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Spaceport Site Selection with Analytical Hierarchy Process Decision Making

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Abstract

Objectives: To determine the spaceport location, and identify the important factors in the selection of spaceport in Indonesia and methods to be used in site selection. **Methods/Statistical Analysis:** Analytical Hierarchy Process (AHP) is used to get the best priority location based on various criteria's. **Findings:** The weighting of criteria; Biak is the first choice alternative, the second alternative is Morotai, the third is Pemeungpeuk and the fourth is Enggano. **Application/ Improvements:** Spaceport selection is important to improve the mastery of high technology in a country.

Keywords: Analytical Hierarchy Process, Operations Management, Spaceport, Site Selection

1. Introduction

Indonesia is a developing country trying to achieve independence in the field of space technology. In legislation of the Republic of Indonesia in 2013 on space technology explained that the space technology will be developed in Indonesia which include: (i) Research and development of rocket technology (ii) The control and development of satellite technology (iii) The control and aeronautics technology development. The development of self-reliance in science and space technology must have the requirements and support facilities in the accomplishment. Supporting facilities in order to develop space technology is either availability spaceport as the test results of the research probe or sounding rockets as launch vehicle and satellite launch location for the research that is being developed.

The need for a spaceport as a facility to support the development of space technology needs to consider many factors and the various disciplines of planning. Given its function as a space launch vehicle that is prone to failure and have a high risk and a considerable impact on the environment in the event of failure, it would require careful consideration in site selection spaceport.

The purpose of this study is to get the best priority for locations of spaceport in Indonesia based on several criteria that becomes barometer of success spaceport in accordance with space technology development in Indonesia.

The aim of this research is to determine the spaceport location, identifying the important factors in the selection spaceport and methods to be used in site selection spaceport in Indonesia. The literature review tries to explain some of the research on site selection, the requirement for a spaceport and methodology for site selection.

The success of a project is also influenced by the choice of location so that the choice of location is a strategic decision-making process at the beginning of a Prospect[1]. Required different disciplines and different points of view to get the right location.[2] Aspects to be considered in determining the priority locations as diverse alternative makes site selection process becomes very complex[3]. The complexity of each of the different projects as well as site

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selection spaceport. Uncertainties exist in a project will come from various aspects[4]. In the selection of spaceport locations in Indonesia, aspects of development launch vehicle technology, satellites and aerospace as well as government policies can cause such uncertainty.

Previous research in choosing locations in various countries for various interests, among others, is the selection of a shipyard in Turkey[5], a military base in the United States[6], an astronomical observatory in Turkey[3]. Previous research explains the disaster management center in Turkey[2]. Research for launch site for satellite launches polar orbit in the United States[7], research in a nuclear power plant in Egypt[8], the fire station in Nepal[9], disposal of hazardous waste in Turkey[10], radioactive waste in Korea[11] and biogas plant in Denmark[12].

The main objective of the research in the selection of this location includes: minimizing, distance, time, operating costs, cost of routine, the number of facilities required, by maximizing the responsibility and servicing[13].

Spaceport site selection has the goal of getting the best location by considering factors of key success in operating a spaceport. By minimizing the distance and time to reach orbit, reducing the possibility of weather conditions and natural losses and improve service testing, boost the security level of the testing process and responsibility spaceport. Identification of factors that must be considered as the key to operational success of a spaceport becomes the focus of this research.

As the supporting facilities in mastering space technology, spaceport should have several major facilities. In the technical operation, there are 12 modules facilities should be owned by spaceport[14]. The must-have facilities include:

–*payload/cargo processing*
–*traffic/flight control*
–*launch*
–*landing/recovery*
–*vehicle turn around*
–*Vehicle assembly/ integration*
–*Vehicle depot maintenance*
–*Spaceport support Infrastructure*
–*Concept-unique logistic*
–*Transportation system operations planning and management*
–*Expendable element*
–*Community infrastructure*

In addition to the facilities should be owned by a spaceport, there are general requirements that must be owned by spaceport locations[15]:

- Approaching the Equator to optimize the performance of the launch vehicle to reach orbit with less fuel as well as the amount of greater cargo.
- The beach area to avoid endangering life, public facilities and relations with other countries.
- Adjacent to the military base as an object vital for the country as it relates to the military needs of a country.
- Can be used for several types of launch azimuth angle

Location spaceport must consider the safety factor. A beach or desert region is selected for spaceport locations in several countries. The sea and the desert are used as a buffer in case of an explosion. Explosion launch vehicle or space vehicle that may occur will be very dangerous for human safety and the environment, failures that occur on the surface of the ocean or desert will reduce the risk of loss or accident that would cause casualties[16].

Transport management is needed in operational spaceport. Ease spaceport to the site by land, sea or air into the factors is considered. Flight Tracks of space vehicle or launch vehicle heading back to the spaceport also becomes a focus of management transportation when spaceport has functioned commercially[17].

The previous study that discusses the key to success and factors in the operational spaceport is as follows; Infrastructure spaceport[18], the cost factor, infrastructure, logistics, flight track, types of orbits[7], the development strategy of spaceport[19], supporting facilities of spaceport [20], the type of spaceport in the world[21], the measurement of spaceport performance[22], operational design[23], development of the spaceport on economic factor[24], the historical development of the spaceport and the influence[25], infrastructure, the environment and the tourism industry of spaceport[26], spaceport Supply chain logistic[27], air traffic[28], the design of safety[29], industrial development of spaceport[15], Master plan of spaceport[30], meteorology[31], the possibility of disaster[32] and the potential of lightning in the spaceport location[33].

Success criteria and factors is existing in the operational spaceport. In the event of diverse and involving many disciplines are complex. The choice of location spaceport is certainly not easy because so many criteria that must be considered. Decision-making which location will be selected requires careful consideration. To avoid losses that might occur because of errors in decisions determining the location due to the many factors that influence the decision required scientific method that can help in the decision making process[5].

Analytic Hierarchy Process (AHP) is one of many methods used by decision makers and researchers. This method focuses on the weighting of the criteria to get the best alternative[34]. AHP is a scientific method that helps decision-making based on a variety of criteria or called by the Multi-Criteria Decision Making (MCDM).

The use of this method in the real world has been applied in several fields ranging from healthcare industry[35], Airlines industry[36], manufacturing industry[37]. The use of AHP for site selection has been done in previous studies. It is ranging from a general location as well as the location of shopping centers in Turkey[38], the hospital in Taiwan[39] and parking location in Tehran[40].

Special locations such as the disposal of radioactive waste active in Korea[11], selection of the disaster management center in Turkey[2], Location for astronomical observatory In Turkey[3], nuclear power plants in Egypt[8], nuclear power plant in Turkey[41], fire station in Nepal[9], Airport In Taiwan[42].

This method uses the opinions of experts in the process of weighting the criteria that will be used as the determination of decision-making. Criteria can be set based on the study of literature and using expert opinion[34].

Determination of criteria in this study uses literature and expert opinion. Criteria of the results of the literature study then proposed to the experts to get the acceptable criteria as criteria in the selection spaceport in Indonesia. Rate determination of criteria can be accepted and it is unable to use Likert scale[43].

2. Methods

This study uses AHP in determining priorities in accordance with the location selection decision-making steps.

By formulating, the main objective is the selection spaceport locations in Indonesia. Determination of criteria and sub-criteria and alternative locations are based on literature study and interviews of experts in space technology in Indonesia.

Weighting criteria and sub-criteria obtained with the help of an expert opinion from space technology in Indonesia that will eventually result in the best location selection decision as an alternative option spaceport in Indonesia based on the hierarchy of criteria, sub-criteria and alternatives that have been determined.

In addition to the best alternative location as the primary goal in this study was also obtained data on what criteria will become the focus for experts and decision makers in the process of site selection spaceport in Indonesia.

3. Results and Analysis

The main criteria are divided into five topics, they are technical operation, economic, safety, and environmental Meteorology. Determination of the main criteria is based on the results of a study of the literature on the importance of each criterion for the success of a spaceport. Apart from the study of literature, the determination of these criteria also includes space technology experts and decision-makers in Indonesia about the site selection spaceport in Indonesia. Using questionnaire and interview process based on a Likert scale of 10 of experts and decision makers in site selection spaceport in Indonesia are produced 12 sub-criteria accepted as factors that influence the choice of location spaceport in Indonesia. Calculation results with geo mean is shown in Table 1.

Table 1. Accepted criteria for Site selection spaceport in Indonesia

No	*Sub criteria*	*Score*	*Yes /No*
1	*Launch Vehicles*	4,36	Yes
2	Type Orbit	4,89	Yes
3	Launch Pad	4,41	Yes
4	Transportation	4,78	Yes
5	Market	4,04	Yes
6	Infrastructure	4,68	Yes
7	Population density	4,44	Yes
8	Flight Trajectory	4,89	Yes
9	Weather	4,35	Yes
10	Potential Disaster	4,44	Yes
11	Geographical location	4,35	Yes
12	Tourism industry	3,72	Yes

Determination of alternative locations based on interviews of experts in space technology in Indonesia and the assessment of the possible options in select locations, which would be alternative spaceport locations, include Biak, Enggano, Morotai and Pameungpeuk.

This study tries to evaluate and make a selection of priorities of the four alternative locations spaceport in Indonesia using five main criteria and 12 sub-criteria that describe the opinion of experts and decision-makers regarding site selection spaceport in Indonesia by hierarchy that can be seen in Figure 1.

Results of pairwise comparisons by considering the criteria, sub-criteria and the alternative location within a hierarchy is to get a priority choice of alternatives is processed using expert choice 11.

According to the matrix of pairwise comparisons among criteria in Figure 2, the criteria of safety have a very strong interest compared to other criteria. Technical and operational criteria are more important from an economic and a bit more important than meteorology and the environment.

By synthesizing the entire assessment of experts based on the matrix of pairwise comparison of criteria, sub-criteria and alternatives will be obtained weighting of each criteria and sub-criteria to obtain the best alternative to the purpose of this research is the best location for a space-

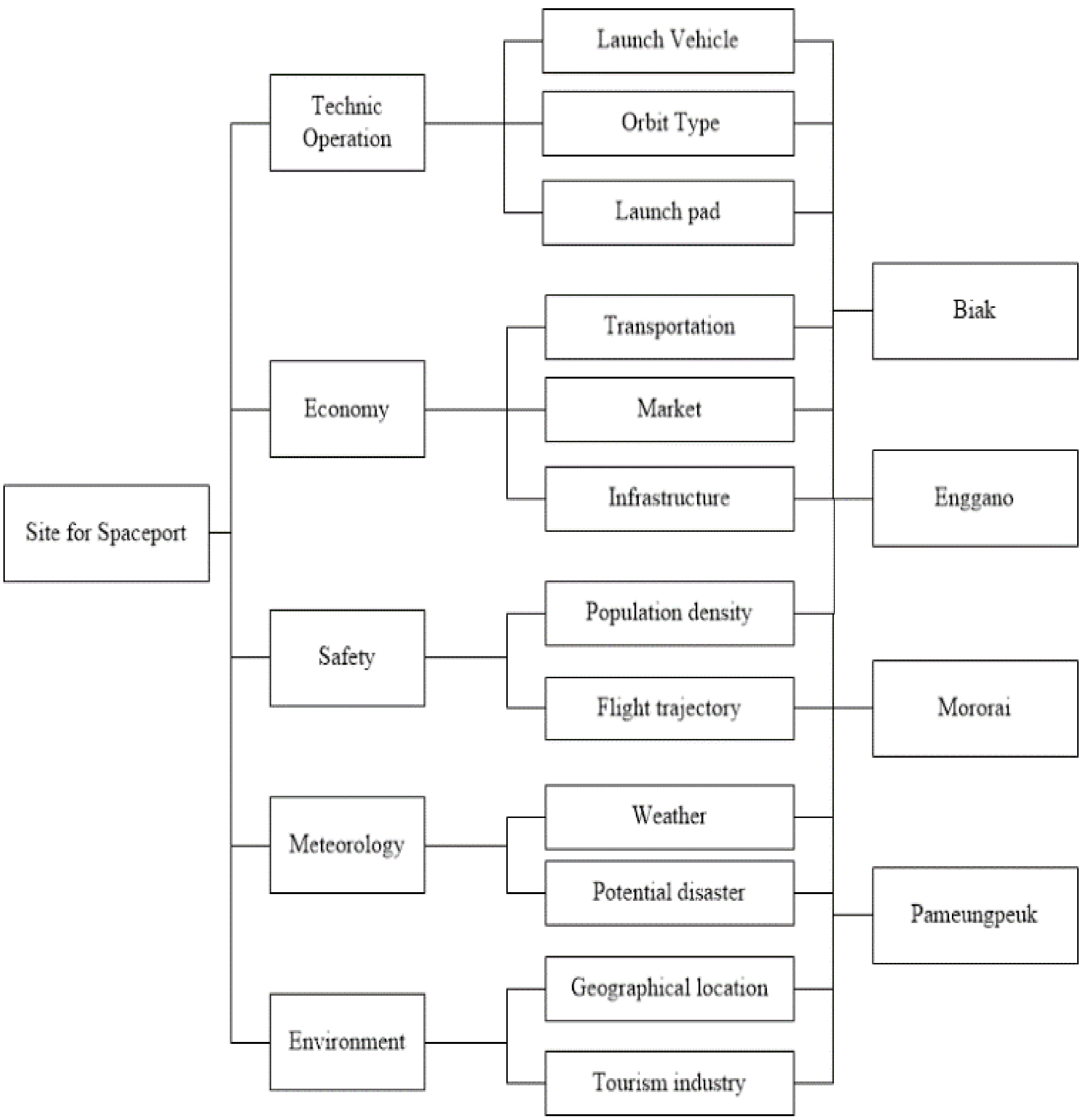
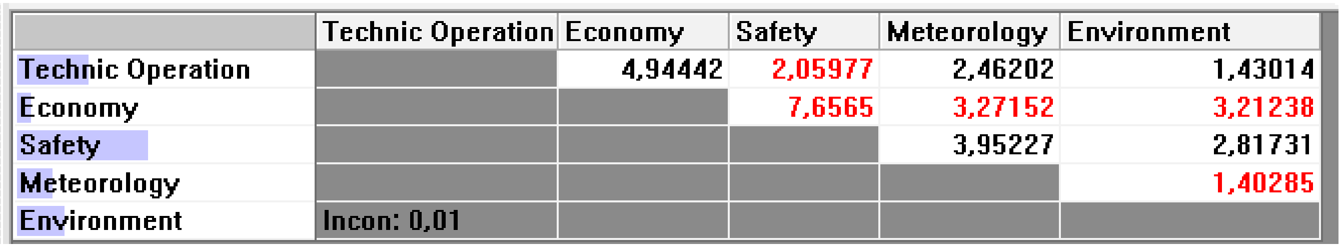


Figure 1. Structure hierarchy of spaceport in Indonesia.



	Technic Operation	Economy	Safety	Meteorology	Environment
Technic Operation		4,94442	2,05977	2,46202	1,43014
Economy			7,6565	3,27152	3,21238
Safety				3,95227	2,81731
Meteorology					1,40285
Environment	Incon: 0,01				

Figure 2. Pairwise comparison main criteria.

port in Indonesia. Checking the ratio of inconsistency made after the entire process of pairwise comparisons is completed. The ratio of inconsistency should be appreciating less than 0.10 so that the entire matrix can be expressed consistently. Results inconsistency ratio in this study can be seen in Table 2.

Table 2. Ratio inconsistency

Expert	Ratio Inconsistency
Expert 1	0,0445
Expert 2	0,0801
Expert 3	0,0899
Expert 4	0,0564
Expert 5	0,0626
Expert 6	0,0686
Expert 7	0,0918
Expert 8	0,0918
Combine	0,0078

Results of pairwise comparisons on all criteria and sub-criteria which are derived based on expert opinion of space technology in Indonesia that is processed to produce relative weighting of all the criteria, sub-criteria and alternatives to the top level of the hierarchy of this research can be seen in Table 3.

Table 3. Relative weighting

criteria / Sub criteria	Relative Weighting
Technic operation	0,239
– *Launch Vehicle*	0,427
– Type of Orbit	0,378
– Launch pad	0,195
Economy	0,047
– Transportation	0,363
– *Market*	0,128
– Infrastructure	0,509
Safety	0,438
– Population density	0,634
– Flight Trajectory	0,366
Meteorology	0,118
– Weather	0,483
– Potential disaster	0,517
Environment	0,158
– Geographical location	0,818
– Tourism industry	0,182

By synthesizing the entire assessment will generate weighting of all the criteria and sub-criteria to the main goal. Ranked weighting criteria and sub-criteria can be seen in Table 4.

Table 4. Ranking of sub criteria

Ranking	criteria	sub criteria	score
1	*Safety*	Population density	0,277
2	*Safety*	Flight Trajectory	0,160
3	Environment	Geographical location	0,130
4	Technic operation	*Launch Vehicle*	0,102
5	Technic operation	Type of Orbit	0,061
6	Meteorology	Potential disaster	0,061
7	Meteorology	Weather	0,057
8	Technic operation	Launch pad	0,047
9	Environment	Tourism industry	0,029
10	Economy	Infrastructure	0,024
11	Economy	Transportation	0,017
12	Economy	Market	0,006

Based on the weighting, the priority ranking of alternative candidate sites for the construction of the spaceport in Indonesia was generated, which can be seen in the Table 5.

Table 5. Percentage priority site selection spaceport in Indonesia

Alternative Location	Percentage Priority	Criteria	Percentage Priority
Biak	36,5 %	Technic operation	10,3%
		Economy	2,0%
		Safety	12,8%
		Meteorology	4,8%
		Environment	6,6%
Enggano	13 %	Technic operation	1,9%
		Economy	0,5%
		Safety	6,3%
		Meteorology	2,3%
		Environment	2,0%
Morotai	35,3%	Technic operation	5,5%
		Economy	1,0%
		Safety	18,8%
		Meteorology	4,7%
		Environment	5,3%
Pameungpeuk	15,2%	Technic operation	3,1%
		Economy	1,5%
		Safety	4,2%
		Meteorology	3,4%
		Environment	3,0%

The percentage contribution of each criteria and sub-criteria to rank the priority candidate sites as the primary destination can be seen in Table 5.

From the results of this study found that the criteria of safety become the main focus. Safety factors must be fulfilled for a spaceport because it is necessary to meet the operational and commercial needs

In this study showed that the technical and operational safety criteria become the main criteria, which have the most attention. It is because the spaceport election is still in early stage in the development of space technology that must meet technical and safety factors before it can operate.

Market users' spaceport has not been a concern of experts so that the economic factor is the factor that smallest weighting. This is consistent with the stage of development of a spaceport was dividing into two phases: early phase and later phase. The initial of early phase in the development of the spaceport is not focused on economic criteria in this regard is the business factors such as tourism.

Transport and infrastructure entered into the economic criteria is an important factor in the development of a spaceport early stage so that more research is needed on these two sub-criteria. Transport and infrastructure associated with the technical, operational, while in this study do not notice the relationship between criteria and sub-criteria. Transport and infrastructure are entered into the economic criteria because the view of the costs incurred in the process of infrastructure development, which has yet to have on prospective alternative locations or expenses incurred for transportation to the alternative location and cost of construction of transportation facilities that may be issued if the alternative locations becomes top priority.

This research output of Biak as best priority of spaceport locations in Indonesia based on predetermined criteria. Biak location is very strategic, approaching the equator. The safety of the flight track can also be fulfilled. Biak location in the coastal areas has the advantages of the sea as a protector and a population density that is not too dense so that of the safety factor, Biak are eligible, as well as the ease of transportation, namely the seaport and an international airport that can support the operation of a spaceport.

Morotai as a second priority based on all criteria has the highest safety factor in the weighting. This is due to Morotai less population density and flight trajectory is safer than Biak. The presence of air force military base on Morotai is very supportive of this location for a spaceport construction.

Development of satellite technology in Indonesia that led to satellite with the equatorial orbit causes the choice of Biak and Morotai is more preferable comparing with Enggano and Pameungpeuk because their geographical location is closer to the equator.

Pameungpeuk has provided easy of transport, port and runway. The location can also be reached by landline of launch vehicle development facility in Indonesia at this time. Other supporting facilities have also been owned Pameungpeuk today because Pameungpeuk is the place where the result of the development of launch vehicle tested.

While from the criteria of safety, Pameungpeuk is rated inadequate because the population density is quite high and the progress of the tourism sector is not synergy with the existence of such testing place.

With the development of launch vehicle technology which is rapidly increasing with the growing magnitude of the size required to fulfill the needs of the satellite orbit so it requires large enough of safety zone. Pameungpeuk is considered not safe enough if it is used for rocket launches satellite orbiter. In addition, for the flight trajectory toward the equatorial orbit is also considered to have a high risk. But if it is used to launch satellites by polar orbit then Pameungpeuk can still be used.

4. Conclusions

Based on the results of the weighting of the criteria, Biak becomes the first choice alternative that was obtained from all of the criteria are weighted with a weight of 36.5%, Morotai as alternative options with the highest safety criteria and is still very likely replace Biak as an alternative second choice. Morotai overall weighting is 35.3%. Development of a new spaceport in Indonesia is still in the early stages so it is not focus on business factors.

Importance of research is conducted more in-depth about the criteria that influence the success spaceport and the relationships between these criteria and observation of the candidate alternative sites is more intensive before making a decision.

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