

MULTI-SCENARIO SPATIAL MODELING OF HEALTH FACILITIES DEVELOPMENT TO SUPPORT THE ACHIEVEMENT OF UNIVERSAL HEALTH COVERAGE

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ABSTRACT :

The availability of health facilities that the community can easily reach is one way to improve the degree of health of residents in a region. The ratio of the number of health facilities and residents in Indonesia is currently only about 1:11000. In addition, the equalization of health facilities in Indonesia is also reasonably uneven because the number of health facilities is more centralized in Java, Indonesia. The transfer of the New Capital of Indonesia launched in 2024 to the island of Kalimantan makes Kalimantan Island a magnet for new people's lives, so it needs to be considered infrastructure development, especially in the health sector. This research attempts to model the conformity of health facilities development on the island of Kalimantan spatially by considering the aspect of accessibility as support and comfort and disaster aspects as a barrier. The accessibility aspect will consider geographical and social criteria, the comfort aspect will consider the criteria for air pollution and noise pollution, and the disaster aspect will consider the criteria for floods, landslides, and forest fires. The integration of Geographic Information Systems and Remote Sensing Technology will be carried out using Multi-Criteria Decision Analysis (MCDA). This study will produce recommendations for the appropriate area for the construction of health facilities on the island of Kalimantan. This study is expected to be a consideration for authorized parties in planning health facilities on the island of Kalimantan in preparation for becoming the Capital of the New Country in Indonesia.

1. INTRODUCTION

Health is a state of complete physical, mental and social well-being that is the fundamental right of every human being regardless of race, religion, belief, political, social, and economic (WHO, 1948; Bickenbach, 2015). These fundamental rights have not been realized because, based on the World Bank and WHO (2015), as many as 400 million people do not have access to essential health. In addition, according to World Bank & World Health Care (2017), half the world's population cannot obtain essential health services.

Based on Statistic Indonesia (2020), there is an increase in the number of people in Indonesia every year, with the population in 2020 reaching 269603.4 thousand people. However, Indonesia's number of health facilities based on the Ministry of Health (2020) is only 24535 with 10203 health centers, 11347 clinics, and 2985 hospitals. This means that in 2020 the ratio between the number of health facilities and the number of residents reaches around 1:11000. The number of this ratio is still tiny to meet the health needs of the entire population in Indonesia. The population that increases every year will also increase the need for health facilities, especially on the island of Kalimantan, targeted by Indonesia's new capital in 2024. This results in population growth, and population migration to Kalimantan Island will increase, directly proportional to the needs of health facilities.

The Law of the Republic of Indonesia Number 36 of 2009 concerning Health explained that health is a human right and one of the elements of welfare that must be realized following the ideals of the Indonesian nation. To make this happen, the

government has a responsibility for the health of its people fulfilled by the provision of adequate health and social facilities (WHO, 1948). To meet the affordability of access to health facilities, the government has been working to increase the number of health facilities in Indonesia, as seen from the increase in the number of health facilities in Indonesia by 70 per year within five years (2015-2019) (Ministry of Health, 2019). Based on the Ministry of Health (2019) report, some of the factors that hinder the accessibility of health facilities in the community are geographical conditions, area, availability of infrastructure, socio-economic and progress of an area. Therefore, spatial modeling is needed to determine strategic areas in the construction of health facilities.

Several previous studies, namely the Halder et al., 2020 study, modeled the area of conformity of health facilities by considering one aspect only focused on accessibility. However, Halder et al., (2020) research has advantages because it uses weighting on each parameter. The second is the study of Abdullahi et al., (2014), which modeled the area of conformity of health facilities using MCDA. The advantage of this research is to divide the method into several aspects. In this model, Abdullahi et al., (2014) consider engineering aspects (land cover, existing health facilities, and areas), environmental issues (polluted areas, noise pollution areas, disposal areas, and river and canal areas), and socio-economic issues (population density, accessibility, and land prices). However, the research of Abdullahi et al., (2014) did not consider the disaster aspects of determining the construction site of health facilities. Another study from Sakti et al., (2022) conducted modeling of school conformity areas in West Java by considering aspects of multi-disaster, school accessibility, and comfort aspects. Sakti et al., (2022) research has advantages because it reviews multi-

disaster aspects, but they do not use weighting. Based on the above research, there has been no study that models health facilities by considering accessibility aspects, comfort aspects, and multi-disasters on the island of Kalimantan. Therefore, the purpose of this study was to model the area of conformity of health facilities on the island of Kalimantan using the MCDA method by integrating aspects of accessibility (geographical and socio-economic), comfort (environmental factors based on air, and sound pollution), and multi-disaster. In addition, these three aspects will also be carried out weighting calculations by using the pairwise comparison method. This research is expected to be a consideration for the government in determining the location of the construction of health facilities on the island of Kalimantan. In addition, the study also supports the sustainable development goals on goal 3: Good Health and Well Being.

2. METHODOLOGY

2.1 Study Area

This research area is Kalimantan, Indonesia. This research is essential in the Kalimantan area because Kalimantan Island is a strategic plan for developing the New State Capital in Indonesia, which was launched in 2024, precisely in East Kalimantan. The plan to move the new national capital will increase carnation and urbanization massively in Kalimantan so that the construction of health facilities becomes very important. The massive development in East Kalimantan certainly affects the surrounding areas, so this study will generally review Kalimantan Island.



Figure 1. Study Area

2.2 Data

2.2.1 Vector Data The vector data in this study is divided into 10 data in more detail can be seen in Table 1. Overall, the vector data used are primary map data sourced from the Geospatial Information Agency, which consists of rivers, airports, industries, roads, railways, health facility points,

education points, and administrative data. These BIG data are taken from the Rupa Bumi Indonesia (RBI) map in 2017 with a scale of 1:50,000. Another vector data used are watershed sourced from the Directorate of Planning and Evaluation of River Flow Control in 2018 on a scale of 1:250,000 data and protected area sourced from UNEP-WCMC (UN Environment World Conservation Monitoring Centre) and IUCN (International Union for Conservation of Nature).

No	Data	Temporal	Resolution	Reference
1	River	2017	1:50,000	(GIA, 2017)
2	Watershed	2018	1:250,000	(PEPDAS), (2018)
3	Airport	2017	1:50,000	(GIA, 2017)
4	Industry	2017	1:50,000	(GIA, 2017)
5	Road	2017	1:50,000	(GIA, 2017)
6	Railways	2017	1:50,000	(GIA, 2017)
7	Health Facilities	2017	1:50,000	(GIA, 2017)
8	Education Facilities	2017	1:50,000	(GIA, 2017)
9	Protected Area	2019	-	(UNEP-WCMC & IUCN, 2019)
10	Administrative Data	2017	1:50,000	(GIA, 2017)

Table 1. Vector Data

2.1.2 Raster Data Raster data consists of 12 remote sensing data obtained and processed through Google Earth Engine (GEE). The data consists of land cover, DEM (Digital Elevation Model), precipitation, wind speed, KBDI (Keetch-Byram Drought Index), Sentinel-5P data (CO, NO₂, SO₂, O₃, and AOD), population, and NDVI (Normalize Difference Vegetation Index). A more detailed explanation of data, temporal, resolution, source, and reference can be seen in Table 2.

No	Data	Temporal	Resolution	Reference
1	Land Cover	2019	100 m	(Buchhorn et al., 2020)
2	DEM (SRTM)	2000	30 m	(Farr et al., 2007)
3	Precipitation	2019	5566 m	(Funk et al., 2015)
4	Wind Speed	2019	4638.3 m	(Abatzoglou et al., 2018)
5	KBDI	2019	4000 m	(Takeuchi et al., 2015)
6	Sentinel-5P OFFL CO	2019	1113.2 m	(ESA, 2018)
7	Sentinel-5P OFFL NO ₂	2019	1113.2 m	(ESA, 2018)
8	Sentinel-5P OFFL SO ₂	2019	1113.2 m	(ESA, 2018)
9	Sentinel-5P OFFL O ₃	2019	1113.2 m	(ESA, 2018)
10	Sentinel-5P OFFL Aerosol	2019	1113.2 m	(ESA, 2018)
11	Population	2019	100 m	(Worldpop, 2019)
12	NDVI	2019	250 m	(NASA, 2018)

Table 2. Raster data

2.3 Methods

The flowchart used in this study can generally be seen in Figure 2. Data processing in this study is divided into three significant aspects: processing accessibility aspects, comfort aspects, and multi-disaster aspects.

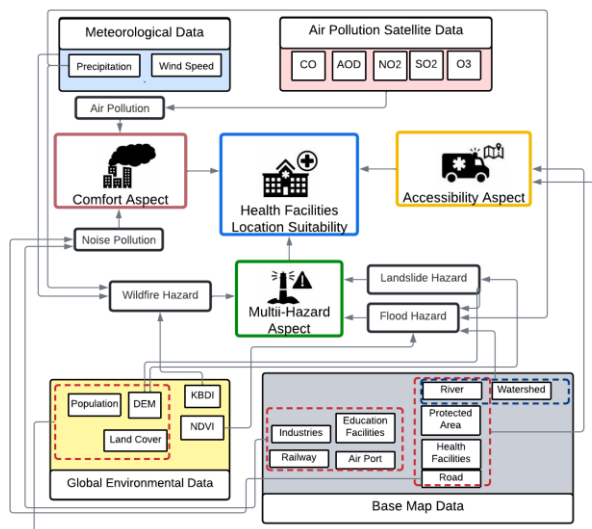


Figure 2. General Methods

2.3.1 Accessibility Aspect Modeling: In terms of accessibility, the data considered are rivers, DEM, roads, railways, health facility points, and populations. River parameters will be considered locations with a considerable distance from the river Ajaj et al., (2019) to ensure that the pollution of health facility waste does not pollute river waters. Not only rivers but the construction of health facilities must also be far from protected areas. Hopefully, the construction of health facilities will not interfere with the ecosystem in the surrounding environment. The construction of health facilities should also consider the ease of access from the location of health facilities so that the slope parameters of slopes, highways, and population density will be considered in the aspect of accessibility (Halder et al., 2020; Nsaif et al., 2020). In addition, the construction of health facilities will also be prioritized in areas that existing health facilities have not reached.

2.3.2 Comfort Aspect Modeling: The construction of health facilities will consider the comfort aspect with location criteria far from air pollution and noise pollution. In addition, the annual increase in population and frequent forest fire disasters have a close correlation with air pollution, so the comfort aspect also needs to be considered. Air pollution parameters use Sentinel-5P data based on air quality standards consisting of gases (Carbon Monoxide), NO₂ (Nitrogen Dioxide), SO₂ (Sulfur Dioxide), O₃ (ozone), and Particulate Matter (PM) (EPA, 2014). PM is closely related to AOD (Aerosol Optical Depth) data. AOD is used to estimate Particulate Matter (PM) because AOD and PM have a positive correlation (Soni et al., 2018). Meanwhile, noise pollution will consider the farthest distance from the source of sound pollution (Sakti et al., 2022b). The sources of noise pollution considered are roads, airports, railways, industry, and education areas (Handayani et al., 2018; Dell'Ovo et al., 2018; Sharmin & Neema, 2013; Xiao et al., 2021).

2.3.3 Disaster Aspect Modeling : Disaster aspect modeling is divided into three stages. The first is flood modeling, integrating river data, land cover, watershed, DEM, precipitation, and NDVI data. River data and watershed data will be processed first to calculate the density of the river. Rivers are significant as a stream of water; increasingly not tight rivers will increase the danger of flooding (Darmawan et al., 2017; Pallard et al., 2009). Land cover that is dangerous to flood is a residential area due to the lack of water catchment areas (Darmawan et al., 2017). The closer an area is from the river, the lower the elevation of the area, the more sloping the slope of the slope, the higher the rainfall, and the higher the value of NDVI it will further increase the level of flood danger (Rahmati et al., 2016; Ullah & Zhang, 2020; Darmawan et al., 2017). The curvature processed from DEM is also an essential factor that affects floods. The more convex a curvature will decrease the flood danger level; otherwise, the more concave the curvature, the more increase the flood danger level is (Cao et al., 2016). The second is modeling landslide hazards using three primary data: DEM, land cover, and precipitation. Steeper slopes, higher rainfall, and settlement-dominated land cover will further increase the danger of landslides (Amri et al., 2016; Reichenbach et al., 2014). In addition, the level of topographic curvature and slope aspect will also increase the danger of landslides (Amri et al., 2016; Chimidi et al., 2017). The aspect will affect the slope stability related to vegetation growth and temperature (Silalahi et al., 2019). Surfaces with concave curvature will be higher than convex and flat ones (Chimidi., et al., 2017). The third is modeling forest fire hazards by integrating data on land cover, precipitation, wind speed, and KBDI. The higher the drought rate (KBDI), the lower the rainfall, the higher the wind speed will increase the danger of forest fires (Amri et al., 2016; Sakti et al., 2022; Takeuchi et al., 2015).

2.3.4 Health Facilities Suitability Modeling: In integrating each aspect, using weighting values defined by the pairwise method can be seen in Table 3. In this weighting certificate, it is necessary to consider the results of discussions with someone in GIS, health, and urban planning conducted in this study. The Pairwise method is suitable for use because it is quite effective in the SIG approach (Malczewski, 1999)

Aspect	Weight
Accessibility	0.77
Comfort	0.10
Disasters	0.13

Table 3. Weight of each aspect

3. RESULT AND DISCUSSION

3.1 Accessibility Aspects

Based on the results of accessibility can be seen in Figure 3, which is divided into five classes of conformity ranging from very low - very high. The highest accessibility distribution is on the outskirts of Kalimantan Island, which is spread evenly in the east, south, and west. However, the northern part of Kalimantan Island has low accessibility caused by protected areas. Protected areas are not recommended for health facilities because they will damage the biodiversity around the site, which makes the area very low suitability. However, in an emergency, the construction of health facilities in the region may be done by

considering and monitoring environmental factors that are quite strict. The area with the highest suitability is in densely populated areas and around settlements, but existing health facilities have not reached it. Therefore, the region is a top priority in constructing health facilities with very high conformity.

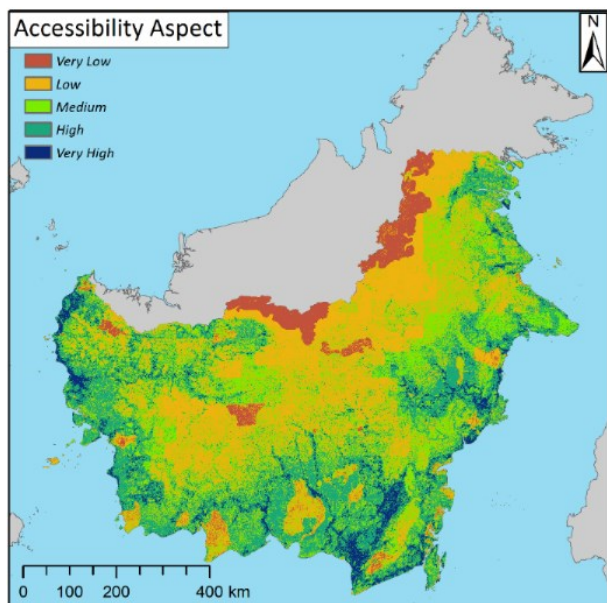


Figure 3. Accessibility Aspects

3.2 Comfort Aspect

The results of modeling the comfort aspect can be seen in Figure 4, which is also divided into five classes ranging from very low – very high. The highest comfort aspect is in the northern part of Kalimantan Island because it is in a land cover area with high enough vegetation to have low air pollution and noise pollution levels. The comfort level is high in the northern area because it is located far from urban locations, the primary source of noise pollution and air pollution. In addition, low-class distribution on the comfort aspect is spread in Kalimantan Island's western and southern parts. The comfort aspect looks inversely proportional to the accessibility aspect because high accessibility has a high mobilization which is a source of pollution. However, using the MCDA method and pairwise weighting is expected to help decision-making determine the location of conformity based on existing criteria and alternative priorities.

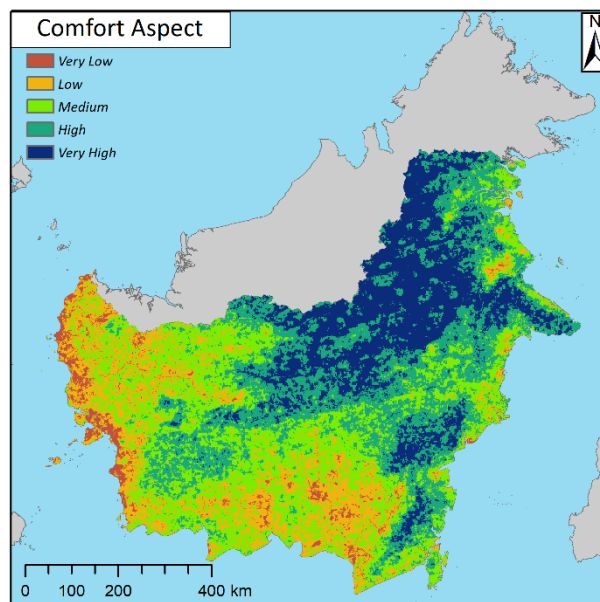


Figure 4. Comfort Aspect

3.3 Disaster Aspect

The results of modeling the multi-disaster aspects of this study can be seen in Figure 5. The higher the level of danger in a disaster, the lower the priority. Conversely, the lower the danger of a disaster in the area, the higher the priority for the construction of health facilities. In figure 5 (a), the land fire disaster model has a low-class distribution in the northern part of Kalimantan Island. Vice versa has a high-class distribution in the southern part of Kalimantan Island. This is because, in the southern part, there is a large peatland. Peatlands have the potential for forest fires. If a fire occurs on peatlands, then surface fires can spread under the surface of the peat. Thus the fire will be difficult to extinguish. In figure 5 (b), the flood hazard has a very high-class distribution in the north-western part of Kalimantan Island because the area has a high river density and a sloping slope of the slope. In addition, the danger of landslides shown in figure 5 (c) has a high class in the northern part of Kalimantan Island. This is because the north of Kalimantan Island has high rainfall and steep slopes. Both of these things cause the possibility of landslides in the northern part of Kalimantan Island to be higher compared to other areas. The integration of the three models results in a multi-hazard model, as seen in figure 5(d). In general, the highest class dominance is around the coast of Kalimantan Island, especially in parts of South Kalimantan.

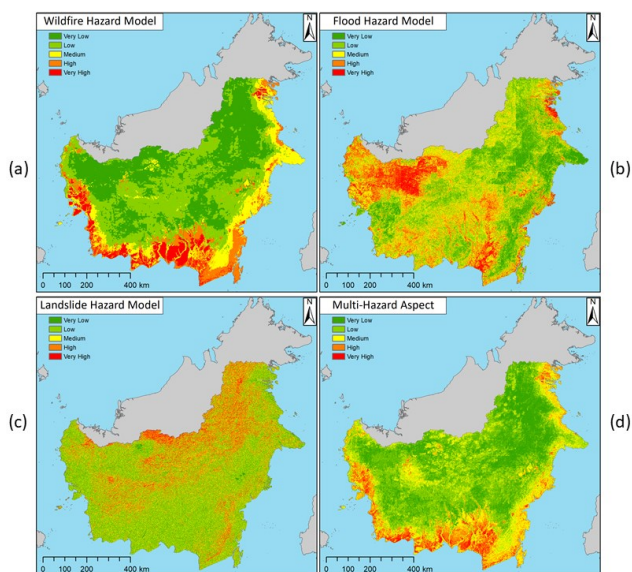


Figure 5. Multi-hazard aspect (note: very high multi-hazard aspect means the location has a very high intensity of multi-hazard)

3.4 Multi-Criteria Area Conformity for Health Facility Development

This study has several limitations, including modelling flood. Figure 6 shows the results of the conformity of health facilities development areas by considering aspects of accessibility, comfort aspects, and disaster aspects. The distribution of conformity areas in deficient classes can be seen in protected areas. Low-very low areas are more dominated in the northern part of Kalimantan Island. In addition, the distribution of conformity areas in high-very high grades is in the vicinity of the suburbs or surrounding coastal areas of Kalimantan Island.

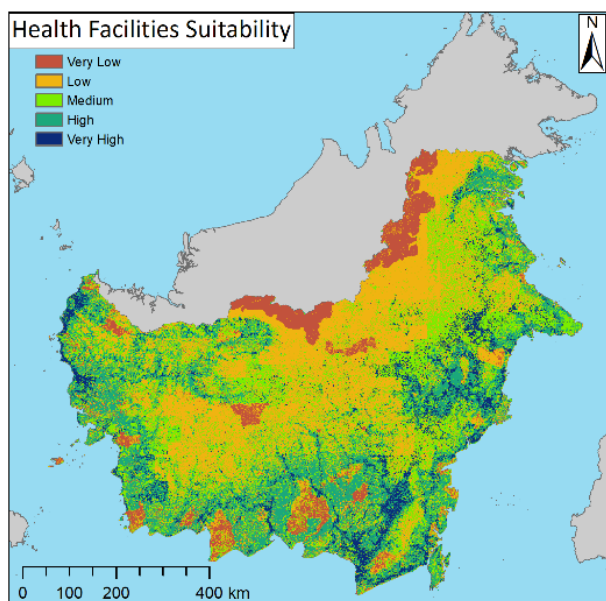


Figure 6. Suitability of the area of construction of health facilities

4. DISCUSSION

4.1 Percentage of Health facilities suitability in Province area

The percentage of conformity areas based on provincial administrative boundaries can be seen in figure 7. The regions with the highest percentage of conformity in the high-very high class are South Kalimantan and East Kalimantan, reaching 57.11% and 35.42%. This is also in line because South Kalimantan has a very high population density compared to other provinces on the island of Kalimantan, namely in 2019, reached 110 people / km² (Statistic Indonesia, 2019). In contrast, the regions with the highest percentage of conformity in the very low-medium class are North Kalimantan, Central Kalimantan, and West Kalimantan reaching 87.81%, 71.02%, and 68.95%.

Percentage of Suitability Area Based on provincial Administrative Data

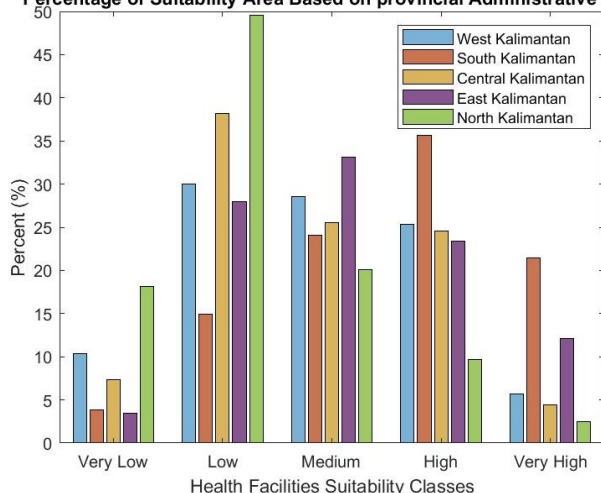


Figure 7 Percentage of suitability area based on provincial administrative data.

4.2 Evaluation of existing health facilities on disaster aspects and comfort aspects

Evaluation of existing health facilities on disaster aspects and comfort aspects can be seen based on Figure 8. Only about 5% of locations have a very high multi-hazard suitability, or the location is in an area with a very low probability of multi-hazard (minimal danger). Only 2% of locations conform to very high comfort aspects. High conformity class in multi-hazard aspect suitability and comfort aspect suitability as much as 28.37% and 9.96%. In the conformity of multi-disaster aspects, there are about 66.72% of health facilities in the very low-medium class. On the other hand, in the conformity of the comfort aspect, 88.11% of the location of health facilities is in the very low-medium class. From these results, it can be concluded that the construction of existing health facilities does not consider the aspects of disaster and comfort.

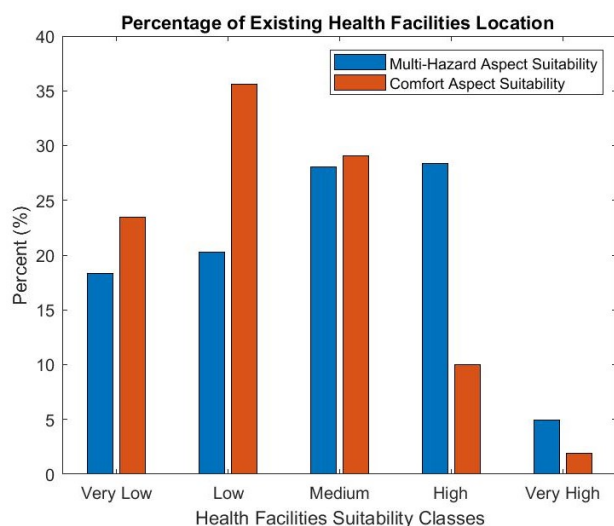


Figure 7 Health Facilities Existing Evaluation (note: very high multi-hazard aspect Suitability means the location has very low multi-hazard)

4.3 Limitation and Future Study

This study has some limitations on modeling the accessibility of health facilities, not considering data on the number of medical personnel residing in each health facility. The number of health workers is significant to consider to see the distribution in existing shrewd facilities whether they have met. The standard ratio between the number of health workers and the population is 1:1000 (WHO, 2016). Based on these standard ratios, the number of health facilities needed in a region can be known with certainty so that conformity modeling can also recommend the location and number of health facilities needed. In addition, this modeling is also not specified for health facilities based on the type of health facilities. Weighting is also only based on aspects in general, not done per parameter of each aspect. Therefore, based on these limitations, this study can be further developed, especially in considering the distribution of medical personnel in existing health facilities, determining the number of health facilities needed, and also determining the area of conformity based on the type of health facilities needed, and weighting in each aspect parameter.

5. CONCLUSION

Based on modeling the suitability of health facilities development, Kalimantan Island has a percentage of classes from very low, low, medium, high, very high as much as 7.78%, 23.33%, 27.71%, 33.06%, and 8.11%. The province with the highest percentage of conformity area locations is South Kalimantan, with a total in very high class reaching 21.46%. This study can be used to consider the first step of the preliminary survey in determining the location of the construction of health facilities on the island of Kalimantan. It is hoped that this study can help accelerate the construction of health facilities on the island of Kalimantan to support global health coverage.

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