DETERMINATION OF LANDING BEACH LOCATION FOR AMPHIBIOUS OPERATIONS ON THE WEST PAPUA SEA WITH ANALYTIC HIERARCHY PROCESS (AHP): CASE STUDY ON SORONG REGENCY

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Abstract: Determination of landing beach is the most important power of the Indonesian Marines Corps in carrying out amphibious operations. Prerequisites for determination of landing beach must conform to predefined parameters and functions. The aim of this paper is to determine the most feasible landing beach for amphibious operation in Sorong Regency by Analytic Hierarchy Process (AHP). The research stages are starting from the determination of the weight value of the selection criteria and the weight value of landing beach alternative. It results from pairwise comparison analysis in the framework of AHP. The selection of landing beach that has objective values in accordance with the data can assist a decision makers to solve a multi-criteria problem in amphibious operations. The result of this paper can be seen as the second beach with a value of weight of 0.639 was chosen to be the most appropriate beach location for amphibious landing operations. While for the second order is the first beach with a weight value of 0.259 and the third beach with a weight of 0.101.

Key words: *Amphibious Operations, Landing beach, AHP method.*

1. INTRODUCTION

The expansion process in the Papua region contributed well to establish a third of The Sea Area Command and Marine Force in Sorong West Papua due to infrastructure development [1], facilities and infrastructure of the local area are getting better. In order to carry out the function of empowering the marine defense area it requires the ability of sea defense and also the ability to maintain all the natural resource potential [2].

Understanding the coastal characteristics of Sorong especially related to determine the landing beach is a should be for landing troop element in order to carry out the task of amphibious operations, especially to determine the ideal landing beach location [3], [2]. Requirements to determine the ideal landing beach should be in accordance with predetermine parameters [2] and serve as an important component in determine the weight value of landing beach selection criteria [4].

With the AHP method, the research stage starts from the establishing of the criteria weighted value and the alternative of landing beach selection processed [5], [4] in the AHP framework which arrangement in the hierarchical model by performing pairwise comparison analysis, it is processed in the form of a complete matrix with consistency analysis [4]. Hence, it is expected that the result of alternative landing beach to be a logic and objective value in accordance with accurate data and is very helpful for decision makers to solve multi-criteria problems [6].

The systematically of this research is as follows: Chapter 2 contains a literature review on the definition of Amphibious Operations, landing beach and basic theories which are used for AHP methods. Chapter 3 – materials / methodology which contains research process stages. In chapter 4 the results and discussion are presented and the last is chapter 5 – conclusions.

2. LITERATURE REVIEW

2.1. Amphibious Operations

The amphibious operation is an attack carried out from the sea by a naval unit and a landing troop of the Indonesian Navy loaded for shipping and amphibious landing means and landed on the beach or coastal potential of the enemy [3]. The development of amphibious operations was initially carried out by US marine as a result of state policy to reduce the budget of the war. The other side, the need for security to protect trade routes in the world belonging to the United States continues to increase. It directs the American Marine Corps to prove the usefulness and efficiency of military operations. The American Marine Corps defines an amphibious assault technique to seize the opponent's shore. In the end, the policy gave rise to an amphibious assault technique [7]. Why is amphibious operation still relevant to use? Amphibious operations are still relevant because they are providing several solutions during warfare, like: (a) overcoming natural obstacles from land, (b) overcoming impasse on land, (c) providing mobility and operational flexibility to troop commanders; and (d) giving psychological benefits [8]. Amphibious operation has many types, such as: (a) Amphibious Raid, (b) Amphibious Demonstration, (c) Amphibious Assault, (d) Amphibious Withdrawals, (e) Amphibious Forces Support and other operations.

Fig. 1. Amphibious Operation of indonesia Marine Corps

2.2. Landing Beach

The landing beach is part of the coastline required for landing one Battalion of Landing Team or equivalent unit [9]. Beach landing can also be part of a coastline that has tactical values, such as a bay beach that can be used to land a smaller entity than the Battalion of the Landing Team [3]. Several landing beaches allow marine force to gain an advantage position against the enemy by distributing weapons and logistics within the enemy areas, then the marine forces concentrate and maneuver toward their ultimate target. In landing beach selection, some types of oceanographic data [2] should be given enough consideration so that the Marines can safely carry out their landing [9], [2]. These types of data include the concept of landing troop operations, coastal capacity to maneuver amphibious landing troops, coastal approache, natural obstacle, coastal backdrop trait, communications infrastructure, including railroad and weather and other hydro-oceanographic data [10].

2.3. AHP Method

AHP method is a method of decision-making analysis that applies pairwise comparison theory to decision variable [11] that become the main criteria of decision as a derived element of the predeterminate objectiveness [12] where the determinate of the priority scale of these criteria depends on the assessment of experts in order to determine the alternative choice of solutions [13].

3. MATERIAL/METHODS

3.1. Flowchart of Research

This study is divided into four stages of research activities that are arranged sequentially starting from the stage of identification, data collection phase, analysis and data processing and conclusions. It can be seen in **Fig. 2** as follows [14]:

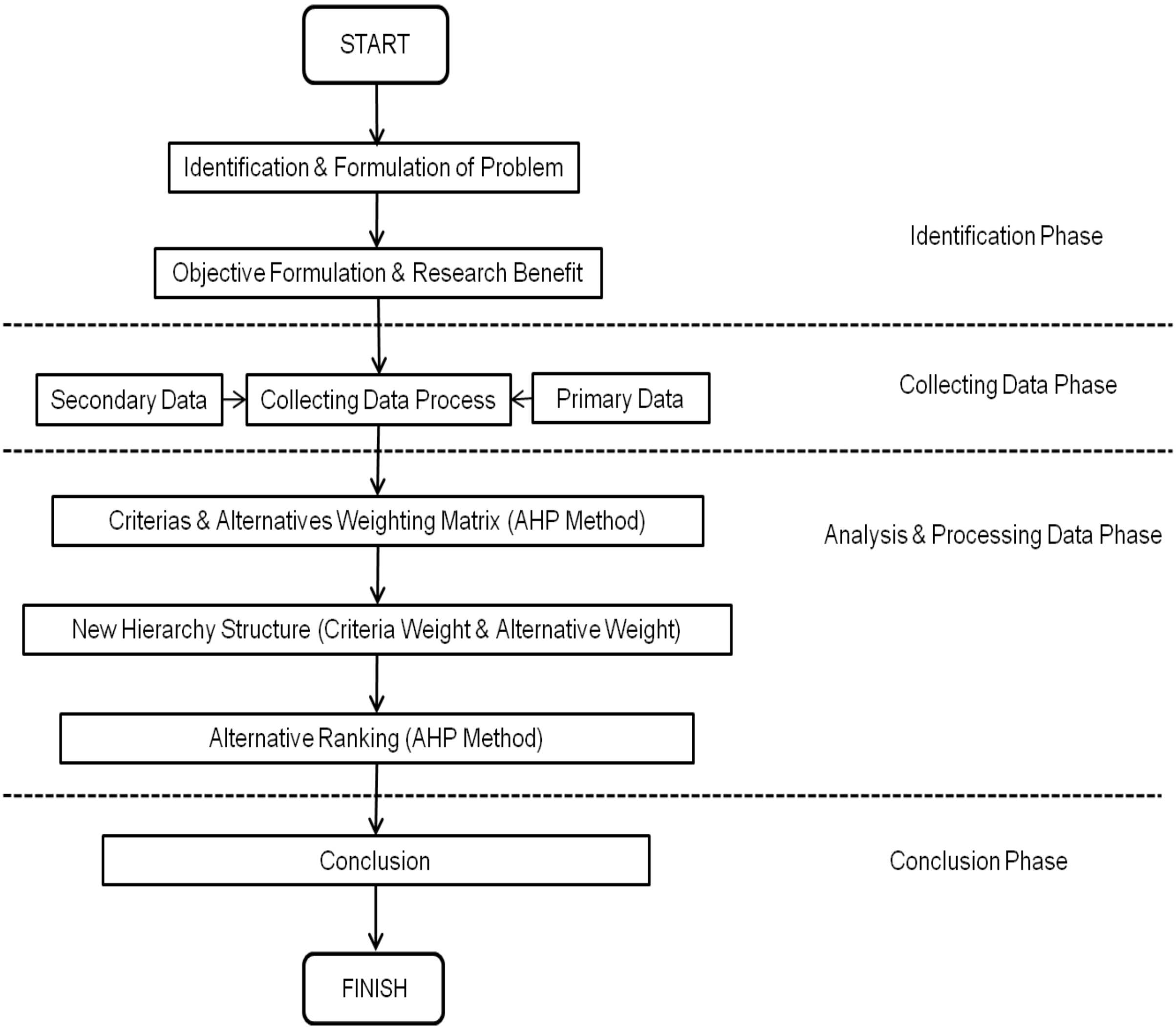

Fig. 2. Flowchart of Research

3.2. Research Object

This research is focused on the process of choosing the ideal landing beach location analysis. Because of that, the variable that become the main criterion in landing beach location should be analyzed according to the preparation method. The location of the research was conducted at TPI Jetty of Sap Papua West Papua (**Fig. 3**) located at 01 ° 07 '34.71 "S - 131 ° 13' 29.98" E [15].

A Sorong regency of West Papua has an area of 13,603.46 km² which consists of a land area of 845,71 km² and a surface of ocean of 514.65 km² [15].

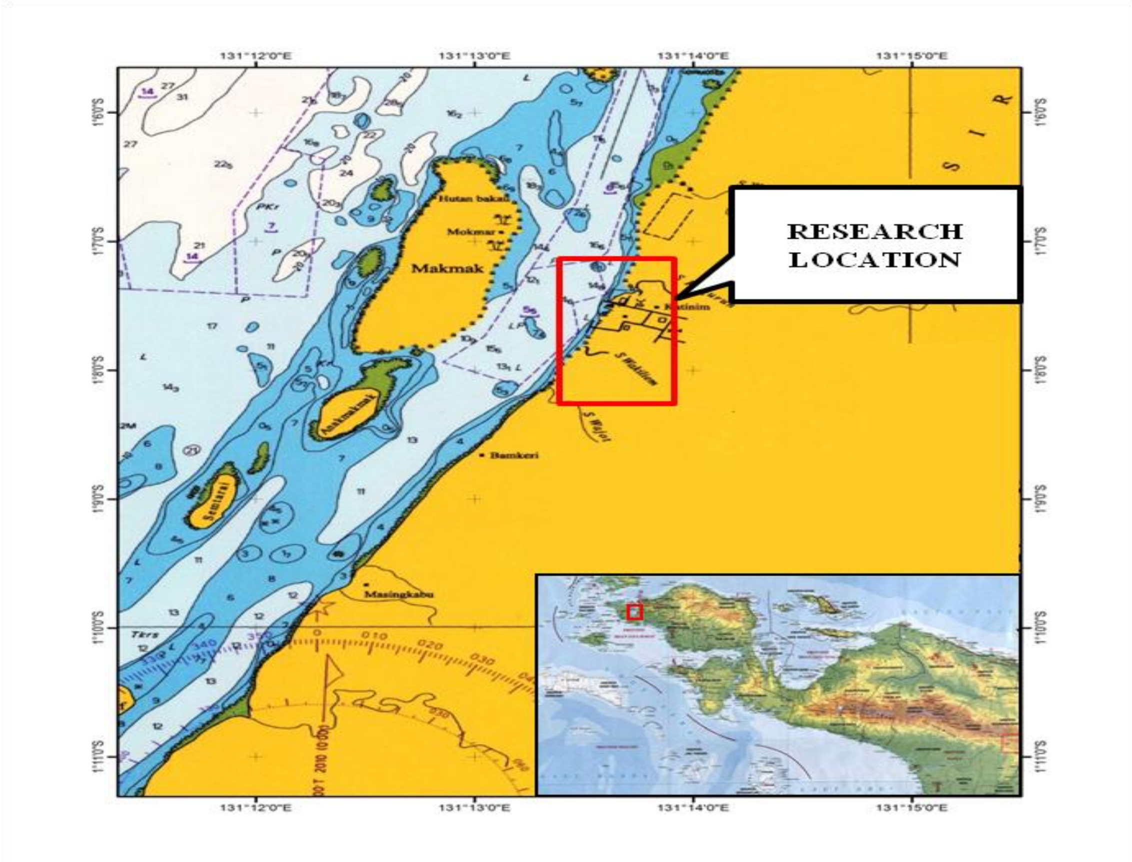

Fig. 3. Map of Research Location.

3.3. Research Steps

This method is used as the main framework of the decision maker system builder as well as to determine the value [16] of alternative weighted value through the process of pairwise comparison analysis up to the final stages of the research [17].

3.3.1. Determination of landing beach selection criteria

The criteria of landing beach selection in this research can be seen in **Table 1** below:

Table 1. Criteria for selection of landing beach

NO	CRITERIA	INFLUENCE IN AMPHIBIOUS OPERATIONS	IDEAL PARAMETER
1	**2**	**3**	**4**
1	**Type of Shorelines**		
	a. Straight shoreline	a. Influence of currents and waves.	Straight shoreline
	b.Convex shoreline	b. Effect on the direction of the shot	
	c.Concave shoreline	the opposing coastal defense.	

2	**Composition of the seafloor**		
	a. Sand.	Influence on surface manouver	Sand
	b. Sand pebbles.		
	c. Muddy sand.		
	d. Rocky gravel.		
3	**Coastal gradient**		
	a. Steep (gradient 1:15)	a. Influence on determination of ship type & landing lifeboat.	a. Moderate gradient
	b.Moderate (1:15 >gradient≥ 1:30)		1:15 > gradient ≥ 1:30
	c.Gentle (1:30 > gradient≥ 1:60)	b. Influence on type of break wave in shallow water area.	b. Gentle gradient
	d.Mild (1:60>gradient≥1:120)		1:30 > gradient ≥ 1:60
	e. Flat (gradient > 1:120)		
4	**Physical hydro-oceanography**		
	a. Wave	a. Effect on landing lifeboat and amphibious vehicle.	a. Spilling wave type.
	b. Tidal	b.To determinate type of lifeboat & amphibious vehicle to be used.	b.Semidiurnal and Mixed Semidiurnal tidal type
	c. Current		c. Current parallel shoreline velocity < 1 knots.
5	**Back area of beach**	a. Influence on manouver of troops & amphibious vehicles.	a. Flat with an elevated beach backdrop.
		b. Defense area for protection after landing.	b. There is a ramp to the rear of the beach.
6	**Point of reference for landing beach**	a. To help identification process of landing beach.	Can be a known terrain sign for its position
		b. As a navigation mark when on sea surface.	
7	**Coastal obstacles**		
	a. Natural obstacles	a. Influence on motion power of combat materials and troops	Selected beaches which minimum natural obstacle.
	b. Artificial obstacles	b. Can make amphibious vehicle and lifeboat become broken.	
8	**Beach access**	Make easy to maneuver for troops & vehicle on landing beach.	Selected beach which has enough total access.

3.3.2. Weighting matrix of criteria with AHP Method

In order to make a decision with the AHP method, it is necessary to process the problem with the following stages [14], [18]:

a. Create a hierarchy structure

The multicriteria problem in AHP is arranged in the form of a hierarchy consisting of three main components, namely the main objectives, assessment criteria and alternative choice [4]. The structure of the hierarchy can be illustrated as shown in **Fig. 4.** [19]:

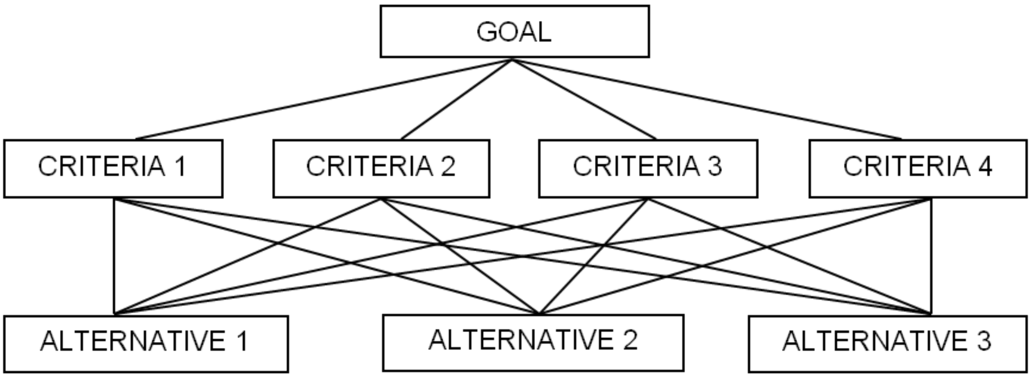

Fig. 4. Hierarchy structure [19]

b. Create a pairwise comparison matrix

1) Pairwise comparison based on Saaty Scale.

Table 2. Assessment of criteria weighting based on Saaty scale [4]

Value	Definition	Explanation
1	The same important	
3	Slightly more important	
5	More important	
7	Very important	
9	Absolute is very important	
2,4,6,8	Average	When in doubt between two adjacent values
1/3,1/5,1/7,1/9	The opposite of the value 1,3,5,7,9 (Reciprocal)	If the value of A to B is 4 then the value of B to A is 1/4

2) Calculating the criteria weight (priority vector).

Then, it is done the calculation of the average value of the sum in each line matrix according to the following formula [13], [20]:

$$A = (a_{ij}) = \begin{bmatrix} 1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & 1 & \cdots & W_2/W_n \\ \vdots & \vdots & \cdots & \vdots \\ W_n/W_1 & W_n/W_2 & \cdots & 1 \end{bmatrix} \quad (1)$$

3) Testing Consistency Ratio (CR).

If *CR*>0,1 then the pairwise comparison process should be repeated again until *CR*≤0,1:

a) Determine λ_{maks} by formula [13]:

$$[Ax = \lambda_{maks} x] \quad (2)$$

Where x is *eigen vector* value obtained from the calculation *priority vector*. After processing (2.4) has obtained λ_{maks} Matrix and then determine the average value of λ_{maks}.

b) Determine Consistency Index (*CI*) by formula [13]:

$$CI = \frac{(\lambda_{maks} - n)}{(n-1)} \quad (3)$$

Where:
CI : Consistency Index.
λ_{maks} : Average value $\frac{Ax}{x}$.
n :Total weight.

c) Determine *CR* value by formula [13]:

$$CR = \frac{CI}{IR} \quad (4)$$

Where Index Ratio value is determined in accordance with **Table 3** as follows:

Table 3. Index Ratio (IR) [13]

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
IR	0,00	0,00	0,58	0,90	1,12	1,2	1,3	1,4	1,5	1,49	1,51	1,48	1,56	1,57	1,59

At this stage it should be ensured that CR values must be consistent ($CR \leq 0{,}1$) [20].

4) Develop a new hierarchy completed with criteria weight.

The preparation of the new hierarchy can be seen in **Fig. 5** [20]:

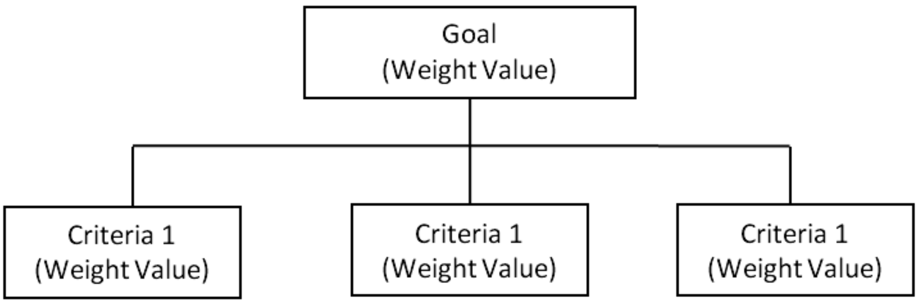

Fig. 5. Hierarchy structure of weight value

5) Calculate the value of alternative weight for each criteria.

This process carried out a number of assessment criteria as shown in **Table 4** [12]:

Table 4. Matrix Table of Assessment Criteria

Criteria	Alternative 1	Alternative 2	Alternative 3	...	Alternative n
Alternative 1	1	...	...	...	...
Alternative 2	...	1	...	...	...
Alternative 3	...	...	1	...	...
...	...	...	...	1	...
Alternative n	...	...	...	...	1

6) Develop a new complete hierarchy with the value of the weighting criteria and the value of alternative weight.

The preparation of the new hierarchy can be seen in **Fig. 6**:

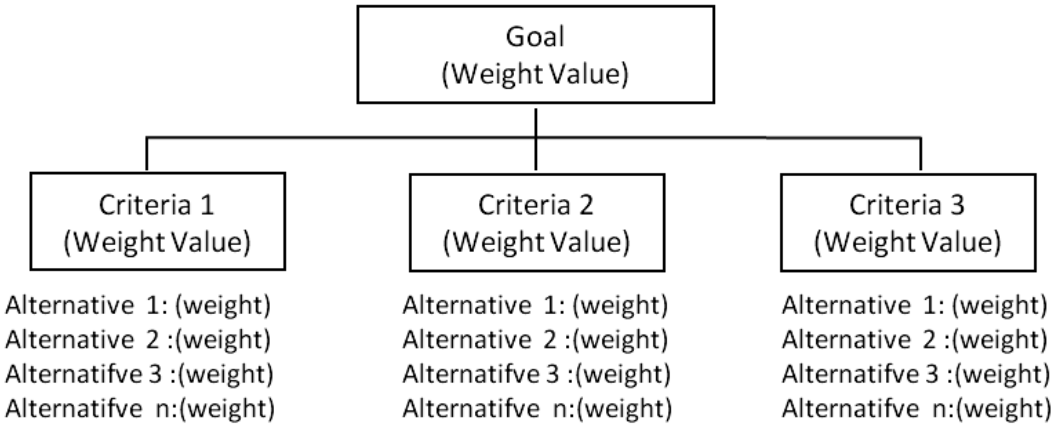

Fig. 6. Structure hierarchy of weight value

c. Determine the preferred alternative ranking

The determination of the optional alternative rank corresponds to the following matrix calculations:

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} k \\ l \\ m \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \quad (5)$$

4. RESULTS AND DISCUSSION

4.1. Matrix weighting criteria with AHP Method

a. Create a hierarchy structure

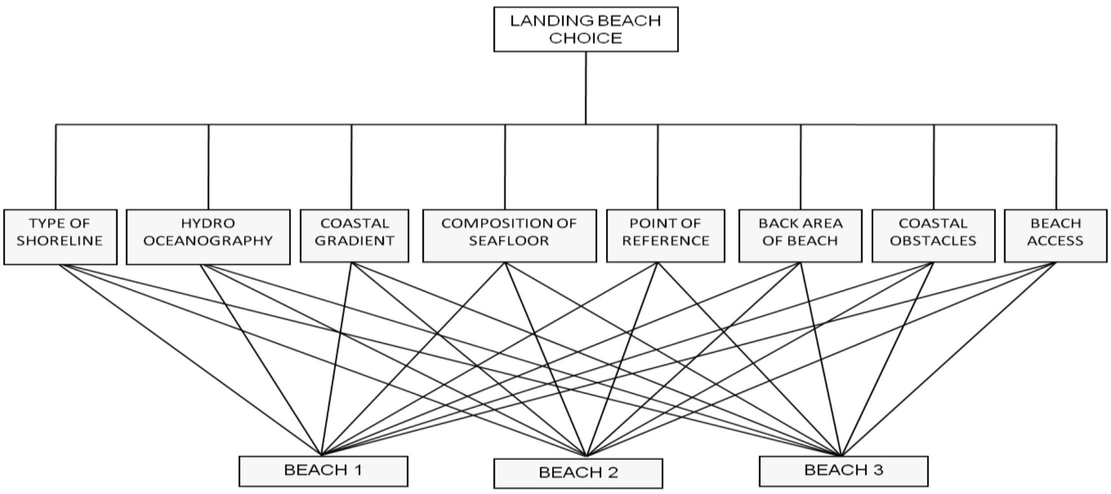

Fig. 7. Hierarchical structure

b. Determine pairwise comparison matrix.

Accuracy in determining the value of scale to matching criteria or alternatives by experts in the previous stage makes the basis of determining the preference at this stage so it is helpful for the decision maker to determine the numbers in a pairwise comparison matrix with Saaty scale like is shown in **Table 5** below:

Table 5. Criteria pairwise comparison matrix

NO	CRITERIA	TYPE OF SHORELINE	HYDRO-OCEANOGRAPHY	COASTAL GRADIENT	COMP. SEAFLOOR	POINT REFERENCE	BACK AREA OF BEACH	COASTAL OBSTACLES	BEACH ACCESS
1	TYPE OF SHORELINE	1	0,333333	2	0,5	0,333333	3	4	5
2	HYDRO-OCEANOGRAPHY	3	1	4	3	2	5	7	9
3	COASTAL GRADIENT	0,5	0,25	1	0,5	0,333333	2	3	5
4	COMPOSITION OF SEAFLOOR	2	0,333333	2	1	0,333333	3	4	5
5	POINT OF REFERENCE	3	0,5	3	3	1	4	5	7
6	BACK AREA OF BEACH	0,3333333	0,2	0,5	0,333333	0,25	1	2	3
7	COASTAL OBSTACLES	0,25	0,142857	0,3333333	0,25	0,2	0,5	1	2
8	BEACH ACCESS	0,2	0,111111	0,2	0,2	0,142857	0,333333	0,5	1
JUMLAH		10,283333	2,870634921	13,033333	8,783333	4,5928571	18,83333333	26,5	37

c. Determine the priority vector.

The normalization result matrix and priority vector can be seen in **Table 6** below:

Table 6. Priority vector

MATRIX A								X	AX	λmax (AX/X)
1	0,333	2	0,5	0,333	3	4	5	0,1177	0,972	8,254
3	1	4	3	2	5	7	9	0,3121	2,631	8,43
0,5	0,25	1	0,5	0,333	2	3	5	0,0871	0,708	8,129
2	0,333	2	1	0,333	3	4	5	0,137	1,158	8,451
3	0,5	3	3	1	4	5	7	0,2307	1,982	8,59
0,333	0,2	0,5	0,333	0,25	1	2	3	0,0553	0,448	8,1
0,25	0,143	0,333	0,25	0,2	0,5	1	2	0,0362	0,295	8,151
0,2	0,111	0,2	0,2	0,143	0,333	0,5	1	0,0239	0,196	8,219
								TOTAL =		66,325
								AVERAGE =		**8,291**

d. Test of Consistency Ratio (CR).

If $CR > 0{,}1$ then the pairwise comparison process should be repeated again until it is obtained $CR \leq 0{,}1$. Determine λ_{maks} by formula: $[Ax = \lambda_{maks}x]$,where *x* is the eigenvector.

Table 7. Table of λ_{maks} matrix

NO	CRITERIA	TYPE OF SHORELINE	HYDRO-OCEANOGRAPHY	COASTAL GRADIENT	COMP. SEAFLOOR	POINT REFERENCE	BACK AREA OF BEACH	COASTAL OBSTACLES	BEACH ACCESS	PRIORITY VECTOR
1	TYPE OF SHORELINE	0,0972447	0,11611833	0,1534527	0,056926	0,0725765	0,159292035	0,1509434	0,135135	0,1177
2	HYDRO-OCEANOGRAPHY	0,2917342	0,34835499	0,3069054	0,341556	0,4354588	0,265486726	0,26415094	0,243243	0,3121
3	COASTAL GRADIENT	0,0486224	0,087088748	0,0767263	0,056926	0,0725765	0,10619469	0,11320755	0,135135	0,0871
4	COMPOSITION OF SEAFLOOR	0,1944895	0,11611833	0,1534527	0,113852	0,0725765	0,159292035	0,1509434	0,135135	0,1370
5	POINT OF REFERENCE	0,2917342	0,174177495	0,230179	0,341556	0,2177294	0,212389381	0,18867925	0,189189	0,2307
6	BACK AREA OF BEACH	0,0324149	0,069670998	0,0383632	0,037951	0,0544323	0,053097345	0,0754717	0,081081	0,0553
7	COASTAL OBSTACLES	0,0243112	0,049764999	0,0255754	0,028463	0,0435459	0,026548673	0,03773585	0,054054	0,0362
8	BEACH ACCESS	0,0194489	0,03870611	0,0153453	0,02277	0,0311042	0,017699115	0,01886792	0,027027	0,0239
TOTAL		1	1	1	1	1	1	1	1	

Consistency Index (CI) is obtained by the formula:

$$CI = (\lambda_{maks} - n)/(n-1) \quad (6)$$

CI = (8,291-1)/(8-1) = 0,291/7 = 0,0416. (7)

Consistency Ratio (CR) testing is shown in **Table 8:**

Table 8. Table of Index Ratio (IR)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
IR	0,00	0,00	0,58	0,90	1,12	1,2	1,3	1,4	1,5	1,49	1,51	1,48	1,56	1,57	1,59

$$CR = CI/IR \text{ (n=8)} \quad (8)$$

CR = 0,0416/1,41 = 0,0295 ($CR \leq$ 0,1 so consistent)

e. develop a hierarchy structure based on the criteria of weight value.

Table 9. Matrix of Criteria Weight

No	Criteria	Weight
1	Type Of Shoreline	0,1177
2	Hydro-Oceanography	0,3121
3	Coastal Gradient	0,0871
4	Composition Of Seafloor	0,1370
5	Point Of Reference	0,2307
6	Back Area Of Beach	0,0553
7	Coastal Obstacles	0,0362
8	Beach Access	0,0239

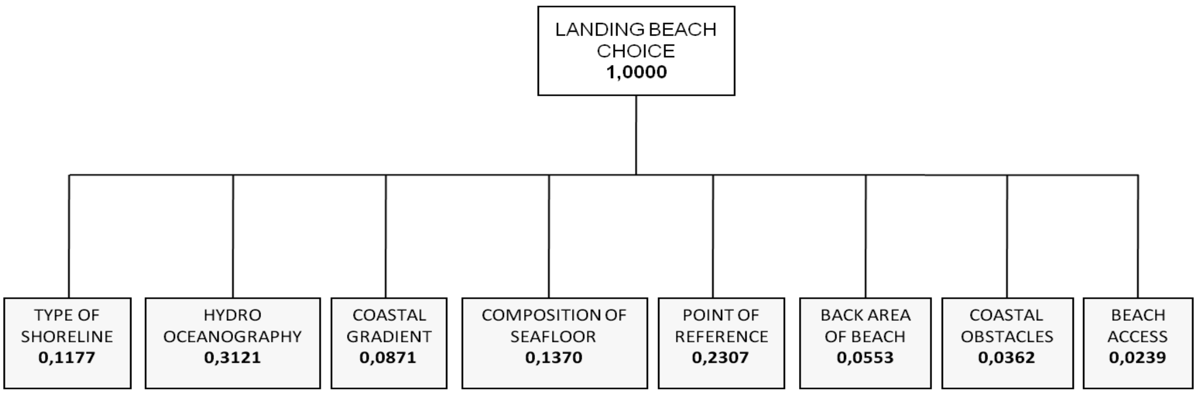

Fig. 8. Hierarcy structure with Weight of Criteria

f. The result of the calculation of the alternative weight values for each criteria.

Table 10. Result of Alternative Weight Values

1. TYPE OF SHORELINE

TYPE OF SHORELINE	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,25	4	0,190	0,167	0,444	0,267
BEACH 2	4	1	4	0,762	0,667	0,444	0,624
BEACH 3	0,25	0,25	1	0,048	0,167	0,111	0,108
TOTAL	5,25	1,5	9	1	1	1	

2. HYDRO-OCEANOGRAPHY

HYDRO-OCEANO	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,2	5	0,161	0,149	0,385	0,232
BEACH 2	5	1	7	0,806	0,745	0,538	0,697
BEACH 3	0,2	0,142857	1	0,032	0,106	0,077	0,072
TOTAL	6,2	1,342857	13	1	1	1	

3. COASTAL GRADIENT

COASTAL GRADIENT	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,33333	3	0,231	0,200	0,429	0,286
BEACH 2	3	1	3	0,692	0,600	0,429	0,574
BEACH 3	0,3333	0,33333	1	0,077	0,200	0,143	0,140
TOTAL	4,3333	1,66667	7	1	1	1	

4. COMPOSITION OF SEAFLOOR

COMP. OF SEAFLOOR	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,333333	3	0,231	0,211	0,375	0,198
BEACH 2	3	1	4	0,692	0,632	0,500	0,608
BEACH 3	0,333333	0,25	1	0,077	0,158	0,125	0,120
TOTAL	4,333333	1,583333	8	1	1	1	

5. POINT OF REFERENCE

POINT OF REFERENCE	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,25	5	0,192	0,179	0,385	0,252
BEACH 2	4	1	7	0,769	0,718	0,538	0,675
BEACH 3	0,2	0,14286	1	0,038	0,103	0,077	0,073
TOTAL	5,2	1,39286	13	1	1	1	

6.BACK AREA OF BEACH

BACK AREA OF BEACH	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,5	2	0,286	0,273	0,333	0,297
BEACH 2	2	1	3	0,571	0,545	0,500	0,539
BEACH 3	0,5	0,333333	1	0,143	0,182	0,167	0,164
TOTAL	3,5	1,833333	6	1	1	1	

7. COASTAL OBSTACLES

COASTAL OBSTACLE	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,5	3	0,300	0,250	0,500	0,350
BEACH 2	2	1	2	0,600	0,500	0,333	0,478
BEACH 3	0,3333	0,5	1	0,100	0,250	0,167	0,172
TOTAL	3,3333	2	6	1	1	1	

8. BEACH ACCESS

BEACH ACCESS	BEACH 1	BEACH 2	BEACH 3	NORMALIZIED MATRIX			PRIORITY VECTOR
BEACH 1	1	0,5	2	0,286	0,250	0,400	0,312
BEACH 2	2	1	2	0,571	0,500	0,400	0,490
BEACH 3	0,5	0,5	1	0,143	0,250	0,200	0,198
TOTAL	3,5	2	5	1	1	1	

g. The hierarchy arrangement is complemented by the criteria and alternative weights.

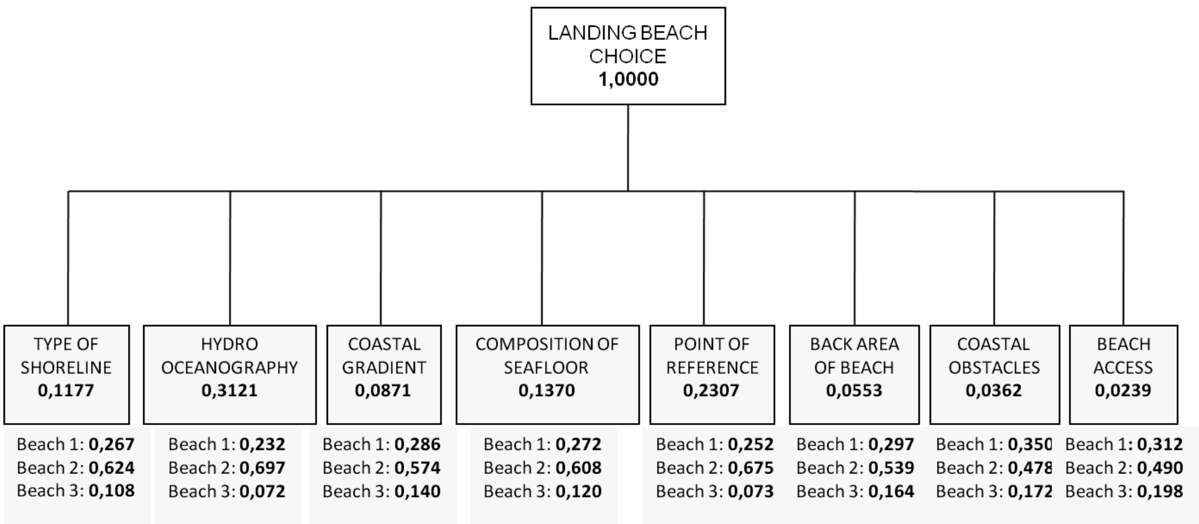

Fig. 9. New Hierarchy Structure with Weight of Criteria and Alternative

h. Determine the preferred alternative ranking (Final Priority).

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} k \\ l \\ m \end{bmatrix} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} \qquad (9)$$

The calculation of priority matrix with the criteria weight can be seen in the following matrix multiplication:

$$\underbrace{\begin{bmatrix} 0{,}267 & 0{,}232 & 0{,}286 & 0{,}272 & 0{,}252 & 0{,}297 & 0{,}350 & 0{,}312 \\ 0{,}624 & 0{,}697 & 0{,}574 & 0{,}608 & 0{,}675 & 0{,}539 & 0{,}478 & 0{,}490 \\ 0{,}108 & 0{,}072 & 0{,}140 & 0{,}120 & 0{,}073 & 0{,}164 & 0{,}172 & 0{,}198 \end{bmatrix}}_{\text{Priority Matrix}} \underbrace{\begin{bmatrix} 0{,}1177 \\ 0{,}3121 \\ 0{,}0871 \\ 0{,}1370 \\ 0{,}2307 \\ 0{,}0553 \\ 0{,}0362 \\ 0{,}0239 \end{bmatrix}}_{\text{Criteria Weight}} = \underbrace{\begin{bmatrix} 0{,}259 \\ 0{,}639 \\ 0{,}101 \end{bmatrix}}_{\text{Final Priority}} \qquad (10)$$

Then, it gets the result of alternative choice of landing beach based on the value of weight on matrix final priority can be seen with table 10 below:

Table 11. Final Result of Landing Beach Rank

Priority Matrix	Final Priority	Rangking
Beach 1	0,259	**2**
Beach 2	0,639	**1**
Beach 3	0,101	**3**

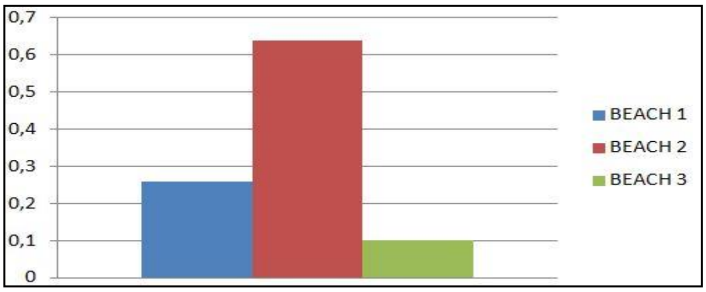

Fig. 10. Result of Landing Beach Determination

From the results of analysis with the AHP method can be seen that the second beach with a value of weight of 0.639 was chosen to be the most appropriate beach location for amphibious landing operations. While for the second order is first beach with a weight value of 0.259 and the third beach with a weight of 0.101. The ranking results show that the second beach is a highest rank, first beach is the second rank and the last is Beach 3.

5. CONCLUSION

Based on the results of research, through data analysis conductance we have obtained the following results:

a. In determining the ideal landing beach to carry out amphibian operations, there is a need for an analysis of the components to be used as the main criterion for selecting and alternating landing beach options that are multi-criteria.

b. From the results of analysis with the AHP method can be seen that the second beach with a value of weight of 0.639 was chosen to be the most appropriate beach location for amphibious landing operations. While for the second order is first beach with a weight value of 0.259 and the third beach with a weight of 0.101.

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