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Spatial Analysis for the suitability of airport locations in the Indonesian National Capital in East Kalimantan

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***Abstract*—The airport is one of the most important places that must be owned by the nation's capital to support transportation, economy, and defense security. Determining the strategic location of an airport requires planning so that the airport can function properly and fully support the nation's capital. With a geographic information system (GIS) we are able to present spatial information and analyze airport development planning parameters including land cover type, disaster vulnerability, existence of a road network, presence of watersheds, land suitability conditions, land slope and air defense points. By using the AHP (Analytic Hierarchy Process) method, the weight value of each parameter is obtained to determine the effect of one parameter on another. The weight of each parameter is 7% land cover, 6% disaster-prone, 17% land, 16% road access, 15% river, 27% land slope, and 12% air defense points. . Then by using the ArcGIS software and the results of the analysis of the coverage of the weights along with the parameters and values of each sub-parameter used, the 5 areas are considered feasible to be used as locations for the construction of a new airport in IKN. archipelago. 1. Closed area. Waru, North Penajam Paser Regency with an area of 543.05 hectares, 27 km from IKN; 2.16 km located in Sepaku with an area of approximately 311.11 ha; The distance between the 3rd location and IKN is 12 km and the area covered is approximately 251.98 hectares and is located in Penajam and Sepaku; and rank 4 and 5 are in Sepaku with an area of 272.91 ha and 67.78 ha, within 16.4 km and 19.6 km.**

Keywords—Airport Location; GIS; AHP

I. INTRODUCTION

A country with an area coverage that has a number of residents and national resources as well as certain characteristics are the state or national assets that must be secured to guarantee the realization of state welfare. In Indonesia the defense system used is SISHANKAMRATA or the universal people's defense and security system based on Pancasila and the 1945 Constitution. The universal defense system involves all national assets with the TNI as the main component, trained people as the reserve component and other national resources such as academics, institutions, private sector and so on as the supporting component.

Safeguarding national assets is a joint obligation of all Indonesian people which is controlled by the government by involving the people and utilizing other national resources in the implementation of defense. The existence of the state capital as a national asset is the center of government of a country for policy makers in formulating regulations and legislation that can have a strategic impact on all its citizens.

Kamus Besar Bahasa Indonesia (The Great Dictionary of the Indonesian Language) states the meaning of the capital city as the seat of the central government of a country[1]. The New Law of the Republic of Indonesia No. 3 of 2022 [2] gave mandate for Indonesia Armed Forces or TNI to design the concept of a new defense system that must be formed to secure the territory of the new State Capital, namely the Nusantara.. The implementation of the policy of moving the Nusantara IKN will not be separated from the defense and security factors of the capital for the sake of upholding national defense.

The IKN Nusantara, which is targeted to be the Administrative Center of theGovernment, is located in the North Penajam Paser and Kutai Kartanegara Regencies in East Kalimantan Province. Based on the results of the study and also a field survey conducted by the Geological Agency of the Ministry of Energy and Mineral Resources of the Republic of Indonesia in 2019[3], it was shown that geographically the IKN Nusantara area, especially in the Central Government Area, hasa hilly morphology with some areas having steep contours and followed by the river density is quite high. The analysis of the carrying capacity of the environment shows that water problems in the IKN area need to be considered properly, both in the management of groundwater and surface water. The content of mineral resources below the surface has its own level of vulnerability that can affect development in the IKN area, which is feared to cause a disaster as a whole for regional development.

Seeing the condition of the territory of Indonesia which is an archipelagic country, IKN Nusantara must be connected with other regions regularly using all forms of transportation modes, especially sea or air

transportation. This condition requires an airport that can be directly accessed by the public and government officials who are at IKN without having to travel long distances overland. In addition, the existence of this airport can also support the economy and improve logistics distribution channels, the defense and security of the IKN area can also be guaranteed from the incomingforeign threats. Based on the Law of the Republic of Indonesia No. 34 of 2004[4] concerning the Indonesian National Army in Article 7 Paragraph 2 states that one of the main tasks of the TNI for the mission of Military Operations Other than War is to protect the President and Vice President and their families. This requires the existence of a VVIP airport at IKN Nusantara as a government effort to secure VVIP and facilitate the mobilization of the VVIP. One of the technologies that can determine the feasibility of the VVIP airport construction site is to use GIS technology with various analysis modules, so that the exact and accurate position will be obtained.

According to article 1 of the Republic of Indonesia Law no. 1/2009 [5] regarding flights, airports are divided into two classifications according to their services, namely domestic airports, and international airports. In number 36 in the same article, a domestic airport means that the airport serves passengers using air transportation services with flight routes only within the country. While at number 37, international airports have a role as a gateway for a country in serving international air transportation services. The main difference from this airport to domestic airports is the existence of immigration facilities (customs and excise) for passengers and goods carried at the time of departure and arrival.

Putri [6] researched the determination and selection of airport locations in Kendal Regency using GIS. The analytical method and technique used is the AHP (Analytical Hierarchy Process) method. The results of the analysis carried out show that the influencing weight for each parameter.

Ramadhan [7] examined the determination of the location of the airport in Lamongan Regency. The analytical methods and techniques used are Delphi, AHP, and Overlay analysis methods using GIS. The results of the analysis using the Delphi method show several criteria that need to be considered in determining the location of the airport in Lamongan Regency, namely technical area development, technical development, environmental aspects, and social aspects.

Sasongko [8] investigated the use of remote sensing and GIS to determine priority locations for an aerosport aircraft emergency landing in some flying areas in the Bantul Regency. The analytical methods and techniques used are visual interpretation of Quickbird imagery and information intercepts from the RBI (Rupa Bumi Indonesia) map. The parameters used are the slope parameters, land use, location size, location shape, and obstacles around the location. The results of the analysis show that land selection can be determined by spatial modeling based on these 5 parameters. There are 21 emergency landing locations according to predetermined parameters, namely 2 locations in the Sleman Regency area, 5 locations in the Kulonprogo Regency area and 14 locations in the Bantul Regency area.

Erkan and Elsharida [9] researched the selection of airport locations in Libya. Methods and analysis techniques using GIS to determine the precise location, namely distance from residential areas, land cover, rainfall, temperature, clarity index, wind speed, atmospheric pressure, relative humidity, elevation in above sea level, land slope, soil characteristics, distance from roads, distance from watercourses, proximity to roads, proximity to water sources, proximity to power lines, proximity to communication stations, land use, distance from wetlands and wildlife, distance from oil wells and fields, distance from refineries and industrial plants, distance from oil and gas lines and proximity to city center

Ertunc and Tayfun [10] researched the selection of airport locations in Bayburt and Gumushane Provinces, Turkey. The analytical methods and techniques used are AHP and MCDM (Multi-Criteria Decision Making) methods. The results of the analysis and map overlay using GIS show the village of Salyazı, Kose district, Gumushane, the location where the actual airport construction began is the location that was determined as the most suitable place in this study. This shows that the methods and analyzes used in this study are not accurate enough.

Another research by Utomo, et al. [11] regarding the analysis of Geospatial Intelligence in supporting the interests of State Defense conduct research It uses a GEOINT approach that combines remote sensing, GIS, and cartography. The study area is limited to the mountainous areas of Poso and Parigi Mouton provinces in Central Sulawesi. The parameters of this study are limited to his four parameters, which are considered to be the most relevant factors for analyzing mountain terrorist locations: water sources, hillsides, settlements and land cover.

The characteristic of AHP methods is the ability to solve decision support challenge with combine knowledge, experience, individual viewpoints, and foresights logically (Zuhra, 2022) [18]. The result from AHP method, will provide a coherent decision model from quantifying result of opinion and the value could be used for multicriteria decision analysis in GIS [13]. The conclusion of this study is that The development of intelligence information technology to support national defense interests using GEOINT can be used as a first analysis in identifying potential terrorist hideouts. Geographic information systems can be used as initial analysis for locating potential terrorists in mountainous areas and can be used as a reference for military operations to combat terrorism and improve national defense and security systems.

II. METHODE

A. Research Methods

This study was conducted using geospatial intelligence analysis approaches in combination with remote sensing science, geographic information systems, and global mapping to acquire and process data. When using geospatial-based intelligence analysis approaches, the primary use of geographic data is special functionality. The geospatial data used is data that includes location information and the shape of the earth's surface and the distribution of natural phenomena, and is used to determine locations that can be used to build government airports and air defense bases in capital areas. Nusantara.

This study uses decision-making methods based on multi- criteria or multi-criteria decision analysis to provide desired results based on the parameters used to analyze existing data. The parameters and data used in this study are superimposed to obtain the desired model from these different parameters. The parameters used have their characteristic values, which are considered in the research analysis.

B. Research Area

The location of this research is in the area of the National Capital of the Nusantara which is in North Penajam Paser Regency and Kutai Kartanegara Regency, East Kalimantan Province. The area around these two areas was chosen

because the infrastructure that will be built in the area that will result from this research is an airport facility that will be used for the mobility of government officials in carrying out their duties, as well as a base for air defense points and terminals in the IKN Nusantara area.

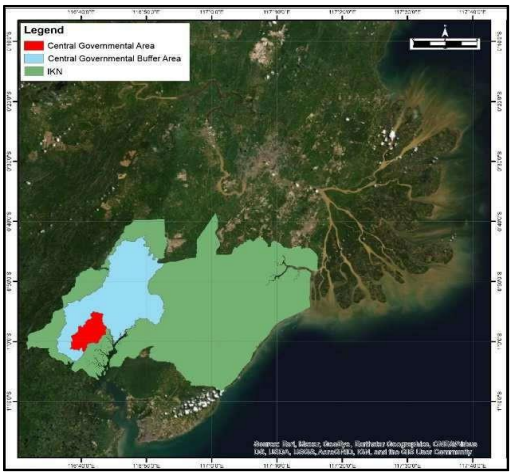

Fig. 1. Map of the National Capital Region

C. Data

The Data used in this study is mainly in spatial data domain. All of the data gathered from available opensource data. in total seven variable or factor there are land cover, disaster vulnerability, land suitability, road network, land slope, river area, and air defense area, were determined for this study to detemine the proper area for airport developmentin Capital Area.

D. Research Parameters

The parameters used in processing research data are as follows;

The land cover parameter is one of the important parameters related to the spatial information used in determining the location of the airport. The location of land that is possible to be used as an airport development is a remote location and there is no residential area. Disaster vulnerability parameter is a parameter related to disaster risk index information in an area. In this case, the location that has the most appropriate assessment for the selection of the airport location is the area that has the lowest disaster risk index, so that during the operation of the airport there will beminimal disasters.

The land suitability parameter is a parameter that measures the relationship between the supporting conditions of the existing land used for airport construction. Land use suitability is the analysis of the existing environmental feasibility of airport development plans, whether the land is paddy fields, forests, mining areas or protected areas. Road network parameters are parameters that measure the relationship between the location of the airport and the distance to existing roads. Road access is one of the necessary infrastructures for an airport, as the airport must of course be easily accessible. The use of river parameters in this study was used to search for watersheds that could pose a potential threat of flood disasters around the airport site. In addition the selection of airport construction sites around IKN is expected to be in stable land conditions considering that most of the land in the Kalimantan area is peat land.

The land slope parameter is related to the topography of the area in planning the runway of an airport. Basuki [12] suggested a relationship between the slope of the land and the addition of the length of the runway where the slope of the runway up requires a longer runway than the flat or downhill one. The distance between the Air Defense Point and the Airport Runway is one of the main factors related to VVIP safety.

TABLE I. PARAMETER VALUES FOR ANALYSIS

Suitability	Value	Parameters						
		Land Cover	Disaster Vulnerability	Land Suitability	Road Network	River	Land Slope	Air Defense Area
		Type	Index Value	Index Value	Distance	Type	Slope Degree	Type
Not Suitable	1	Settlement	High Index	Low Bearing Capacity	1 Km	River Area	High	Point Area
Less Suitable	2	Forest	Medium Index	Medium Bearing Capacity	2.5 Km	Land Area	Medium	Terminal Area
Suitable	3	Farm and DryField	Low Index	High Bearing Capacity	5 Km		Low	
Very Suitable	4	Agriculture			8 Km			

A. *Research Design and Flow*

This research will use a combined weighting method which will be analyzed based on the appropriate spatial parameters for airport facilities to be built following the applicable regulations in Indonesia. By using the SMCA (Spatial Multi-Criteria Analysis) method, it is possible to combine and compile spatial data based on the phenomena that occur.

According to Siqueira et al. (2017) [15] in Supriyadi and Manessa (2020) [16] there are 5 stages in the implementation of SMCA, the first and second are data acquisition from various sources which are then normalized or pre-processed on each data before being analyzed separately. together.

In the third stage, after all the data to be used have been obtained, normalized, and determined to calculate the magnitude of the influence of a parameter on the parameter. At this stage, the Analytic Hierarchy Process (AHP) is used to determine the magnitude of the influence of the parameters used (saaty, 1989) [13]. The use of AHP in SMCA in several studies is seen to give good results. In assessing the relationship between each parameter, the researcher conducted a literature study and conducted interviews and discussions with resource persons from the air defense expert team. Calculations for each parameter follow the scale compiled by Saaty [13] where a value of 1 indicates the less influence of the parameter to 9 which indicates the very importance of the parameter.

Fourth, the sensitivity analysis of each parameter is carried out to test how sensitive the percentage of parameters in the airport location determination model is using a consistency index [13]. later if the value of consistency index will be less than 10% then the calculations performed on the pairwise matrix can be accepted as in Ghorbanzadeh et. al. [14].

In the final stage, a weighted overlay is performed on all spatial data that has been weighted on each sub-parameter and calculates the percentage effect of each parameter using

AHP. This stage is the core of this research which will produce new information related to areas that are suitable for establishing airports. empirically, the weighting performed on the software using this equation as in;

$$V(xi) = \sum w_j v_j(x_i) = \sum w_j v_{ij} \quad (1)$$

Wj is the weight of the normalized parameters, as in this study is the weight of 1 - 10. The weight of each parameter is normalized to a percentage that is proportional to 100. *Vj*(*xi*) is the value of each *j* attribute, while *Xi* = (*xi1*, *xx2*, …, *xin*) and *rij* is the value transformed to the same comparison scale, 1 to 5 in this study. The weight of each parameter indicates the relative importance of the parameter. The best alternative is to find the maximum value of *V(xi)* of i = 1, 2, 3, 4, 5. This equation is the algorithm for weight analysis for the parameters to get novel information.

III. RESULT

A. *Results of Quantitative Data Analysis*

By using Method AHP then the data obtained from the survey results are then processed and presented in a matrix table 8. From the table 8, we can analyze the sensitivity value of each of the existing parameters so that we can get the weight value of each parameter that has the most influence (table II). Based on the AHP method, the Consistency Ratio Value is 1.32%. According to Banica (2017) [17] in Supriyadi and Manessa (2020) [16] this value is considered safe and far from the 10% threshold value. The results of the pairwise analysis on each parameter produce a percentage value as shown in the table below.

TABLE II. AHP MATRIX

	Preferred Over						
	Land Cover	Disaster vulnerability	Land Suitability	Road Network	River	Land Slope	Air Defense Area
Land Cover	1	0.2	0.142857	5	1	0.142857	7
Disaster Vulnerability	5	1	0.5	9	7	0.2	7
Land Suitability	7	2	1	7	9	1	5
Road Network	0.2	0.11111	0.142857	1	1	0.111111	1
River	1	0.142857	0.111111	1	1	0.142857	1
Land Slope	7	5	1	9	7	1	9
Air Defense Area	0.14	0.14	0.2	1	1	0.11	1
Sum	21.34	8.6	3.1	33	27	2.71	31

TABLE III. AHP SENSITIVTY ANALYSIS

Normalized Over								
	Land Cover	Disaster Vulnerability	Land Suitability	Road Network	River	Land Slope	Air Defense Area	Average
Land Cover	0.047	0.023	0.046	0.152	0.037	0.053	0.226	0.083
Disaster Vulnerability	0.234	0.116	0.161	0.273	0.259	0.074	0.226	0.192
Land Suitability	0.328	0.233	0.323	0.212	0.333	0.369	0.161	0.280
Road Network	0.009	0.013	0.046	0.030	0.037	0.041	0.032	0.030
River	0.047	0.017	0.036	0.030	0.037	0.053	0.032	0.036
Land Slope	0.328	0.582	0.323	0.273	0.259	0.369	0.290	0.346
Air Defense Area	0.007	0.017	0.065	0.030	0.037	0.041	0.032	0.033
Sum	1	1	1	1	1	1	1	1

Based on the AHP method, the Consistency Ratio Value was 1.32%. According to Banica (2017) in Supriyadi and Manessa (2020) this value was considered safe and far from the 10% threshold value. The results of the pairwise analysis on each parameter produced a percentage value as shown in the table below.

B. Land Cover

By using GIS, we can see land cover maps that were suitable for airport locations marked in green and heading to red for land cover areas that were not suitable for airport construction. From the results obtained, unsuitable areas were around the river flow and there were still several other locations. When viewed in general, the locations that were classified as Very Suitable and Suitable for airport construction in the IKN area were still very widely available.

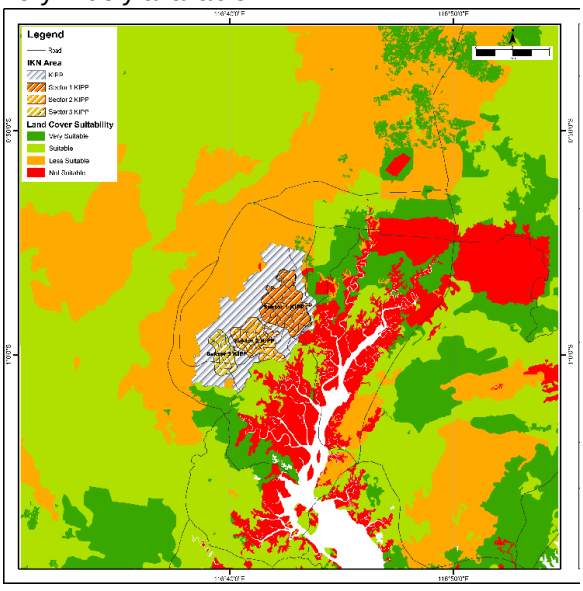

Figure 2. Map of Land Cover

C. Disaster Vulnerability

From the results of the processing, we can see that the disaster vulnerability in the area around the IKN that was suitable for establishing an airport is shown in green and those that were not were shown in red. So that the areas with the least disaster can be seen.

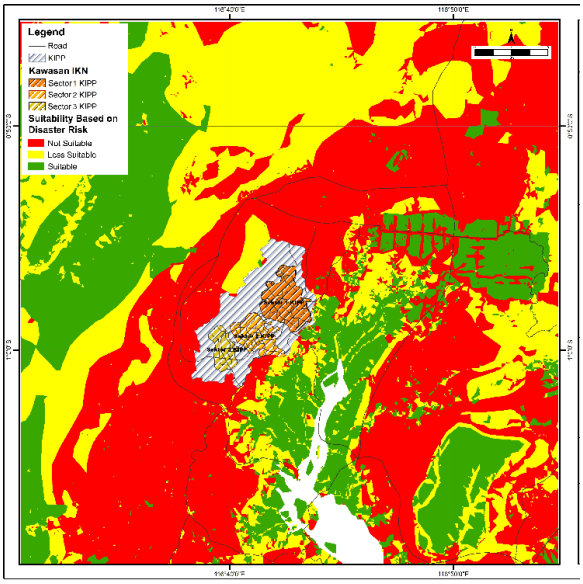

Figure 3. Map of Disaster Vulnerability

D. Land Suitability

From the processing results, the support for land conditions for airport construction can be seen. We can see that green represents areas that provide high support and red represents areas with low support.

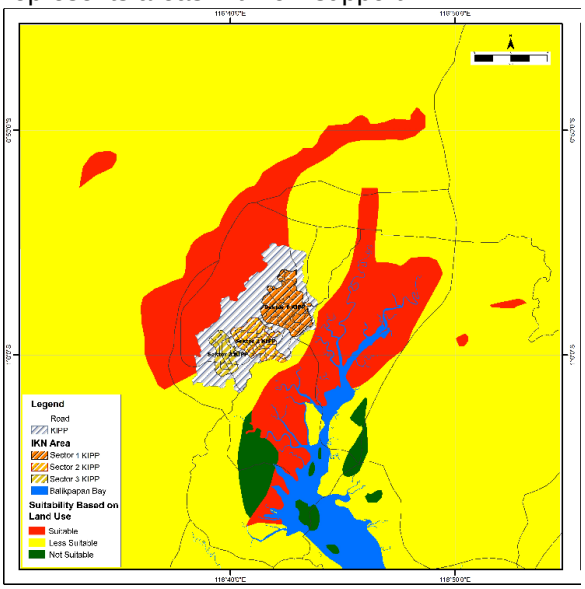

Figure 4. Map of Land Suitability

E. Road Network

In the construction of the airport for IKN Nusantara, the road network also provided an assessment to maintain flight safety in residential areas of local residents. Based on the analysis of the road network on land suitability for airport construction, the green area provided security information for airport construction.

This road network map was the result of a buffer process from a map of the entire road network available around the IKN Nusantara area with a buffer coverage distance of 1 km to 8 km, as shown in the image below.

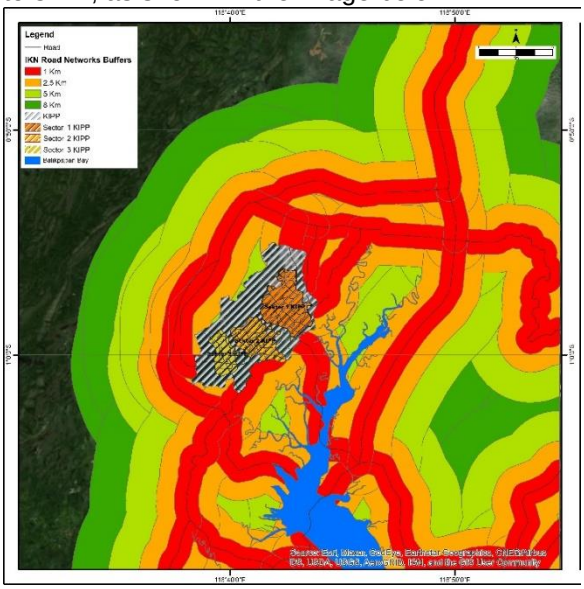

Figure 5. Map of Road Network

F. River

Based on the results of the land suitability analysis for airport construction around IKN Nusantara towards the watershed area, it showed that almost all of the land can be used as a location for airport construction. This map was generated by using an overlay process from river flow map data and topographic maps. The results of this method can be seen by the image of the River Basin Map below.

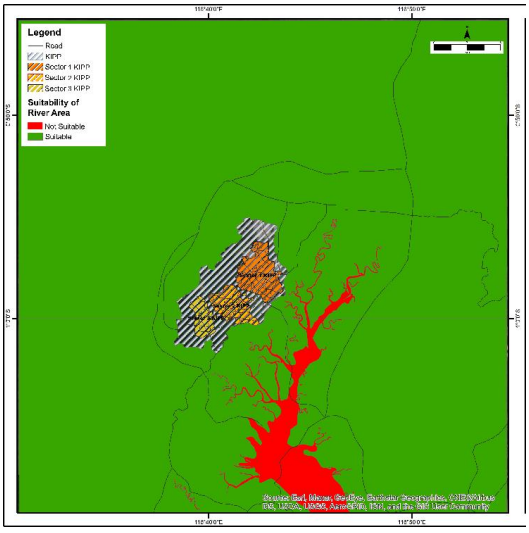

Figure 6. Map of River

G. Land Slope

Based on the results of data processing, the parameters of the land slope can be seen in the Land Slope Map below. The red indicator showed a high level of slope, the yellow indicator showed a moderate level of slope, while the green indicator showed a low level of slope. Therefore, from the map below it can be seen that areas with low slopes can be alternative locations for VVIP airport construction.

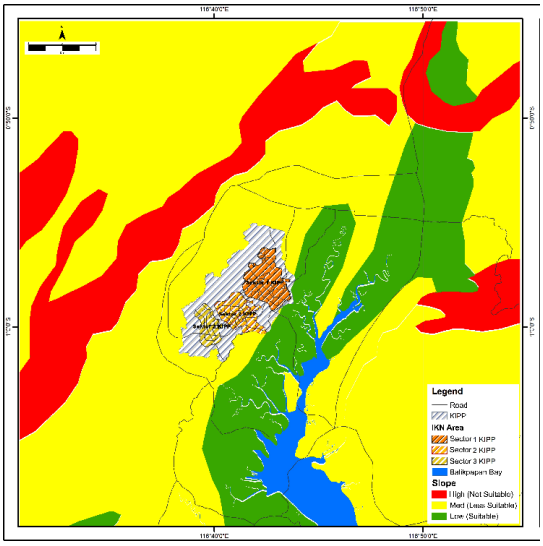

Figure 7. Map of Land Slope

H. Air Defense Area

The results of the air defense area parameter analysis were shown on the Air Defense Area Map below. The green indicator was the Air Defense radius with a radius of <18 Km which can be used as an alternative location for the VVIP airport construction.

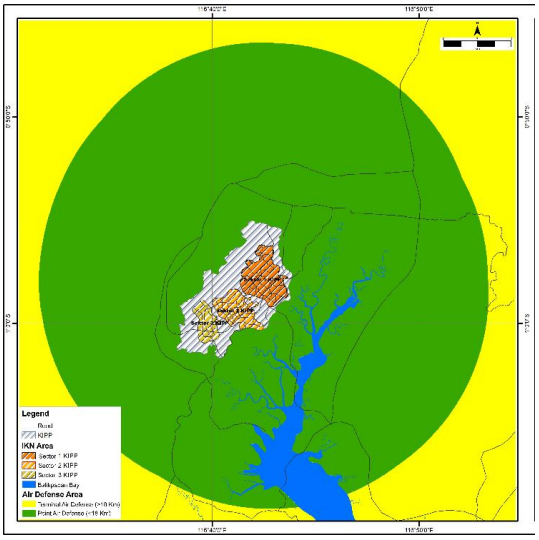

Figure 8. Map of Air Defense Area

IV. DISCUSSION

A. Alternative Areas for Airport Development

The results of the AHP ranking are then used as the basis for calculating the percentage of each criterion that shows the magnitude of its influence in decision making by utilizing weighting analysis processed in ArcGIS, in order to help the ArcGIS tools, find the location that is considered appropriate as an alternative recommendation for the construction of a new airport at IKN Nusantara.

Based on the seven criteria land slope is the criterion that has the greatest influence with a percentage of 27%, then soil bearing capacity (17%) and road access (16%). Meanwhile, the river and air defense areas have an influence that can be said to be equivalent to soil bearing capacity and road access, because the differences in the percentage values is not that far, with 15% and 12% respectively. While, land cover and disaster-prone have an effect of 7% and 6%. The percentages of each of criteria that have influence the decision making to determine the location of the airport using weighting analysis in ArcGIS,

Based on the weighting overlay analysis carried out using ArcGIS software and following the parameters and values of each sub-parameter used, there are 5 areas (Red Boxes) that are considered suitable to be used as locations for the construction of a new airport in the IKN Nusantara area for transportation purposes and support airspace defense.

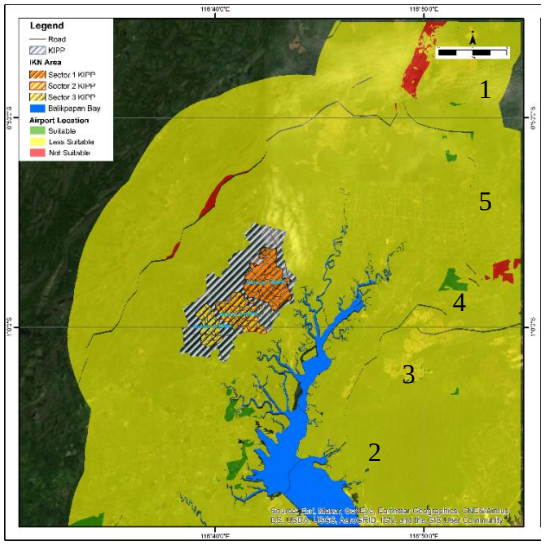

Figure 9. Map of Alternative Areas for Airport Development

Table IV. Alternative Areas for Airport Development

AIRPORT	AREA OF COVERAGE (Ha)	DISTANCE WITH IKN (km)	LOCATION OF AREA (District)
location 1	543.05	27.06	Waru
location 2	311.11	16.09	Penajam
location 3	251.98	11.92	Penajam dan Sepaku
location 4	272.91	16.45	Sepaku
location 5	67.78	19.58	Sepaku

B. Recommended Runway Direction based on wind data

The direction of the runway is also one of the things to consider in airport development planning in order to improve the safety of flight activities. Runway direction is determined based on wind conditions in an area obtained from observations. In Indonesia, wind data can be obtained by conducting observations independently or by collaborating with government agencies or universities. In planning for airport development in the IKN area, observations of wind conditions were not carried out, therefore the wind data used was taken from the nearest Meteorological Station, namely the Sam Sepinggan Meteorological Station, Balikpapan from 1991 to 2020.

From the wind data, the dominant wind direction comes from North - South depending on the month and in the transition season the wind pattern is somewhat even but still shows the dominant wind direction is from North - South. Therefore, the recommended runway direction is the North - South direction

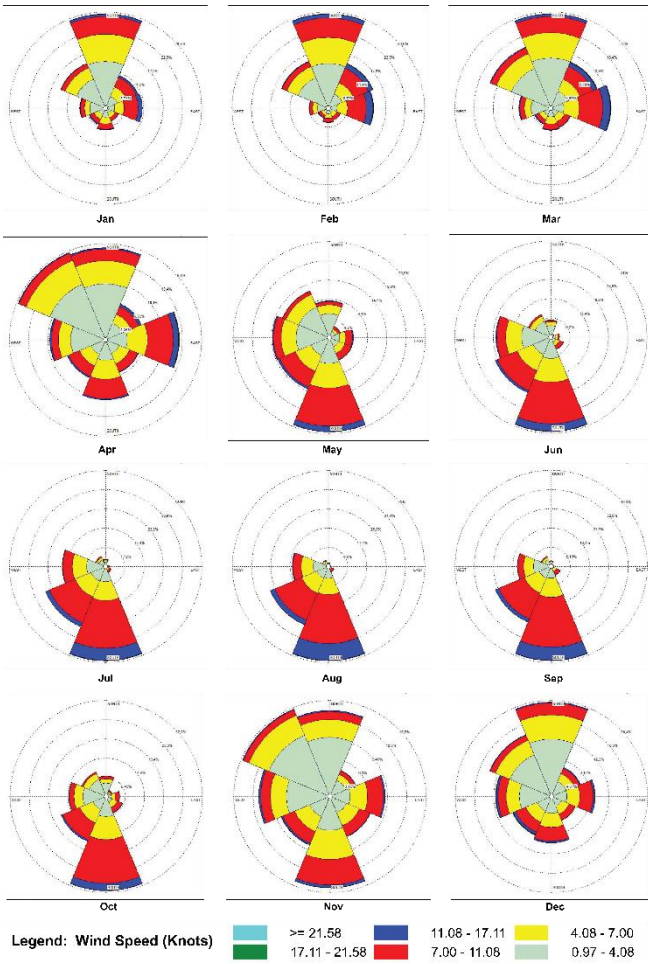

Figure 10. Chart of 30 year monthly wind data for SAMS station, Sepinggan Balikpapan

V. CONCLUSION

Based on the analysis of determining the location of the airport in the IKN Nusantara area using the Geographic Information System and the Analytical Hierarchy Process (AHP) method, it was found that 5 locations were considered suitable to be used as locations for the construction of a new airport to support air transportation and air defense areas in IKN. The parameters used in this study include; Land Cover, Land Slope, Road Network, Location of the River, Disaster Vulnerability, Soil bearing capacity, Air Defense Area. As an additional suggestion in this study, by using the dominant wind direction data in the East Kalimantan region, especially from around the Balikpapan City area, the right direction of runway construction will be obtained in accordance with applicable aviation regulations.

Location 1 has the largest area compared to other locations but the distance from location 1 is farthest from other areas. Locations 2 and 4 have almost the same distance but the area of location 2 is wider than location 4. Location 5 has the smallest area and the area is too small for an airport to be built so that location 5 is the location that is obtained with the smallest priority. So, the most suitable location to build an airport is location 3 which has the closest distance and sufficient area to build an airport. And for the second election priority, there is location 2 seen from the closest distance to 2 and the area is wider than location 3.

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