevant criteria such as accessibility, distance, cost, attractiveness, and safety. The results show that Bukit Sibebea emerges as the leading tourist destination with the highest priority weight (12.45%), followed by Godang Beach and Paromasan. The web-based system provides not only accurate geographical information but also recommends the best tourist destinations based on traveler preferences, making it a useful tool for more targeted and equitable tourism planning and development in Samosir Regency.

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INTRODUCTION

Tourism in Samosir Regency is one of the leading sectors in North Sumatra Province. According to the official website of the North Sumatra Provincial Office of Culture, Tourism, and Creative Economy, Samosir Regency is the most famous destination in North Sumatra and a tourist attraction that is visited by many local and foreign tourists. Based on data from the Samosir Regency Culture and Tourism Office in 2024, Samosir Regency has around 140 tourist attractions classified as developed or still under development destinations. However, even though the number of tourist attractions continues to grow, there is an imbalance in the number of visitors to various tourist locations. Based on information from the Detiksumut media on April 12, 2024, there are only three tourist attractions that are most popular in 2024, including Bukit Sibebea, Waterfront Pangururan, and Batu Hoda Beach. Among the three, Waterfront Pangururan reaches 6,000 visitors per day, while other tourist attractions experience a lack of visitors. This is due to several factors, one of which is the lack of information about certain tourist attractions, which makes tourists unaware of their locations and unfamiliar with their appeal. Tourists tend to choose attractions that are currently

popular and those close to their accommodation due to the lack of information about other tourist attractions. In addition, accessibility is difficult, as many locations are difficult to reach due to their hilly and winding terrain, making it difficult for tourists to access tourist destinations. This causes tourists to prefer visiting natural attractions in lowland areas and coastal areas. Another factor is the language barrier, where some tourist attractions have names in the local language, making it difficult for tourists from outside the area to understand what type of attraction it is.

Based on the above issues, it is necessary to develop a decision support system that integrates GIS (Geographic Information System) and MCDA (Multi-Criteria Decision Analysis) to support spatial data mapping and analysis (Rentizelas et al., 2025). GIS functions as a location visualization tool that helps tourists easily identify the location of tourist attractions and determine efficient travel routes (Rahman & Irwansyah, 2025). On the other hand, the use of MCDA, particularly ANP weighting, determines the priority of tourist attractions by considering various criteria relevant to the selection of tourist attractions so that the decisions made are focused and in line with their interests (Maulana et al., 2024).

GIS is a technology that can display geographical areas by processing, storing, and analyzing the earth's surface (Arifin & Supriyatna, 2023). Meanwhile, MCDA assists the decision-making process and utilizes data through models to find and solve structured and unstructured problems (Tirtayasa & Kristiyanto, 2023). Thus, the integration of GIS and MCDA can produce effective analytical tools capable of solving existing problems.

As in previous research by Romadhoni et al. (2024), entitled "Analytical hierarchy process and weighted product in selecting tourist attractions in Jombang based on the web (Zufria et al., 2022). The AHP method helps in breaking down complex problems into simpler hierarchies of criteria and sub-criteria, thereby facilitating decision making. WP is used to evaluate and compare alternative tourist attractions based on predetermined criteria (Priambodo et al., 2023). The final results based on the parameters of cost, road access to the location, facilities, and age show a ranking list of tourist attractions in Jombang, where Kampong Djawi ranks first with the highest vector value of 0.2092 and the last rank is Taman ASEAN with a vector value of 0.0398 as a less recommended place (Romadhoni et al., 2024).

In this study, the author has introduced a novelty through the development of criteria that are more relevant to the needs and preferences of today's tourists, namely accessibility, distance, cost, attractiveness, and safety with ANP weighting (Wisely, 2024). ANP weighting was chosen because ANP is a method capable of representing the level of importance between existing criteria and sub-criteria, thereby providing a realistic approach that focuses on tourist needs. In addition, this study integrates GIS to present tourist locations visually and also provides recommendations based on priorities calculated according to tourist preferences and real-time conditions (Zufria et al., 2024).

Based on the relevant research, ideas, and reviews above, the author presents this study entitled "Implementation of Geographic Information System (GIS) and Multi-Criteria Decision Analysis (MCDA) in Determining Tourist Attractions in Samosir Regency".

METHODS

Location and Time of Study

The research was conducted from February 2025 to June 2025 at the Samosir Regency

Culture and Tourism Office, located in Parbaba Dolok, Pangururan District, Samosir Regency, North Sumatra.

Types and Stages of Research

This study uses a quantitative approach with an MCDA-based decision-making analysis method (Amsharuk & Łaska, 2023). The weighting used is ANP weighting, which aims to process criterion data to produce accurate priority values and recommendations. The research stages are a series of structured concepts that aim to provide understanding and reference for researchers to determine the direction of the research. The following are the research stages that will be applied to the research discussed :



Figure 1. Research Framework

Planning

The planning stage is the first step in the research process, which aims to formulate the direction of activities in the research. In this study, the planning stage involves identifying the problem, namely that Samosir Regency has tourist attractions scattered across various regions, but these are not yet supported by a system capable of mapping and displaying results visually in real time to help tourists choose tourist attractions systematically based on various criteria (Amiri et al., 2024).

Data collection

- 1) Literature Study: reviewing theories to investigate related literature, such as previous research developments, formulating research gaps, and formulating new approaches.
- 2) Observation: conducting direct observations at the Samosir Regency Culture and Tourism Office to obtain data to be used in this study.
- 3) Interviews: conducting in-depth interviews with stakeholders, from the Samosir Regency Culture and Tourism Office, to collect data.
- 4) Document collection: Processing relevant documents to validate data such as spatial data lists (for GIS) and non-spatial data (for MCDA assessment), which are registered at the Samosir Regency Culture and Tourism Office.

Requirement Analysis

The analysis aims to identify and detail the features of the system to be developed. The requirements analysis consists of two parts:

1. Functional: in a GIS and MCDA-based tourist attraction selection system, the functional requirements that must be met in order for the system to fulfill its intended purpose include login, input, tourist map visualization, results and recommendations, search, and data management.
2. Non-functional: Describes the quality of the system. Requirements that must be met include user-friendliness, performance, security, and scalability.

Design

1. Flowchart

A flowchart is a flow diagram that helps illustrate the flow of a web-based tourist attraction selection system with GIS and MCDA integration using ANP weighting (Taherdoost & Madanchian, 2023). This comprehensive information is crucial for understanding and evaluating the research reported in the journal. The system flowchart visualizes tourist attraction data in real-time to assist in the decision-making process.

GIS-MCDA Flowchart Process:

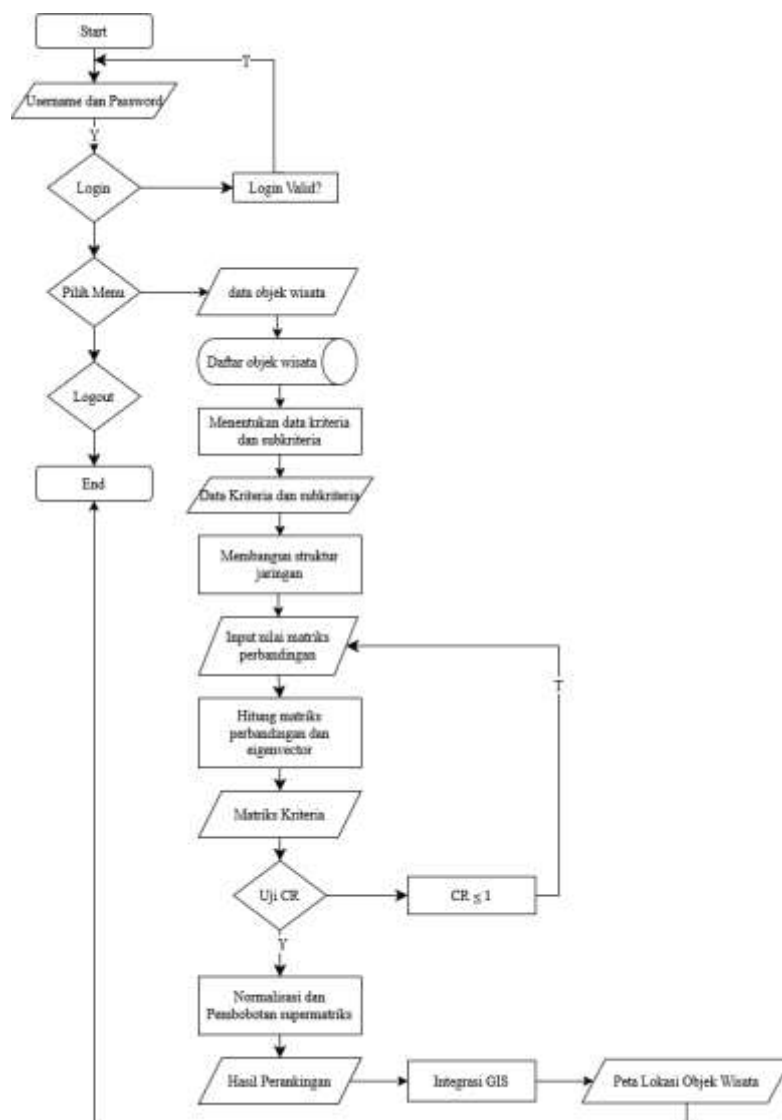


Figure 2. Flowchart

2. Modelling

Modeling systems using the Unified Modeling Language (UML) approach to visually describe the processes, structures, and interactions within a designed system (Rusydia et al., 2023).

3. Interface Design

Interface Design: the interface is designed to make the system easy to use, responsive, and display information interactively. The interface designed in this system includes the Login Page, Admin Dashboard, Input Form, Map Page, User Dashboard, Input Form, Tourist Attraction Recommendation Page, and Validation Notification.

System Testing

In this study, the system will be tested to ensure that its functionality, user-friendliness, and overall performance are successful and running as expected. The testing method used is black box testing. This test aims to evaluate whether the system output matches the input provided, based on the specified specifications.

System Implementation

In this study, the implementation was carried out on a web-based system that integrates Geographic Information System (GIS) and Multi-Criteria Decision Analysis (MCDA) methods using the Analytical Network Process (ANP) approach (Rusydi et al., 2023). The system was implemented using PHP (Hypertext Preprocessor) programming language, MySQL database, client-side HTML, CSS, JavaScript, and Leaflet.js for map visualization, Apache server, and supporting tools: XAMPP, Visual Studio Code, and QGIS for spatial data processing (Armansyah & Hidayat, 2024).

RESULTS AND DISCUSSION

Data Analysis

Analysis is the first step in understanding the problem to be solved before taking action or making decisions in planning a system to be created. In this study, the data used consisted of 144 tourist attractions spread across Samosir Regency. This data was obtained from observations, documentation, and interviews conducted by the Samosir Regency Culture and Tourism Office and other supporting sources.

The data processing in the system begins with the definition of key criteria. These criteria are selected because they have a significant influence on tourist preferences when determining travel destinations (Musfikar et al., 2023).

In this study, the determination of leading tourist attractions in Samosir Regency was carried out by integrating the Analytic Network Process (ANP) method within the Multi-Criteria Decision Analysis (MCDA) framework. The initial stage of ANP is to identify and formulate assessment criteria relevant to the research needs. Based on literature studies, field observations, and interviews with tourism stakeholders, five main criteria were established as the basis for analysis, namely:

Table 1. Criteria for Tourist Attractions in Samosir Regency

Code	Criterion	Description
C1	Accessibility	Ease of reaching the tourist location (roads, transportation, parking, travel time)
C2	Distance	Proximity of the tourist location to the city center or major transportation routes
C3	Cost	Affordability of entry fees, facilities, and nearby accommodation
C4	Attraction	Beauty, uniqueness, cultural value, natural and artificial attractions
C5	Security	Level of environmental safety, safety facilities, social conditions, and risk mitigation

Each destination represents an alternative in the decision analysis process. The data collected includes key attributes such as the name of the tourist attraction and spatial coordinates (latitude and longitude) that support accurate geographic mapping. The dataset is then supplemented with several sub-criteria such as the level of accessibility of the tourist attraction, distance from the city center, cost, attractiveness of the tourist attraction, and level of safety of the tourist attraction. The number of alternative data and criteria data can be seen in Table 2.

Table 2. Dataset

No	Tourist Attraction Name	Latitude	Longitude	Accessibility	Distance	Cost	Attraction	Security
1	Taman Putri Lopian	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Quite Good
2	Homestay Lumban Bagas	2.6392	98.6786	Quite Good	Close	Quite Cheap	Not Interesting	Quite Good
3	Homestay Simalango	2.6392	98.6786	Quite Good	Close	Quite Cheap	Not Interesting	Quite Good
4	Pantai Pasir Putih Parbaba	2.6298	98.6823	Quite Good	Close	Quite Cheap	Quite Interesting	Poor
5	Paromasan	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Quite Good
6	Desa Wisata Bagot	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Poor
7	Dermaga Jetty	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Quite Good
8	Panggung	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Quite Good
9	Bursok Mangalandong	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Quite Good
10	Sianggo Ihurna	2.6392	98.6786	Quite Good	Close	Quite Cheap	Quite Interesting	Quite Good
...

No	Tourist Attraction Name	Latitude	Longitude	Accessibility	Distance	Cost	Attraction	Security
144	Mual Si Raja Sonang di Pakpahan	2.4612	98.6854	Very Good	Close	Quite Cheap	Not Interesting	Good

Based on these five criteria, a summary can be compiled in tabular form for greater structure:

Table 3. Criteria for Determining Tourist Attractions in Samosir Regency

Code	Criterion	Range	Weight
C1	Accessibility	Very difficult to reach	1
		Moderate	3
		Easy to reach	5
C2	Distance	Far from the city center	1
		Moderate	3
		Close	5
C3	Cost	Very Expensive	1
		Expensive	3
		Affordable	5
C4	Attraction	Very Ordinary	1
		Less Interesting	3
		Interesting	5
C5	Security	Not Safe	1
		Less Safe	3
		Safe	5

The amount of tourist attraction data used in this study is 144 tourist destinations in Samosir Regency. Each destination represents an alternative in the decision analysis process. The data collected includes key attributes such as the name of the tourist attraction and spatial coordinates (latitude and longitude) that enable accurate geographical mapping. The dataset is also supplemented with several sub-criteria such as the level of accessibility of the tourist attraction, distance from the city center, level of costs required, attractiveness of the tourist attraction, and level of safety of the tourist attraction.

Data Representation

The data representation stage is carried out to describe the data that has been collected previously into a more structured form and ready for analysis using the Analytical Network Process (ANP) method. At this stage, ten tourist attraction samples were selected from the entire data set. The selection of samples was based on the diversity of characteristics that were considered capable of representing the entire population of tourist destinations studied. Each tourist attraction sample has data related to five assessment criteria, namely accessibility, distance, cost, attractiveness, and safety. The data is represented in tabular form to facilitate the comparison process between alternatives in the next calculation stage. Through this representation, each tourist attraction can be compared

objectively based on the value or score of each criterion, so that network analysis and weighting using the ANP method can be carried out in a more systematic and measurable manner.

Table 4. Data Sample

No	Alternatif	C1	C2	C3	C4	C5
1	A1	1	1	3	3	1
2	A2	2	2	3	3	1
3	A3	3	3	3	2	3
4	A4	3	3	3	3	2
5	A5	3	3	3	3	3
6	A6	3	3	3	3	2
7	A7	3	3	3	3	3
8	A8	3	3	3	3	3
9	A9	3	3	3	3	3
10	A10	3	3	3	3	3

The ANP network structure was then created to map the connections between the main criteria and sub-criteria, so that weighting could be carried out more realistically. The ANP network structure in this study consisted of clusters of criteria that were interconnected. For example, accessibility plays an important role because the easier a location is to reach, the more efficient the distance traveled will feel, even if it is relatively far away physically.

Conversely, excessive distance can reduce accessibility and increase transportation costs and travel time. Cost is also related to attractiveness, as locations with high costs usually have better facilities, security, and comfort, thereby increasing their attractiveness to users. However, if the cost is too high, this can reduce economic attractiveness. Safety also directly affects attractiveness and cost—safe locations tend to be more desirable and have higher economic value. On the other hand, low safety levels can reduce attractiveness even if the location is easily accessible or close by. Thus, these five elements are interrelated, forming a complex network of influences, where changes in one factor can affect the others.

Application of the Analytic Network Process

1. Pairwise Comparison Matrix and Ratio Consistency Test

The first step in ANP is to compile a paired comparison matrix between criteria based on expert/stakeholder assessments. This matrix shows the relative importance of one criterion compared to another using the Saaty fundamental scale (1–9).

Table 5. Saaty Scale Assessment Weights

Weight	Description
1	Equally important
2	Less important
3	Quite important
4	Important
5	Very important
6	More important
7	Much more important

Weight	Description
8	Very, very important
9	Absolutely more important

This pairwise comparison matrix is used to examine the eigen and consistency ratios.

- 1) Calculation of the pairwise comparison matrix between criteria and A01.

Table 6. Pairwise Comparison Matrix A01

Bukit Sibebe-Bea (A01)	C1	C2	C3	C4	C5
C1 (Accessibility)	1	3	2	0.5	0.5
C2 (Distance)	0.33	1	0.5	0.33	0.25
C3 (Cost)	0.5	2	1	0.5	0.33
C4 (Attraction)	1	3	2	1	0.5
C5 (Security)	2	4	3	2	1

Everything that is gray is filled with the reciprocal value or inverse value (1/n) of that column.

Explanation:

K21 = Row 2 Column 1

K12 = Row 1 Column 2

The next step is to calculate the normalization of the pairwise comparison matrix, where each element is divided by the number of columns. As shown in Table 7 below.

Table 7. Continued Pairwise Comparison Matrix

Bukit Sibebe-Bea (A01)	C1	C2	C3	C4	C5	Prioritas	Consistency Measure
C1 Accessibility	0.2069	0.2308	0.2353	0.1154	0.1935	0.19637	4.955739
C2 Distance	0.0690	0.0769	0.0588	0.0769	0.0968	0.07568	4.920360
C3 Cost	0.1034	0.1538	0.1176	0.1154	0.1290	0.12387	4.935397
C4 Attraction	0.2069	0.2308	0.2353	0.2308	0.1935	0.21945	4.934616
C5 Security	0.4138	0.3077	0.3529	0.4615	0.3871	0.38461	4.915671
Consistency Index							-0,016911
Ratio Index							1,12
Consistency Ratio							-0,015099
Consistency							Konsisten

For value K11 (Row 1 Column 1):

$$K11 = 1 / 4.83 = 0.2069$$

Explanation: 1 = row K_11 in the table; 0.2069 = Total sum of column C1 in the table.

The next step is to calculate the priority weight, Consistency Measure, Consistency Index, and Consistency Ratio. For the Priority weight for Row 1 Priority (P1):

$$P_1 = 0,20 + 0,23 + 0,23 + 0,11 + 0,19 / 5 = 0.192$$

Note: priority weight (the result of dividing the comparison matrix is averaged by summing each row, then the sum is divided by the number of criteria to find the criteria weight.

Calculate the consistency measure for row 1 (CM1)

$$CM1 = ((1*0.20) + (3*0.23) + (2*0.23) + (0.5*0.11) + (0.5*0.19))/0.20$$

$$= 1.5$$

Explanation: The Consistency Measure is obtained by multiplying the matrix in the table by the priority weight of each row.

Next, find the Consistency Index using the formula:

$$Ci = \frac{\lambda_{maks} - n}{n - 1}$$

λ_{maks} is the average of CM (Consistency Measure)

$$= 4.95 + 4.92 + 4.93 + 4.93 + 4.91 / 5 = 4.92$$

$$\frac{4,92834 - 5}{4} = -0,01796$$

Based on Saaty's theory, the Ratio Index value is determined based on the order of the number of criteria matrix. The table is as follows:

Table 8. Ratio Index

Ordo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Matriks															
Ratio Index	0	0	0,5	0,8	1,1	1,2	1,3	1,4	1,4	1,4	1,5	1,4	1,5	1,5	1,5

Since the matrix consists of 5 criteria, RI automatically equals 1.12.

From CI and RI, CR can be calculated using the formula $CR = \frac{CI}{IR}$

$$CR = \frac{-0,017916}{1,12} = -0.0160.$$

CR values below 0.1 (≤ 0.1) are considered consistent, while values above that are considered inconsistent.

...

10) Calculation of the pairwise comparison matrix between criteria and A10.

Table 9. Pairwise Comparison Matrix A10

Pantai Pandua(A10)		C1	C2	C3	C4	C5
C1	Accessibility	1.00	1.00	0.88	0.78	1.00
C2	Distance	1.00	1.00	0.88	0.78	1.00
C3	Cost	1.14	1.14	1.00	0.89	1.14
C4	Attraction	1.29	1.29	1.13	1.00	1.29
C5	Security	1.00	1.00	0.88	0.78	1.00

Tabel 10. Pairwise Comparison Matrix A10

Pantai Pandua(A10)	C1	C2	C3	C4	C5	Prioritas	Consistency Measure
C1	Accessibility	0.184	0.184	0.184	0.184	0.184	5.005
C2	Distance	0.184	0.184	0.184	0.184	0.184	5.005
C3	Cost	0.211	0.211	0.211	0.211	0.211	4.988
C4	Attraction	0.237	0.237	0.237	0.237	0.237	4.996
C5	Security	0.184	0.184	0.184	0.184	0.184	5.005
Consistency Index							0.000002
Ratio Index							1,12
Consistency Ratio							0.000002
Consistency							Konsisten

The results of alternative calculations 1 to 10 are shown in Table 4.11.

Table 11. Results of alternative calculations A1-A10

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10
C1	0.1962	0.1740	0.143	0.167	0.118	0.238	0.179	0.227	0.138	0.184
		0	0	0	0	0	0	0	0	0
C2	0.1100	0.0500	0.200	0.100	0.100	0.120	0.120	0.080	0.060	0.060
			0	0	0	0	0	0	0	0
C3	0.1238	0.0430	0.071	0.278	0.235	0.190	0.250	0.136	0.207	0.211
			0	0	0	0	0	0	0	0
C4	0.1833	0.1167	0.125	0.141	0.133	0.041	0.033	0.066	0.091	0.066
			0	7	3	7	3	7	7	7
C5	0.3846	0.3480	0.214	0.167	0.294	0.238	0.250	0.318	0.310	0.184
			0	0	0	0	0	0	0	0

The calculation of the pairwise comparison matrix between each alternative and criteria 1 to 5 is done in the same way as the pairwise comparison matrix between each criterion and the previous alternative, until the priority weight is obtained.

Table 12. Priority Weight Calculation Results

	K1	K2	K3	K4	K5
A1	0.19637	0.07568	0.12387	0.21945	0.38461
A2	0.17400	0.05000	0.04300	0.11670	0.34800
A3	0.14300	0.20000	0.07100	0.12500	0.21400
A4	0.16700	0.10000	0.27800	0.14170	0.16700
A5	0.11800	0.10000	0.23500	0.13330	0.29400
A6	0.23800	0.12000	0.19000	0.04170	0.23800
A7	0.17900	0.12000	0.25000	0.03330	0.25000
A8	0.22700	0.08000	0.13600	0.06670	0.31800
A9	0.13800	0.06000	0.20700	0.09170	0.31000

A1	0.18400	0.06000	0.21100	0.06670	0.18400
0					

2. Supermatrix

The supermatrix is a consolidation matrix that integrates all pairwise comparison results from various dependency relationships in the ANP network. This matrix is 15×15 in size, consisting of 5 criteria and 10 alternatives. The upper left section (5×5) represents the relationships between criteria, while the upper right section (5×10) shows the influence of criteria on alternatives. The main diagonal has a value of zero because no element influences itself in this model.

3. Weighted Supermatrix dan Limit Matrix

The Weighted Supermatrix is obtained by normalizing each column of the Unweighted Supermatrix so that the sum of each column is equal to 1.0. This normalization process is essential to ensure that the supermatrix is stochastic, which is a mathematical requirement for performing power iterations in the limit matrix stage.

The weighted supermatrix results show a balanced influence between elements in the network. Each column in the weighted supermatrix shows a standardized distribution of influence so that it can be used for the iteration process towards the limit matrix. At this stage, all values have the same scale so that they can be compared and operated on mathematically.

The Limit Matrix is the final result of the Weighted Supermatrix iteration process until convergence is achieved. At this stage, all columns in the matrix have the same value for each row, indicating that the system has reached a stable state. The values in each row are the final global weights of each element after considering all dependency relationships in the complex ANP network.

Iteration Process Towards Limit Matrix: First, normalize the Unweighted Supermatrix into a Weighted Supermatrix. Each column is normalized so that the sum = 1.0. After normalization, the Weighted Supermatrix is ready for iteration. Then, power iteration, where the weighted Supermatrix is raised to a power until convergence is reached:

Iteration 1: $W^1 = \text{Weighted Supermatrix}$

Iteration 2: $W^2 = W^1 \times W^1$

Iteration 3: $W^3 = W^2 \times W^1$

...

Iteration k: $W^k = W^{(k-1)} \times W^1$

The convergence condition is achieved when:

$W^k = W^{(k-1)} = W^{(k+2)} = \dots = \text{Limit Matrix}$

In this study, convergence was achieved at the 24th iteration. One of the main characteristics of a stable limit supermatrix is:

1. each column has identical values,
2. the rows in criteria (C1–C5) have a value of 0, because all influences have flowed to the alternatives,
3. the rows in alternatives (A1–A10) contain the final global weights of each alternative.

Thus, the limit supermatrix becomes the basis for determining the final ranking of each tourism alternative.

4. Final ANP Results

After going through the weighted Supermatrix iteration process until convergence is achieved, a stable Limit Matrix is obtained where all columns have the same value for each row. The values in each row are the final global weights of each element. These weights reflect the relative importance of each element after considering all dependency relationships in the complex ANP network.

Table 13. Final Weight of ANP and Ranking

Rank	Objek Wisata	Koordinat	Nilai Limit Matrix
1	A01 - Bukit Sibeas-Bea	2.6355, 98.7128	0.1245
2	A05 - Godang Beach	2.5445, 98.7334	0.1095
3	A04 - Paromasan	2.6342, 98.7161	0.1078
4	A07 - Air Terjun Pangaribuan	2.6342, 98.7161	0.0977
5	A08 - Pantai Lumban Manik	2.638, 98.715	0.0973
6	A09 - Monumen Liberty Malau	2.5467, 98.7302	0.0973
7	A06 - Pantai Pasir Putih Parbaba	2.5788, 98.6874	0.0971
8	A03 - Parhorasan	2.6342, 98.7161	0.0954
9	A02 - Pusuk Buhit	2.6342, 98.7161	0.0887
10	A10 - Pantai Pandua	2.6342, 98.7161	0.0847

Based on the Analytical Network Process (ANP) calculations integrating five key criteria—accessibility, distance, cost, attraction, and security—along with evaluations of 10 tourist attractions in Samosir Regency, a clear and consistent ranking pattern emerged. Bukit Sibeas-Bea (A1) ranked highest with a global weight of 12.45%, leading by 1.05% over the closest competitor, Godang Beach (A5), which scored 10.95%. This difference is significant, considering the narrow distribution of weights across the alternatives.

Bukit Sibeas-Bea's top rank is primarily driven by its strong and consistent performance in key criteria, particularly attraction and security, where it achieved the highest ratings. This highlights its aesthetic appeal and strong security, factors that are crucial for modern tourists.

Godang Beach (A5) ranked second with 10.95%, closely following Bukit Sibeas-Bea, thanks to its high visual appeal and good security, maintaining competitiveness in the ANP model. Paromasan (A4) secured third place with 10.78%, also showing strong performance, though slightly behind the top two in several core criteria.

On the other hand, Pantai Pandua (A10) ranked lowest with 8.47%, primarily due to weaker scores in attraction and security, which are critical factors in the ANP model. Despite its accessibility, these shortcomings placed it at the bottom of the ranking.

The ANP ranking provides a clear strategic direction for tourism development in Samosir Regency. Bukit Sibeas-Bea should be prioritized for investment, facility development, and promotional strategies. The use of ANP in this study demonstrates that data-driven decision-making leads to more objective, measurable, and realistic priority recommendations compared to traditional methods based on intuition or subjective evaluation. With proper

implementation, Samosir Regency has a strong opportunity to enhance its tourism competitiveness sustainably through targeted, evidence-based planning.

Modelling UML

1) Use Case Diagram

Use Case Diagrams are used to model the relationship between actors and the system. These diagrams explain how actors (i.e., Admin and User) interact with the tourist attraction information system. The administrator has a broader role, such as logging in, managing tourist data, adding new data, managing criteria, and viewing recommendations. Meanwhile, users interact by logging in, viewing distribution maps, and viewing tourist attraction recommendations. The relationship between actors and system functions is illustrated using connecting lines, while the relationship between functions can use include or extend to show the connection.



Figure 3. Use Case Diagram

2) Class Diagram

A Class Diagram depicts the logical structure of a system based on a database design that has been created. Each class in the diagram represents a table in the database, complete with attributes and relationships between classes.

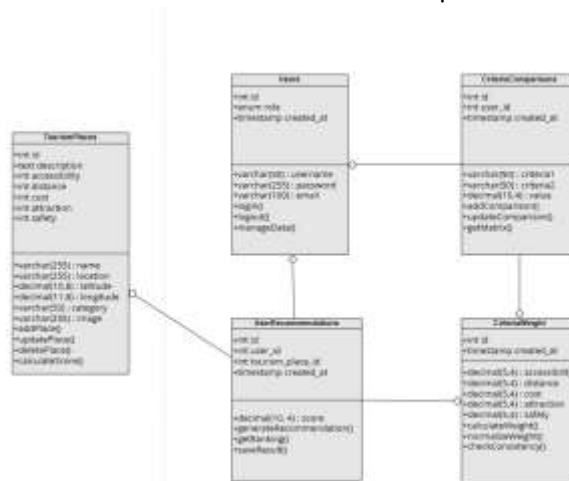


Figure 4. Class Diagram

This diagram serves as a link between the requirements analysis stage and the database design for a decision support system based on the Analytic Network Process (ANP) method. Based on the tables in the database design (Alternative

Table, Criteria Table, Alternative Relationship Table, Criteria Relationship Table, Comparison Value Table, and User Table).

System Implementation Results

This section describes the results of the implementation of the design. The implementation was carried out using PHP for the backend, MySQL as the database, and Leaflet with OpenStreetMap for map visualization.



Figure 5. Map Distribution

The Samosir Regency Tourist Attractions Distribution Map page serves as a Geographic Information System (GIS)-based visualization medium to display the location and characteristics of tourist attractions spatially to support the tourism analysis and recommendation process. On this page, users can view the distribution of tourist attraction points on an interactive map using Leaflet and OpenStreetMap, complete with a category filter feature to display specific tourist attractions and coloring options based on criteria such as accessibility, distance, cost, attractiveness, and safety, which are part of the Multi-Criteria Decision Analysis (MCDA) parameters. Each marker on the map provides detailed information about the tourist attraction via a popup, while the table at the bottom displays structured data about the tourist attraction to facilitate comparison of each criterion's value. Additionally, there is a Heatmap button to view the density of tourist attractions and a Calculate ANP Recommendations button that links to the recommendation calculation process using the Analytic Network Process (ANP) method. Thus, this page plays an important role as a spatial analysis tool and decision-making support in determining the best tourist attractions in Samosir Regency.



Figure 6. Recommendation Results Page

The recommendation.php page is designed as the main page for the results of tourist attraction recommendations in this study, which is used to display the final results of the ANP (Analytic Network Process) method calculations that have undergone consistency

testing, tourist attraction ranking, and GIS-based spatial visualization. At the top of the page, the consistency test results (Consistency Ratio/CR) are displayed to ensure that the criteria comparisons are mathematically consistent ($CR < 0.1$), so that the recommendation results are reliable. Next, the system displays a table of tourist attraction recommendations containing rankings, attraction names, locations, categories, and ANP scores, where the scores are obtained from multiplying the criteria weights by the rating values of each attraction. A detailed calculation feature is provided to explain the transparency of the MCDA process, so that users can see the contribution of each criterion to the final score. On the right side of the page, the ANP criteria weights are displayed, showing the level of importance of each criterion in decision making, as well as a comparison matrix and dependency matrix as a representation of the ANP analysis process. In addition, this page is integrated with a Leaflet-based GIS map that visually displays the locations of the top recommended tourist attractions with ranking markers, making it easier for users to understand the spatial distribution of leading tourist attractions.



Figure 7. Details of MCDA or ANP Calculations (Summary)

The summary page serves as the main display of the ANP calculation results that have been performed previously. On this page, the system retrieves calculation results from the session to ensure that the calculation process has been executed. This summary provides an overview of the alternative tourism evaluation process based on predetermined criteria, allowing users to understand the entire decision-making process before viewing detailed calculations such as matrices, consistency tests, and final ranking results.



Figure 8. Ranking Page

The ranking page is the final page that displays the results of the entire ANP process. On this page, the system ranks alternatives based on the final weight values obtained from the limit matrix, starting from the highest to the lowest value. These ranking results are used

as the main recommendation, where the alternative with the highest value is considered the best choice according to the criteria and relationships that have been analyzed.

Based on the results of the design and implementation of the decision support system using the Analytic Network Process (ANP) method, it can be concluded that this system is capable of processing alternative assessments in a structured manner through the stages of comparison matrix, consistency test, supermatrix formation, to limit matrix to produce stable global weights. Each page designed has an important role in ensuring that the decision-making process runs systematically, logically, and consistently. The final result in the form of alternative ranking provides objective recommendations based on the interrelationships between criteria and alternatives, so that this system can be used as an accurate and accountable decision-making tool.

CONCLUSION

This study uses tourist attraction data from Samosir Regency as the basis for decision-making in selecting tourist destinations. The data includes spatial information (geographic coordinates) and non-spatial data (tourist attraction attributes). The criteria analyzed include accessibility, distance, cost, attraction, and security. This data enables the system to represent tourist destinations comprehensively and systematically, providing a valid foundation for recommending destinations.

The priority-setting process for tourist destinations was conducted using the Multi-Criteria Decision Analysis (MCDA) method with the Analytical Network Process (ANP) approach. This method accounts for the interdependencies between criteria, resulting in more accurate and realistic priority weights. The data processing results show that ANP is effective in ranking tourist destinations based on the importance of each criterion, ensuring that the recommendations align with tourist needs and preferences.

The research produced a web-based decision support system integrating Geographic Information System (GIS) and MCDA. The system displays tourist destinations visually on a digital map and provides recommendations based on priority calculations. The GIS and MCDA integration makes it easier for tourists to access location information and select destinations more effectively, supporting tourism development and equitable distribution in Samosir Regency.

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