Seaplane Base Site Selection Using Analytical Hierarchy Process (AHP) for Amphibian Plane Test Flight and Operation

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https://doi.org/10.5109/7326986

出版情報：Evergreen. 11 (4), pp.3507-3519, 2024-12. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Japan
バージョン：

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(Received August 18, 2024; Revised September 3, 2024; Accepted November 26, 2024).

Abstract: The development of amphibious aircraft (N219 Amphibian) in Indonesia requires seaplane base facilities to conduct a flight testing and the selection of seaplane base location becomes more important parameter of the development. This study aims to determine the proper location for the seaplane base that can be used for the flight testing of amphibious aircraft. The study used analytic hierarchy process (AHP) due to its compatibility to include multicriteria in decision making, with consideration of four main criteria, i.e technical, operational, territorial, and cost criteria to assess the alternative locations. The results of the AHP model show that the visibility criterion is selected as the most critical criterion, since visibility play important part in the safety of plane operation. The evaluation of the location candidates indicates that the score for Panjang Island is 6.75, higher than Karimunjawa Island that only get 5.73. Thus, Panjang Island is deemed as more suitable location for the amphibious plane flight test. Therefore, this result can be used by the authority as a consideration in choosing the flight test location.

Keywords: seaplane base; amphibious aircraft; location; analytical hierarchy process

1. Introduction

Indonesia's enormous archipelago spanning 81,000 km necessitates the establishment of efficient transportation systems to successfully connect its numerous small islands. This is in accordance with a study from US Department of Transportation and Federal Aviation Administration which stated that when urban population mass plus large bodies of water are associated closely, there will be a demand for seaplanes in a community[1]. The development strategy for the amphibious aircraft in Indonesia aligns with the Indonesia National Medium-Term Development Plan (RPJMN) 2020-2024 and the Indonesia National Industrial Development Master Plan (RIPIN) 2015-2035, that encourage the development of the national aviation industry to support air transportation connectivity, one of which is through the development of a waterbase airport (Seaplane base) to supports the tourism destinations in the archipelago[2]. It is targeted that by 2023/2024 Indonesia will be able to produce amphibious aircraft which is the further development of the N219 Nurtanio aircraft with amphibious feature made by PT Dirgantara Indonesia, hereinafter referred to as the N219 Amphibian aircraft or N219A.

Seaplane Base, as a simple part of waterbase airport, is an important infrastructure facility in supporting amphibious aircraft test and operations. Hence, it is imperative to conduct a site selection study in order to identify the most optimal area and fulfill the predetermined selection factors[3]. According to Chang et al., the site selection process usually involves screening and evaluation[4]. The screening stage identifies some location candidates with consideration of the selection factors. The evaluation step involves a meticulous analysis of many options in order to choose the best suitable location. Choosing the right location is essential for the cost competitiveness[5]. Location selection is an irreversible or high-return investment that necessitates the allocation of long-term money, to determine the most appropriate facility site possibilities for both physical area and growth technique selection, competent decision-making tools, and analytical skills are required[6].

AHP is one of the traditional Multi-Criteria Decision

Making (MCDM) method developed by Saaty[7,8]. AHP is a multi-criteria decision procedure that uses a pair-wise comparison to derive priority scales based on expert judgment[7,9,10]. That is, given alternatives and a set of selection criteria, for getting the optimal decision in a given situation. AHP is a simple method that focuses on peer-to-peer comparisons that are suitable to evaluate both qualitative and quantitative data. The point is the method focuses on assessing the importance of the selection criteria and differentiate between the more important criteria and the less important ones. The method also allows for consistency test in judgment to check and reduce inconsistencies in opinions or judgments. A study from Szatmári shows several advantages of the AHP method, including require minimum data input, and has a clear hierarchical process, that easily understood even for people who are using AHP for the first time in making decisions[11-13].

Among several decision-making method, AHP was widely used due to its simplicity and compatibility to include multiple criteria. On the Greek island of Samothraki, the analytical hierarchy process (AHP) was employed to select an airport site[14]. The collaborative assessment of multiple possibilities in location-based decision-making challenges connected to site selection or land distribution is a challenging process phase. To tackle this challenging process, AHP was used for a shipyard site selection in the Iskenderun, Turkey[15]. A study by Anderluh et al. created a generic model for selecting inner-city hub locations that take into account both quantitative and qualitative characteristics as well as different stakeholder groups, and AHP is considered as a good way to accomplish this[16]. AHP was also used to find the optimal location for a hospital in Turkey's Mugla province, by selecting factors that influence the venue selection process, as well as determining the weight of those criteria[17].

The common weakness in AHP is a lack of consistency. To overcome inconsistency in AHP, there was an integrated model for AHP proposed by Benítez et al. that enables balancing consistency and expert judgment[12]. The model is an extended version of the linearization procedure published by Delgado-Galván et al.[13], which can help practitioners and experts to develop comparison matrices based on their judgment while ensuring the efficiency and reliability in deriving priorities. Singh et al. used fuzzy AHP method with various criteria to select of the optimum warehouse location in various Special Economic Zone (SEZs) and Free Trade Zones (FTZs) in Iran[18]. The study by Mohajeri & Amin found the optimal location of the train station for the city of Mashhad, Northeastern Iran, which is an important issue for environmental managers, using the combination of AHP and Data Envelopment Analysis (DEA) methods[3]. Ghorbanzadeh et al. has studied subway station site selection in a developing country using MCDM[19]. Monajjem et al. used AHP for site selection of freight cars inspection post in Iran[20]. Yavaşoğlu et al. used AHP method in conjunction with Geographical Information Systems (GIS) to determine the best possible location for an Antarctic research station[21]. Similarly, Önüt & Soner conducted site selection for transshipment in the industrial region of Turkey using AHP[22]. Rosenberg & Esnard used hybrid scoring for transit site selection in South Florid[23], while Erkan & Elsharida used combination of AHO and ROC for site selection of airports in Libya[24]. AHP can help to solve complex problems by structuring a hierarchy of criteria, combining multiple interested parties, and drawing on various considerations to develop weights or priorities. AHP considers logical consistency in the judgments used to determine priorities.

AHP method has been widely used for site selection with predetermined criteria by many other studies [3,5,6,9,14–17,25–38]. However, the using of AHP for seaplane base site selection of N219 amphibious aircraft model has not been done before. This study analyzes the best seaplane location for flight test and operation of N219A using the AHP method. As a part of development plan for N219A, a flight test holds an important factor to ensure the readiness of the amphibian plane. The location of flight test needs to be carefully determined, considering various aspect that can affect the operation and the flight test. Furthermore, the flight test location is expected to be used as operational seaplane afterwards. The large archipelagic landscape of Indonesia creates a challenge to determine the suitable location. This paper examines the determination of seaplane base location based on predetermined criteria using the process hierarchy analysis (AHP) method. AHP were chosen as it allows decision making based on multicriteria and combined expert judgement. AHP helps to ensure decisions are taken objectively and transparently by considering various important factors and perspective. For now, the need for the construction of a seaplane base is mainly to support amphibious aircraft flight test activities with intention to be used for operational activities afterwards. It creates a unique situation to consider in the selection process. Therefore, the criteria used are specific criteria that are considered influential in determining the location of the seaplane base for flight test activities and the operation of the N219 amphibious aircraft.

2. Methodology

2.1 Potential Location for Seaplane Base

Early location theory focused mostly on the manufacturing of raw materials and markets to find a factory's best place by minimizing transportation costs[39]. The technical standard requirements for seaplane bases have been regulated in SKEP/227/VIII/2010, by the Ministry of Transportation Republic of Indonesia, including the facilities needed for the operation of marine airports as well as technical requirements for waterside and shoreline facilities. The seaplane base, as a simple seaplane base, is an important facility for the N219 Seaplane test flight phase. Therefore, Khoirunnisa et al. have observed specific condition on one of the given alternative locations, namely Karimunjawa, such as waves, currents, bathymetry, and wind conditions for operational safety[40)]. There many criteria that can be applied to assess the alternatives. However, a careful look should be applied in choosing the tangible factors, such as cost as well as the intangible factors, such as social impacts[13)]. The criteria that should be taken into consideration in selecting a seaplane base location are accessibility, stakeholder view, realm condition, and cost investment. In this study, four major criteria have been determined, i.e technical, operational, territorial, and investment cost.

The potential locations designated as alternatives are Panjang Island in Seribu Islands Regency, DKI Jakarta and Karimunjawa Island in Jepara Regency, Central Java Province. Figure 1 and 2 show the map of those two alternatives for seaplane base location.

Fig. 1: Panjang Island, Kepulauan Seribu District, Province DKI Jakarta (Source: Pulau Panjang Subdistrict in Figures 2022).

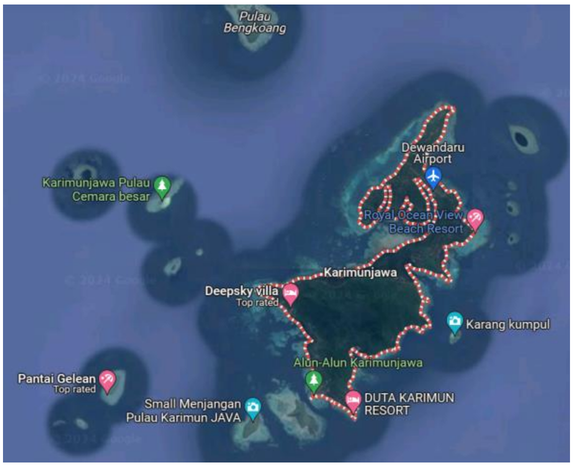

Fig. 2: Karimunjawa Island, Jepara District, Province Central Java (Source: Map data google 2024).

2.2 Development of the Hierarchical Structure

The AHP model was started by creating a hierarchical structure in which the main objective was highlighted, and the criteria and alternatives were identified. The main objective of the AHP model is to select the location for seaplane base. The selection of criteria that were included in this study was based on the literature review with consideration of availability of the supporting data. The suitability of the criteria with the objective of this study, i.e. site selection for seaplane dock, was also considered during the selection. Several aspects such as technical, operational, territorial, and cost are some criteria that were usually used in location selection[41,42)]. These became the main criteria for this study. Each main criterion was broken down into more detailed and measurable sub criteria. Table 1 shows all the criteria that were included in this study, including the main criteria and the sub criteria.

The tree diagram was developed to represent the AHP model including the objective and selection criteria. The tree diagram of AHP hierarchical structure can be divided into some parts, i.e. top part, middle part, and bottom part. The top part is the aim or main objective. The middle is the place for the selection criteria. In this study, the selection criteria have two level. The first level of middle part is set to place the main criteria, namely technical, operational, territorial, and cost criteria. Then, the main criteria were broken down into 24 sub-criteria that occupy the second level. The bottom part is set to place the alternatives, which are Karimunjawa and Panjang. The hierarchical structure of the research was shown in Fig. 3.

Table 1. Seaplane dock site selection criteria.

Main criteria	Sub criteria
Technical Criteria	Wave Height
	Sea Depth
	Tidal Wave
	Current Speed
	Wind Speed
	Sedimentation
	Rain Intensity
	Accommodation Facility
Operational Criteria	Cruise Line
	Obstacle to Cruise
	Obstacle to Aerodrome
	Visibility
	Air Traffic Interference
Territorial Criteria	Accessibility
	Land Availability
	Trip Demand
	Economy Condition (GDP)
	Population
	Tourism Potential
	Distance to The Nearest Airport
	Distance to the Nearest Healthcare

Main criteria	Sub criteria
	Facilities
	Fuel Availability
Cost Criteria	Construction Cost
	Mobilization and Demobilization Cost

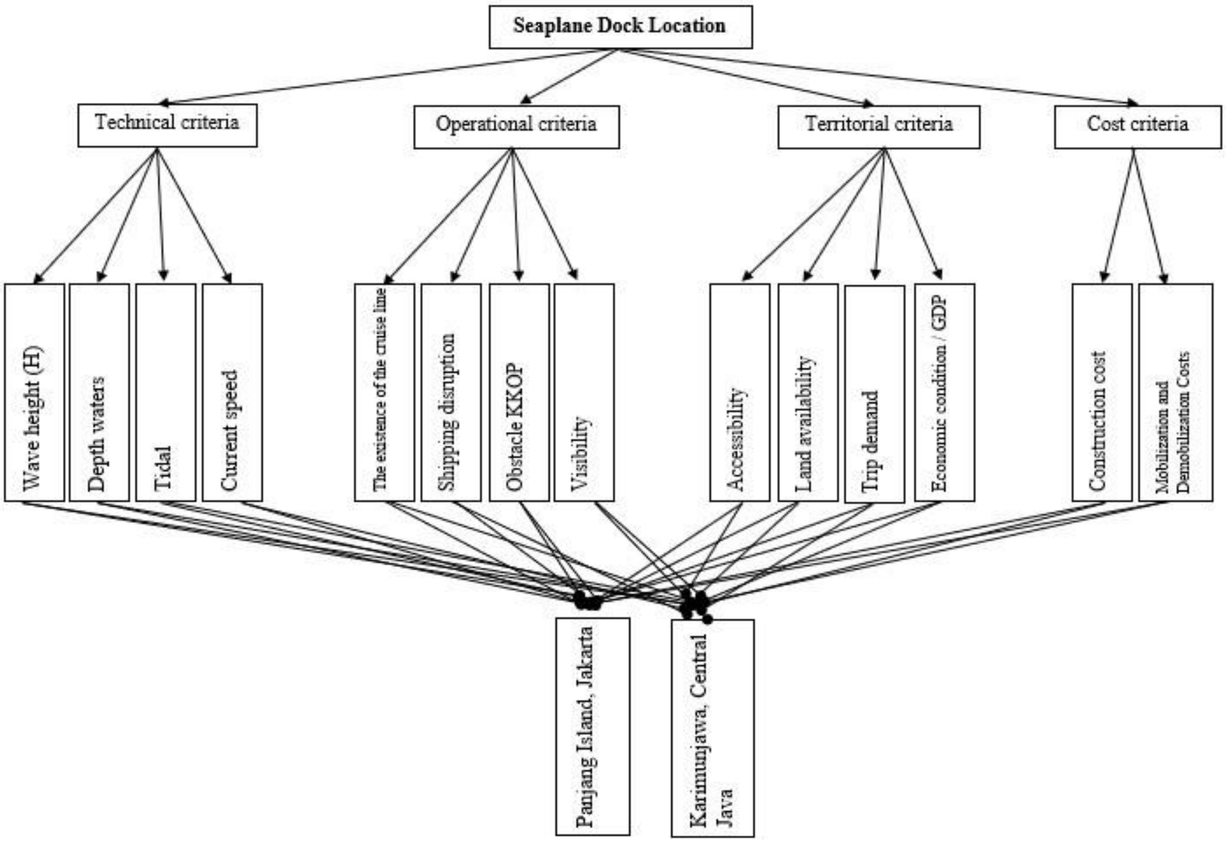

Fig. 3: Hierarchical structure of seaplane base site selection.

2.3 Assessment of the Selection Criteria

After the criteria tree is agreed upon, simultaneously with a weighting survey for experts, data collection is carried out according to the criteria to be assessed. The type of data or criteria will determine how the assessment will be carried out.

The weighting of criteria is carried out by conducting surveys with experts in the field of air and sea transportation. Nine experts were recruited in this study to give their judgement on the importance of the criteria and sub criteria. The experts were selected from stakeholder's representative of amphibian plane and seaplane dock development in Indonesia such as: aviation manufacture industry, researchers in aviation and ocean engineering, as well as Ministry of Transportation as regulator. Their expertise ranging from aeronautical engineering, ocean engineering, mechanical engineering, transport planner, and construction. Each expert gave their independent judgement to the set of criteria and sub criteria that were proposed in this study. Experts who become respondents are asked to compare the level of importance between one criterion and another at the same hierarchical level. Table 1 summarizes the main criteria and sub-criteria in this site selection.

2.4 Weighing Process

The implementation of AHP are done in three continuous stages[21)]:

- Vector computation of the criteria weights based on expert judgement;
- Computation of score for each alternative/option; and
- Ranking the options based on their score

In order to apply AHP in decision making process, these steps need to be converted into mathematical functions. The conversion is done by constructing a matrix that express the relative values of a set of criteria that has been defined beforehand. This matrix will be used by the decision maker and expert to evaluate the importance of each criterion relative to another one in the relation to the main decision problem. Each of the judgment that was given by experts is assigned a number that represent their relative importance. This process will establish a pair-wise comparison matrix A

Let $C_1, C_2, \ldots, C_n$ denote the set of criteria, while a_{ij} represents a quantified judgment on a pair of criteria C_i and C_j. This yields an n x n matrix A as follows: $C_1, C_2, \ldots, C_n$

$$A = [a_{ij}] = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \quad (1)$$

If a_{ij} represent the importance of criteria i compared to j, then a_{ji} is the reverse value of a_{ij}. Thus $a_{ji} = 1/a_{ij}$, (for $i, j = 1, 2, \ldots, n$). In matrix A, the problem becomes one of assigning to the n criteria $C_1, C_2, \ldots, C_n$ a set of numerical weights $W_1, W_2, \ldots, W_n$ that represent the expert judgement. If A is a consistency matrix, the relation between weights W_i and judgments a_{ij} are simply given by $W_i/W_j = a_{ij}$ (for $i, j = 1, 2, \ldots, n$) and $C_1, C_2, \ldots, C_n$

$$A = \begin{array}{c} C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_1/w_2 & w_2/w_2 & \cdots & w_1/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \quad (2)$$

Saaty[9] stated that the largest eigenvalue λmax could be calculated based on this formula

$$\lambda_{max} = \sum_{j=1}^{n} a_{ij} \frac{w_j}{w_i} \quad (3)$$

If A is a consistency matrix, eigen vector X can be calculated as follows

$$(A - \lambda_{max}\mathrm{I})X = 0 \quad (4)$$

The maximum value is used to calculate the Consistency Index (CI), with the formula[9]:

$$CI = \frac{(\lambda_{maks} - n)}{n-1} \quad (5)$$

Furthermore, to assess the consistency of the responses given by each respondent, it is necessary to calculate the consistency ratio (CR) value, where:

$$CR = \frac{CI}{RI} \quad (6)$$

RI is a random consistency index that depends on the number of elements in the matrix, the RI value is based on the study by Saaty[9]. The priority vector (VP) shows the weight of each criterion. First, the elements of each row in the pairwise matrix are multiplied and the root of the power of n is drawn, where n is the number of criteria.

$$VP_j = \sqrt[n]{A_{j1} \times A_{j2} \times \ldots \times A_{jn}} \quad (7)$$

VP_j represents the priority vector of row j, where n is the number of criteria. The VP values of all rows are then added up to obtain VP. The weight of each criteria is calculated by dividing the VP of each row by VP. Each row in the matrix represents one criterion.

$$Weight_j = \frac{VP_j}{\sum_{j=1}^{n} VP_j} \quad (8)$$

RI represents the average consistency index from numerous random inputs of same order pair-wise matrices. If $CR \leq 0.1$, the estimated is deemed consistent and accepted; otherwise, the matrix needs to be iterated until $CR \leq 0.1$. The following AHP steps were adopted from Wu et. al.[43] for selecting the optimal location:

- Step 1: Establish the assessment criteria for determining the most advantageous location for the seaplane base in order to secure a competitive edge.
- Step 2: Develop the framework. Utilizing the modified Delphi technique, gather significant indicators and organize them into a hierarchical structure of interconnected decision factors, which include goal, criteria, sub-criteria, and alternatives.
- Step 3: Create the pair-wise comparison matrix using formula (1). Each decision maker and expert do a pairwise assessment of the choice factors and assigns them scores based on their relative importance.
- Step 4: Compute the eigenvalue and eigenvector of each matrix obtained by comparing pairs using formulas (2) – (3).
- step 5: Validate the coherence of each comparison matrix by applying formulas (4)–(5).
- Step 6: Utilize the geometric mean method to combine the scores given by all decision makers and determine the relative weights of the items at each level.
- Step 7: Aggregate the respective weights of the elements inside each level to determine the most advantageous site for the seaplane base, so securing a competitive edge.

Typically, only the reliable questionnaire data are considered for the AHP analysis. Nevertheless, this scenario diminishes the quantity of questionnaire outcomes for a multi-criteria decision support analysis. Furthermore, if there is a scarcity of scientists available for assessing the potential sites. Hence, Yavaşoeğlu et al. incorporated both congruent and incongruent questionnaire findings to ascertain the weights[35].

Ultimately, the computation method yielded no substantial disparities between the outcomes of the congruent and incongruent surveys.

This demonstrates that the weight obtained using the subjective assessment approach mostly represents the intentions of experts and researchers, and is frequently impacted by their expertise and experience, so it is highly recommended to make a comprehensive weight determination method by combining AHP with objective determination methods (entropy method) like TOPSIS, which was carried out by Ding et al.[38].

3. Results and Discussion

3.1 Survey Results

The objective of this study is to select a location that suitable for flight test of N219 Amphibian Aircraft. Therefore, it is important to carefully select the location with consideration from all related aspects that may affect a flight test. As mentioned before, a set of criteria is chosen to the scoring parameter of the location candidates. Analytical hierarchy process is used to analysis the site characteristic based one chosen criterion and come up with the preferable site location.

Questionaire survey was done by experts from various related field such as aircraft manufacture industry, academics, regulators etc. It produces individual pairwise comparison between criteria. The experts give their judgement on whether one criterion is more important than the other. A nine-level scale is used to measure the importance of each criterion. Table 2 shows the example of the responses from the expert for the main criteria. The pairwise comparison then transformed into a matrix, for further calculation. The example of pairwise matrix is shown in Table 3.

Table 2. Expert responses for the main criteria.

No.	**Criteria A**	**Scale**																	**Criteria B**
		9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
1	Technical Criteria									1									Operational Criteria
2	Technical Criteria					1													Territorial Criteria
3	Technical Criteria									1									Cost Criteria
4	Operational Criteria							1											Territorial Criteria
5	Operational Criteria					1													Cost Criteria
6	Territorial Criteria											1							Cost Criteria

Table 3. Example of pairwise matrix of the main criteria based on an expert response.

	Technical	**Operational**	**Territorial**	**Cost**
Technical	1.00	1.00	5.00	1.00
Operational	1.00	1.00	3.00	5.00
Territorial	0.20	0.33	1.00	0.33
Cost	1.00	0.20	3.00	1.00

However, to be used in the calculation for the criteria weight, an aggregated value of pairwise comparison from all experts is required. The individual pairwise comparison from all the experts are further analyzed and calculated to produce an aggregated pairwise comparison of the selection criteria that will be used in the seaplane base site selection process. The pairwise comparison between criteria from all experts are combined to produce one pairwise matrix. Combined pairwise matrix represent the perspective from the experts. Geometry means of the pairwise comparison values are used to combine all the expert responses into one aggregated pairwise matrix for each level of criteria and sub criteria. There are five pairwise matrices: one for Criteria Level 1 (Main Criteria) and four for the sub-criteria. Table 4 shows the example of aggregated pairwise matrix of the main criteria (level 1).

After aggregated pairwise matrices are developed for all level of criteria (main criteria and sub-criteria), the calculation for criteria weight can be done by calculating the priority vector. The summation of the pairwise value in each column in the matrix is calculated and denoted as ΣXi. Then, every pairwise value in each cell of the matrix is divided by ΣXi. It forms an eigen matrix that will be used to calculate eigen vector of each row. The eigen vector is calculated by averaging each row of eigen matrix. Table 5 shows the eigen vector of each row that represent each criterion.

Table 4. Pairwise matrix of main criteria's aggregated value from experts' responses.

	Technical	Operational	Territorial	Cost
Technical	1.00	0.70	1.16	1.77
Operational	1.43	1.00	1.81	1.97
Territorial	0.86	0.55	1.00	2.11
Cost	0.57	0.51	0.47	1.00

Table 5. Eigen vector.

	Eigen Vector
Technical	1.00
Operational	1.43
Territorial	0.86
Cost	0.57

3.2 Consistency Test

After the initial calculation are done, it is required to ensure that the judgements from the respondents are consistent. Therefore, it is necessary to conduct a consistency test from the obtained responses. First, the maximum eigen value (λmaximum) are calculated by summing up the product between each ΣXi value and the eigen vector of the related row. random consistency index (RI) is an index that depend on the number of elements in the matrix, as explained on the study by Saaty[9)].

A set of responses can be considered consistent if the consistency ratio (CR) value is less than 0.1. If the CR value is bigger than 0.2, the set of responses is considered not-consistent. CR value between 0.1 and 0.2 is considered quite consistent. The calculation results of CR value from the aggregated responses shows that the set of responses is consistent for all criteria level.

3.3 Criteria's Weight Calculation

After one ensure that the set of responses is consistent, the weight of each criterion can be calculated. Similar process is done for all criteria and sub-criteria. Then, we get the weight of all criteria that will be used in the site selection process.

The pairwise matrices, like Table 4, were further analyzed to get the priority vector (VP) for each criterion. The priority vector was calculated using Equation (7). The VP for technical criteria is 1.095. Then, the weight of technical criteria ($Weight_j$) was calculated using the formula that is shown in Equation (8). The result indicates that the weight for technical criteria is 0.26 or 26%. Table 6 shows the weight of all criteria and sub-criteria.

Table 6. Weight of criteria.

Main criteria	Weight	Sub criteria	Weight
Technical Criteria	26%	Wave Height	28%
		Sea Depth	6%
		Tidal Wave	5%
		Current Speed	16%
		Wind Speed	26%
		Sedimentation	3%
		Rain Intensity	7%
		Accommodation Facility	9%
Operational Criteria	36%	Cruise Line	11%
		Obstacle to Cruise	8%
		Obstacle to Aerodrome	21%
		Visibility	40%
		Air Traffic Interference	20%
Territorial Criteria	24%	Accessibility	6%
		Land Availability	8%
		Trip Demand	13%
		Economy Condition (GDP)	10%
		Population	6%
		Tourism Potential	15%
		Distance to The Nearest Airport	18%
		Distance to the Nearest Healthcare Facilities	14%
		Fuel Availability	10%
Cost Criteria	14%	Construction Cost	40%
		Mobilization and Demobilization Cost	60%

The calculation results show that among the four first level criteria, operational criterion has the highest weight (36%). This can be understood as the objective of this study to select a location for seaplane base that suitable to conduct flight for the N219A Amphibian Airplane, thus it is important to ensure that there is no operational problem that can hinder the flight test. Overall, among all operational sub-criteria, visibility has the highest weight percentage of about 40%. Visibility is one of important factors in aviation field. Poorer visibility could be very dangerous for the flight since the pilot cannot clearly see the area to make a necessary judgement. Therefore, it could be understood that visibility hold a bigger proportion in the criteria since one need to ensure that the location has an ideal visibility and minimize the problem caused by limited visibility. Another factor that has quite big proportion in the criteria is air traffic interference. It defined as whether the area is passed by existing flight route that can interfere the flight test. This criterion becomes an important criterion to make sure that the flight test will not interrupt the existing flight route, vice versa.

Trip demand and tourism potential are also important aspects that need to be considered in the site selection. It is important during the daily operation. These criteria represent the demand that will be served by the seaplane base after it is open for the operation of amphibian airplane or seaplane. Higher demand and tourism potential will allow the seaplane base to have a sustainable demand.

All the weight of criteria that calculated based on expert response are used to calculate the overall score and rank the seaplane base location candidates. The weight will be multiplied with the score of the corresponding criteria. The score is calculated based on the data collected on the location candidates' characteristics.

3.4 Scoring of Location Candidates

After the weight of all criteria are obtained, the next step is to calculate the score of alternative locations for each criterion. As mentioned before, the location candidates are: Panjang Island and Karimunjawa Island. Each site has their characteristics that translated into the scoring of the criteria. Supporting data, both quantitative and qualitative data, about the characteristics of the sites related to the selection criteria are collected from various secondary data source. The data will be the reference to define the scores.

For the scoring, the team determine the ideal state or preferable condition of each criteria for development of seaplane dock. The team also referred to the existing standard and regulation on each criterion to define the scoring range. Table 7 shows the data that was gathered for both alternative location and the scoring rule for each criterion. The scoring range define the score that given to each site for different criteria. Table 8 shows the score of both alternatives for each criterion.

Table 7. Data on characteristics of location alternatives.

Main criteria	Sub criteria	Score		Scoring Rule
		Panjang	Karimunjawa	
Technical Criteria	Wave Height	0.244 m (Monsoon Season) 0.124 m (East Monsoon)	0.113 m (Monsoon Season) 0.575 m (East Monsoon)	Maximum at 30 cm; lower wave height is better
	Sea Depth	-2 s/d -10 m	-3 s/d -20 m	Deeper sea depth is better; minimum at 1 m
	Tidal Wave	1.178 m	1.158 m	Lower tidal wave is better
	Current Speed	0.05 - 0.08 m/s 0.19 m/s (maximum)	0.05 - 0.08 m/s 0.20 m/s (maximum)	Maximum at 1.54 m/s. Lower current speed is preferable
	Wind Speed	3.0 - 7.0 m/s	5.7 - 8.8 m/s	Maximum at 10.7 m/s. Lower wind speed is preferable
	Sedimentation	Small	Small	Smaller sedimentation is better
	Rain Intensity	0.03 - 0.73 mm/hour	0.01 - 0.77 mm/hour	
	Accommodation Facility	Available, in surrounding island	Available in Karimunjawa	Closer accommodation is preferable
Operational Criteria	Cruise Line	No cruise line	Existing cruise within 250 m	The further the seaplane location from cruise line is better
	Obstacle to Cruise	Temporary closed dock within ±308 meter.	Nearby existing dock and fishing port within ±250 meter.	Fewer obstacle is better
	Obstacle to Aerodrome	No	No	Fewer obstacle is better

Main criteria	Sub criteria	Score		Scoring Rule
		Panjang	Karimunjawa	
	Visibility	Medium	Medium	Higher visibility is better
	Air Traffic Interference	Medium	Low	Lower interference is better
Territorial Criteria	Accessibility	Available	Available	Easier accessibility is better
	Land Availability	Sufficient	Sufficient	Bigger available area is better
	Trip Demand	411,432/year	147,523/year	More trip demand is better
	Economy Condition (GDP)	4,598,959.97	235,132.58	Higher GDP is better
	Population	14,049	9,784	Higher population is better
	Tourism Potential	411,432/year	14,7523/year	Higher tourist visit is better
	Distance to The Nearest Airport	0 km (Panjang runway) 53.13 km (Soekarno-Hatta)	15 km (Dewandaru Airport) 130 km (Ahmad Yani Airport)	Closer to existing airport is better
	Distance to the Nearest Healthcare Facilities	13 km (to Regional Hospital) 1.95 km (Community Healthcare Centre)	83 km (to Hospital) 0 km (Community Healthcare Centre)	Closer to healthcare facilities is preferable
	Fuel Availability	Very far from fuel sources	Very close to fuel sources	Closer to fuel sources is preferable
Cost Criteria	Construction Cost	Moderate	Moderate	Lower cost is better
	Mobilization and Demobilization Cost	Moderate	Moderate	Lower cost is better

Table 8. Scores of location alternatives.

Main criteria	Sub criteria	Score	
		Panjang	Karimunjawa
Technical Criteria	Wave Height	10	8
	Sea Depth	10	10
	Tidal Wave	6	6
	Current Speed	4	4
	Wind Speed	4	3
	Sedimentation	8	8
	Rain Intensity	10	10
	Accommodation Facility	7	9
Operational Criteria	Cruise Line	10	3
	Obstacle to Cruise	3	1
	Obstacle to Aerodrome	10	10
	Visibility	5	5
	Air Traffic Interference	6	8
Territorial Criteria	Accessibility	7	8
	Land Availability	5	5
	Trip Demand	10	5
	Economy Condition (GDP)	1	1
	Population	8	5
	Tourism Potential	10	5
	Distance to The Nearest Airport	10	1
	Distance to the Nearest Healthcare Facilities	10	8
	Fuel Availability	2.5	10
Cost Criteria	Construction Cost	5	5
	Mobilization and Demobilization Cost	5	5

Table 9. Final score calculation.

Sub criteria	Weight	Score		Score x Weight	
		Panjang	Karimunjawa	Panjang	Karimunjawa
Wave Height	7%	10	8	0.74	0.59
Sea Depth	2%	10	10	0.17	0.17
Tidal Wave	1%	6	6	0.08	0.08
Current Speed	4%	4	4	0.16	0.16
Wind Speed	7%	4	3	0.27	0.20
Sedimentation	1%	8	8	0.05	0.05
Rain Intensity	2%	10	10	0.17	0.17
Accommodation Facility	2%	7	9	0.17	0.22
Cruise Line	4%	10	3	0.41	0.12
Obstacle to Cruise	3%	3	1	0.09	0.03
Obstacle to Aerodrome	7%	10	10	0.74	0.74
Visibility	14%	5	5	0.71	0.71
Air Traffic Interference	7%	6	8	0.43	0.57
Accessibility	1%	7	8	0.10	0.11
Land Availability	2%	5	5	0.10	0.10
Trip Demand	3%	10	5	0.32	0.16
Economy Condition (GDP)	2%	1	1	0.02	0.02
Population	1%	8	5	0.11	0.07
Tourism Potential	4%	10	5	0.36	0.18
Distance to The Nearest Airport	4%	10	1	0.43	0.04
Distance to the Nearest Healthcare Facilities	3%	10	8	0.34	0.27
Fuel Availability	2%	2.5	10	0.06	0.23
Construction Cost	6%	5	5	0.29	0.29
Mobilization and Demobilization Cost	9%	5	5	0.44	0.44
Total				6.75	5.73

The score shown in Table 8 is not the final score. As calculated in previous section, each criterion has their own weight or proportion to the final score. Final score is obtained from the accumulation of score for each criterion multiply with the weight of each criterion. The result of calculation for the final score is shown in Table 9. The result indicates that Panjang Island has higher score (6.75) than Karimunjawa Island (5.73).

The result shows that Panjang Island has higher final total score. It indicates that Panjang Island should has higher priority to be chosen as the flight test location. Panjang Island is more superior in criteria related to territorial condition, especially on the availability of healthcare facility and distance to the nearest airport. Panjang island, and Seribu Islands in general, is part of Jakarta Special Region Province, the capital city of Indonesia. Its location gives advantages for Panjang Island in term of the availability of various facilities. Panjang Island served by healthcare facilities such as Puskesmas (Community Health Centre) Harapan and Seribu Islands Regional Hospital (RSUD Kepulauan Seribu). Meanwhile, Karimunjawa is quite far from the regional hospital, although it close to the community health centre. The availability of health centre or hospital is important as part of mitigation plan in case of incident, especially for flight test.

Another point that make Panjang Island more preferable is the location of major airport. Panjang Island is relatively close to the major airports such as Soekarno-Hatta International Airport and Halim Perdanakusumah Airport. Panjang Island also have higher yearly trip demand and tourism potential compared to Karimunjawa. As a part of the capital city of Indonesia, most of the islands around Panjang Island is already occupied and some of them have become tourism spots. It gives more potential demand for N219 A in the future, from the tourist trips to the surrounding islands. Panjang Island also has higher population. The residence of Panjang Island and the surrounding islands can be potential market for N219 A. This conditions also places Panjang Islands as a potential location for hub that will connect the surrounding islands with the mainland Java. It is an important factor that need to be considered if the seaplane base will be used to facilitate regular or day-to-day air services in the future.

Cruise line is another factor that give Panjang Island higher point in the selection process. Since there is no active ship dock or port in Panjang Island, there is no cruise nearby the potential seaplane dock location. Therefore, there is lower obstacle surrounding the location. Meanwhile, Karimunjawa has active fishing port and ship dock that is routinely used by the residence and tourist that visit Karimunjawa. It creates more obstacle for the amphibian plane operation.

On the other hand, Karimunjawa Island also have its strong points. Karimunjawa has lower air traffic interference. Its location that quite far from major airports leads to less air traffic route above its airspace. Karimunjawa also has higher score in the availability of fuel station for the flight test. It is because Karimunjawa has Dewandaru Airport, thus they have a regular supply of aviation fuel to the island. Panjang Island has a balance between the requirement that needed for test flight and also the potential for future use to facilitate regular use of seaplane. Therefore, it has higher score than Karimunjawa, and also a preferable candidate for the seaplane base.

Decision making process using AHP is useful for determining the best choice based on criteria because of several advantages including transforming extensive and unstructured problems into a flexible and easy to understand model, solving complex problems through a structured system approach, and considering logical consistency in the assessment used to determine priorities.

4. Conclusions

Various aspects need to be considered to represent different requirements that need to be fulfilled for selecting seaplane base in Indonesia for the test flight and also for operational activity. Four main criteria and 24 sub-criteria are proposed in this study (Table 1) based on in-depth literature review and insight from internal experts. By using analytical hierarchy process (AHP) as the decision-making method, the evaluation on the location candidates shows that Panjang Island has higher score by 6.58 than Karimunjawa by 5.56. The most contrasting aspects between the two location candidates are the distance to the nearest airport and the tourism potential. Future research maybe can input the natural disaster risk and geospatial consideration to get more suitable location, also modification and combination of AHP with other decision making method. The results of this study can be useful for stakeholders in the fields of air and waterborne transportation, supply chain, and also tourism, especially to address the problem of inter-island connectivity and tourism development in Indonesia.

Acknowledgements

The results presented in this manuscript is part of study titled “Study on Selection Criteria for N219A Seaplane Base Location” funded by Indonesia Endowment Fund for Education (LPDP). The authors would also like to thank all the experts that contribute in the survey process.

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