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Regional Case Study

Spatial Analysis of Noise Levels and Evaluation of Noise Zones Around Radin Inten II International Airport, Lampung Province

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Abstract
Radin Inten II International Airport is the largest airport in Lampung Province which in 2019 underwent a status change to become an international airport. This article tries to present changes in the acoustic environment caused by flight activities around the airport. Noise measurements were carried out at 12 sampling points in the range of 300-4000 m and under the flight path, which then calculated the noise level (Leq) and the WECPNL index. Contour mapping of noise exposure uses an overlay technique visualized with contour lines. Leq measurement results are 60.4-81.4 dBA with an average value of 69.8 dBA. The distance of the sampling point to the runway is known to have a negative correlation with the noise level, while the noise measured on weekdays and weekends has no difference. The mapping results show that the most affected zones are dense settlements about 600 m from the runway. Three locations are known to fall into the noise level 3 zone, and two other sites fall into the noise level 1 and 2 zones. The non-noise zone is within a 2.5 km distance from the runway. The reduced comfort of living due to noise is a consequence of the economic improvement that may be felt by the people living around the airport.

Keywords: Radin inten II international airport; noise zone; noise level; noise mapping WECPNL

1. Introduction

Noise in the environment that initially only interfered with the quality of verbal communication, annoyance, and hearing loss has now developed into a more complex health problem. Several studies have shown a strong association between environmental noise and chronic health problems such as cardiovascular disease (Münzel et al., 2014) and various psychological problems. Even research on environmental noise in the last decade has discussed the impact of noise on the growth and development of the younger generation. Several strong relationships between noise and children's growth and development include the emergence of symptoms of hyperactivity in children (S. Stansfeld & Clark, 2015) the emergence of annoyance and stress in children (Evans et al., 1998; Haines et al., 2001), decreased reading ability. And long-term recall (S. A. Stansfeld et al., 2005) and cognitive decline (Hainesa et al., 2001). From studies in various cities in the world, most of the noise problems encountered come from airport activities. Aviation activity is one of the main causes of noise reported in many cities. The characteristics of aviation transportation modes that can move quickly have become the main choice for some people in both large and medium cities in Indonesia. Noise from flight activities is dominated by airport activities which are determined by the number of aircraft activities at the airport, including take-off, landing, movement on the runway, and engine testing (Handayani et al., 2018). Radin Inten II International Airport is the largest airport in Lampung Province in South Lampung Regency, with a runway dimension of 3,000 x 45 m. The airport has an apron with a zone of 43,600 m^2 to accommodate eight aircraft parking stands.

The average passenger movement at Radin Inten II International Airport reaches 2.6 million per year with a maximum annual capacity of 3.7 million passengers (Resti, Gita Angga; Hutagalung, 2019). Before the COVID-19 pandemic, this airport became an international airport, where international flights are dominated by hajj and umrah activities (Husni et al., 2021). The community's positive impact from the increasing flight activity is that the economy around the airport is getting better than before. However, there are potential negative impacts, namely disturbances in the comfort of life and even health problems due to noise caused by airplanes. Therefore, it is necessary to analyze the noise intensity and spatial distribution of noise around the Radin Inten II International Airport zone, most of which are residential zones. Noise mapping is integral to determining noise exposure to the public (de Kluijver & Stoter, 2003). Noise mapping is an important tool to provide relevant information needed to plan noise control in the zone around the airport zone (Vogiatzis, 2012).

Many researchers have studied the impact of noise from airport activities, including the amount of noise generated and its effect on public health. However, few researchers have made their research outputs from maps to map noise in the study location. In the future, Tsao & Lu (2022), in their study, recommends the use of maps containing noise levels to help airport noise control and land use planning. Al-Harthy et al. (2021) stated that noise maps could help generate more accurate data that will be useful for public health policy reviews. Roca-Barceló et al. (2022) also argue that in the future, there is a need for research that provides outputs in the form of a noise map. It can be used to evaluate urban development interventions and formulate public policies that ensure people's health in areas exposed to high decibel levels. Thus, based on the recommendations of previous studies, the purpose of this article is to present a map of changes in the acoustic environment caused by airport activities and the status of the area around the airport that has the potential to worsen people's quality of life.

2. Method

2.1 Research Time and Location

Radin Inten II International Airport is located at Jalan Lintas Sumatra No. 758, Natar District, South Lampung Regency. There are 12 sampling points within the airport zone and settlements around the airport (Table 1). Primary data collection in the form of noise level was carried out using a Sound Level Meter (SLM). Primary data collection was carried out in the second week of September 2021 for four consecutive days. Weekdays are represented by Monday and Wednesday, while weekend noise level data is represented by Friday and Saturday. The duration of the noise level measurement adjusts the airport's working hours in the conditions of the COVID-19 pandemic. Measurements focused on the noise of flight activity on the runway for various activities.

The twelve sampling points are representative of the zone that is within a specific distance of range. This study takes a distance of 300–4,000 m from the runway under the provisions recommended by the International Civil Aviation Organization (ICAO). Besides the distance from the runway, based on ICAO guidance, the sampling point location must also consider the flight path of landing and take-off activities towards the airport. In this study land use was not considered. For spatial analysis, the buffer method is used starting from the runway zone, and then a distance range line is made to ensure that the sampling point can be represented according to the distance range (Figure 1).

Table 1. Allotment of land and coordinates of each sampling point

Point	Land Designation	Distance to Runway (m)	Latitude	Longitude
1	Jalan Brantiraya, Pondok Pesantren Perkemas	± 300	5°15'3.76"S	105°11'25.40"E
2	Jalan Brantiraya, residential zone	± 300	5°15'7.02"S	105°11'28.11"E
3	ATC Tower, Radin Inten II International Airport	± 300	5°14'31.78"S	105°10'33.70"E
4	Apron, Radin Inten II International Airport	± 300	5°14'35.92"S	105°10'37.13"E
5	Jalan Rajawali, Gg. 12, residential zone	± 1.000	5°15'41.51"S	105°11'50.19"E
6	Jalan Candimas 1, Natar	± 1.000	5°13'47.89"S	105°10'18.11"E
7	Jalan Rajawali, residential zone	± 2.000	5°16'3.79"S	105°12'14.74"E
8	Nurul Huda Mosque, Natar	± 2.000	5°13'16.68"S	105°10'8.82"E
9	Jalan Rajawali, SMP Negeri 5 NATAR	± 3.000	5°16'13.65"S	105°12'47.47"E
10	Jalan Branti Raya, Natar	± 3.000	5°12'38.12"S	105°10'20.46"E
11	Miftahul Huda Mosque, Natar	± 4.000	5°16'17.33"S	105°13'16.24"E
12	Al Istiqomah Mosque, Natar	± 4.000	5°12'7.97"S	105°10'30.33"E

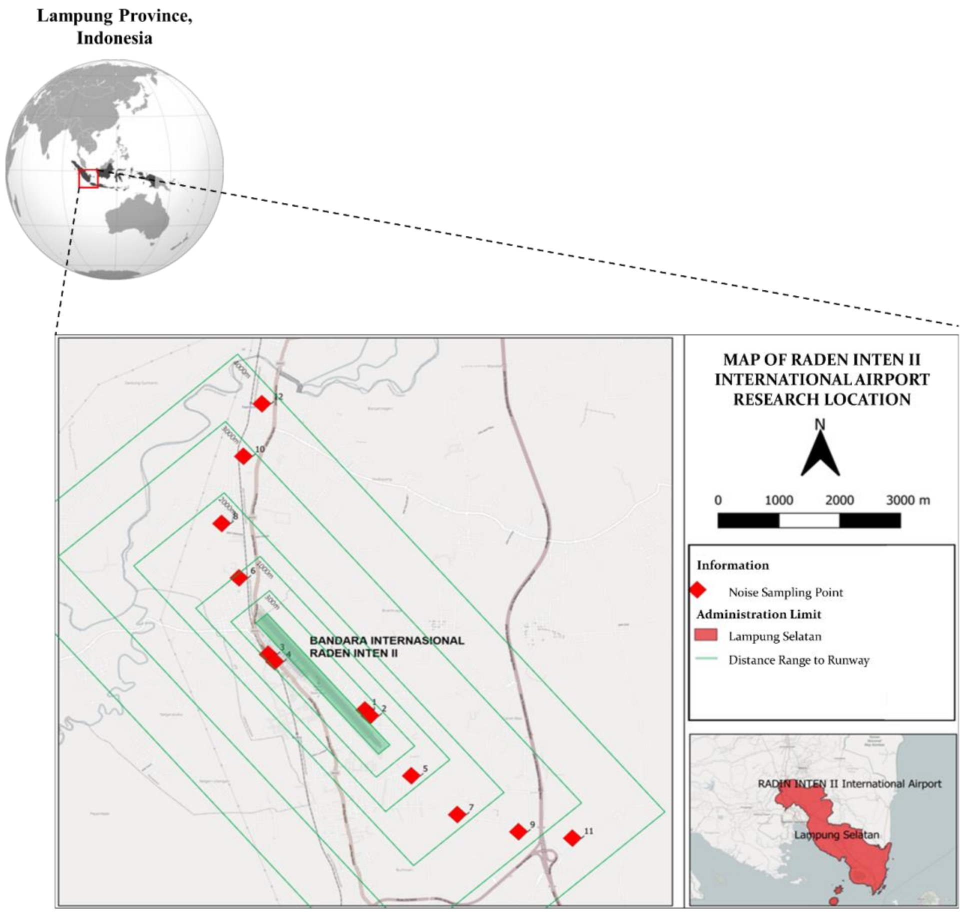

Figure 1. Sampling point location

2.2 Data Processing and Calculation

The method used in measuring the noise level is a simple manual method where the readings of the SLM are recorded every 5 seconds for 10 minutes. This study used SLM AS824 from *Smart Sensor* manufacturer with an accuracy of ±1.5 dB. The weighting used sin the SLM is class A-weighting (measuring range level 30-130 dBA), suitable for measuring aircraft noise. The readings were carried out in 4 different periods (L1-L4) which L1 represents noise level for morning time (06.00-09.00), L2 & L3 for afternoon time (09.00-14.00 & 14.00-17.00), and L4 for nighttime (17.00-22.00). Each period was then averaged according to the logarithmic calculation method (Badan Standardisasi Nasional, 2009). The method of calculating the average noise intensity per period is as in Equation (1):

$$L_{1\text{-}4}\ (\text{dBA}) = 10\ \text{Log}\ (1/120)\ (T_1.10^{0,1L1} + T_2(10^{0,1L2} + \ldots\ldots + T_n(10^{0,1Ln})) \quad (1)$$

In Equation (1), Tn is the measurement duration (5 seconds), and Ln is the result of measuring the noise level at each of these durations. The calculation results from each period (L1-L4) are then averaged to obtain a Leq representation at that point using the formula as in Equation (2):

$$\text{Leq (dBA)} = 10 \log \left[\frac{10^{\frac{l1}{10}} + 10^{\frac{l2}{10}} + \cdots + 10^{\frac{ln}{10}}}{n}\right] \quad (2)$$

Then to evaluate the land use of the zone around the airport specifically, the noise index calculation using the Weighted Equivalent Continuous Perceived Noise Level (WECPNL) method is used. ICAO began recommending the use of the WECPNL method as a noise index in 1971, which was adapted from a study in Japan. WECPNL calculation is a simple form and a combination of the Effective Perceived Noise level (EPNL) method, which tends to be more complex, so it is not widely used (Handayani et al., 2018). Based on Government Regulation of the Republic of Indonesia No. 40 of 2012, the noise level in the airport zone and its surroundings is determined by the WECPNL index or the equivalent noise level value. The formula for calculating the noise index of the WECPNL method used is according to Equation (3):

$$\text{WECPNL} = \text{Leq} + 10 \log N - 27 \quad (3)$$

The WECPNL calculation uses the average Leq variable at that point and also data on the number of aircraft (N). The WECPNL index is used to determine the boundaries of noisy zones based on the Decree of the Minister of Transportation No. 48 of 2002 is divided into 3. Region 1 is in the 70 index value of 75, region 2 is in the 75 index value of 80, and region 3 80. Government regulations require airport operators to monitor noise and environmental pollution thresholds inside and around airports under established quality standards. The noise threshold or noise quality standard is the noise level or the equivalent value of the noise level in an zone around the airport that is still acceptable within a certain period. Regulations also regulate the boundaries of noise zones. Noise zone boundaries are zones around the airport that are affected by aircraft operating noise during engine warm-up, taxiing, landing, take-off, or crossing, which can disturb the environment. To evaluate the noisy zone around the airport, spatial analysis is used to see the distribution of noise caused by flight activities at Radin Inten II international airport. The spatial analysis used in noise mapping uses the krigging method, where unknown values will be predicted based on the closest known points' values with the Surfer application's help, which is processed using the Quantum GIS (QGIS) application.

3. Result and Discussion

3.1 Identify the Noise Level Around the Airport

Data collection for measuring noise levels is carried out at several predetermined points in the Radin Inten II International Airport zone, where each point is considered capable of representing the location of the entire airport zone. The data is then processed into the form of sound level intervals to be used as a determinant of the Leq noise criteria. Measurements made during this research period showed that the maximum noise average for the 12 sampling points was 69.8 dBA, with the highest measured noise level at point 3 (81.4 dBA) while the lowest measured noise level was at point 11. The measurement results show a value of 60.4 dBA. The measurement value of noises for each sampling point can be seen in Figure 2.

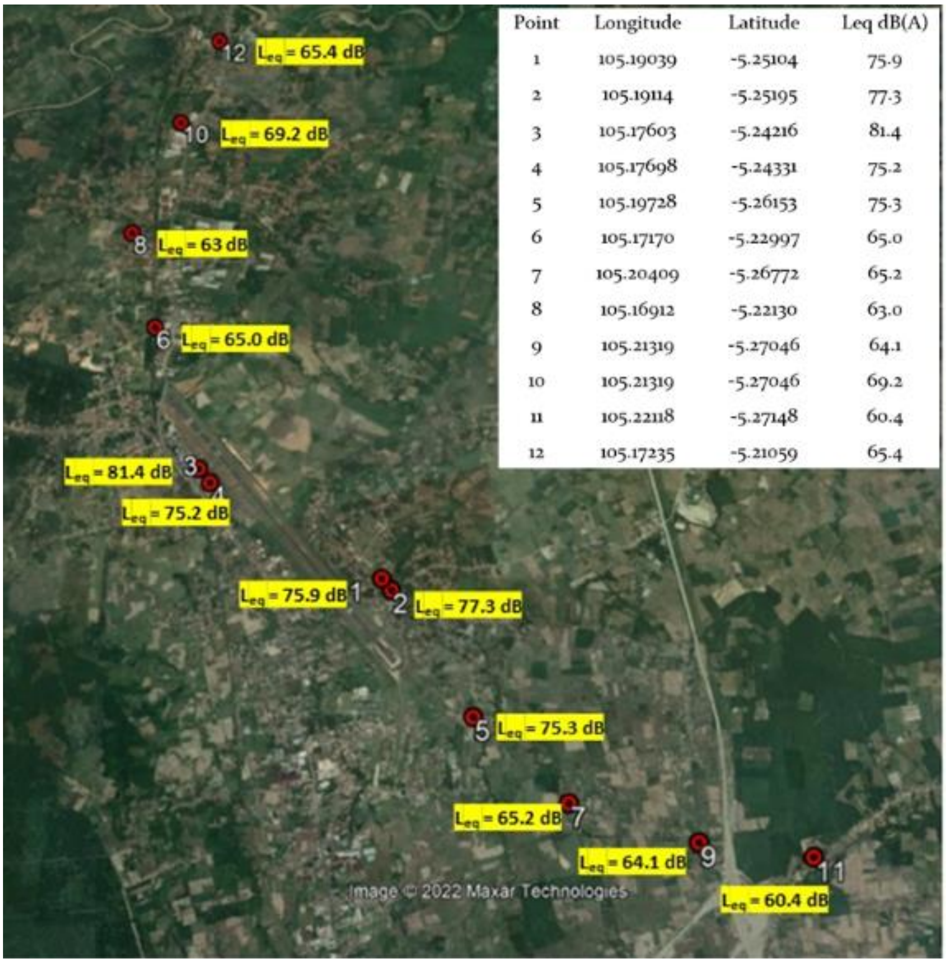

Figure 2. Noise level measurement results

The Indonesian Government sets a standard value for noise levels where the standard is the maximum level that is allowed to be released into the environment from businesses or activities so as not to cause disturbance to human health and environmental comfort (Menteri Negara Lingkungan Hidup, 1996). Based on this regulation, the noise quality standard for residential zones is 55 dBA. This noise level measurement results show that the noise level in the zone around the airport exceeds the specified quality standard. It shows that, in general, flight activities at airports have a significant impact on changes in people's comfort levels even during the COVID-19 pandemic, where the number of flight activities decreased significantly compared to normal conditions before the pandemic. It is under previous research at Halim Perdanakusuma Airport Jakarta (Handayani et al., 2018), Husein Sastranegara Airport Bandung (Ramadhan, 2019), and Sultan Thaha Airport Jambi (Herawati, 2016), where in general, the noise level in the zone around the airport has a value that exceeds the quality standard. Different noise levels at each point are highly dependent on local noise sources, which also depend on land use around the point. (King et al., 2012).

In Figure 2, based on satellite imagery, it can be seen that the location of point 11 has a different land use from other points with fewer residential zones around it. It makes the noise level at this location the lowest compared to other points. The highest noise level is at point 3, where there is additional non-commercial aircraft activity in the Indonesian Navy aircraft hangar on the northwest side of the airport. Apart from being based on land use, it is also necessary to look at the relationship between the distance of each location point from the runway and the measured noise level during flight activities. The noise level fluctuation of each point is described in Figure 3.

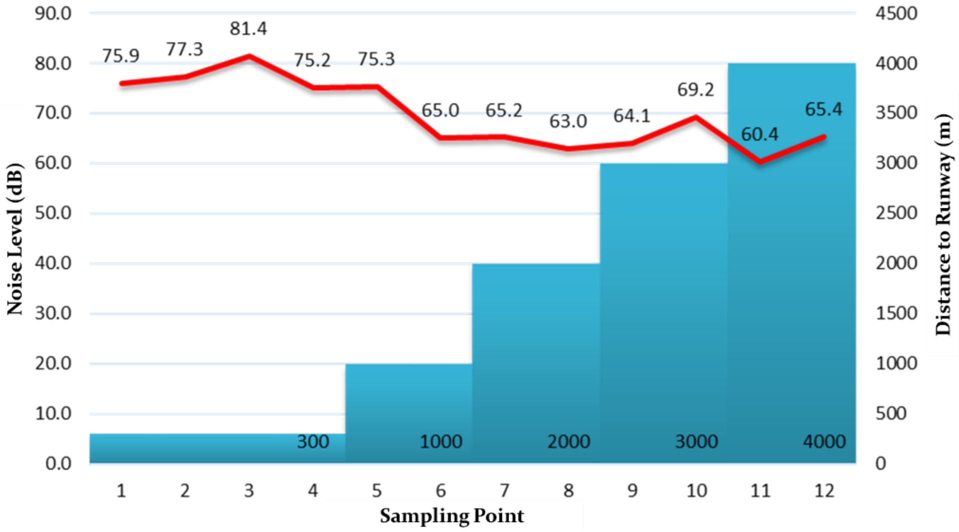

Figure 3. The fluctuation of the measured noise level with the distance to the runway

The noise level decreases gradually as the distance between the sampling point and the runway increases (Figure 3). A correlation test was carried out to obtain a relationship strength between the sampling distance point from the runway and the noise level. The results of the Spearman's Rank correlation test obtained the value of rho (ρ) = -0.753, proving a strong negative correlation between the two variables. Some differences in noise levels are seen at the sampling points at the same distance range, and this is not only due to local noise sources but also to differences in aircraft activity based on the flight path. The differences in aircraft activities are divided into 3, namely activities within the airport, landing lanes, and takeoff lanes (Table 2).

Table 2 Noise rating based on aircraft activity

No	Airplane Activities	Sampling Point	Average Noise Level (dBA)
1	Landing, Take off, Taxing & Machine Test	1,2,3,4	77.4
2	Landing Path	6,8,10,12	66.2
3	Take off Line	5,7,9,11	65.7

The source of noise in the airport zone comes from aircraft that are operated and currently under maintenance. The level of noise released into the environment depends on the type of aircraft engine. The size of the noise value is also influenced by the distance between the object and the noise source, the weather, as well as the presence or absence of obstacles, such as buildings where residents live, office buildings, public facilities, and other components that can absorb sound which causes the noise to get smaller. Noise exposure during the day and night can also differ significantly. However, in the case study at Radin Inten II International Airport, activities inside the airport are the biggest noise source of all flight activities with a higher noise level than the noise measured in the landing and take-off lanes. Based on Table 2, the noise in the landing and take-off lanes has a non-significant difference with a relative difference of less than 1%. If the measurement results are compared based on weekdays (Monday and Wednesday) and weekends (Friday and Saturday), based on research the highest noise level in 1 measurement interval is 81.4 dBA which occurs in the L3 interval on Friday, while the lowest noise in one interval obtained worth 57.6 dBA which is at point 11 on the L1 interval on Monday. However, when calculating the average noise level on weekdays and holidays, there is no significant difference between each other (Figure 4). The COVID-19 pandemic has greatly impacted the business of the aviation industry. The daily average number of passengers is 150 passengers per day, a decrease of 83% compared to the normal period of the pandemic. Comparative studies need to be carried out during the new-normal period when activities from the airport have started to return to how they were before the pandemic thus it can show the reduction of noise level due to pandemic.

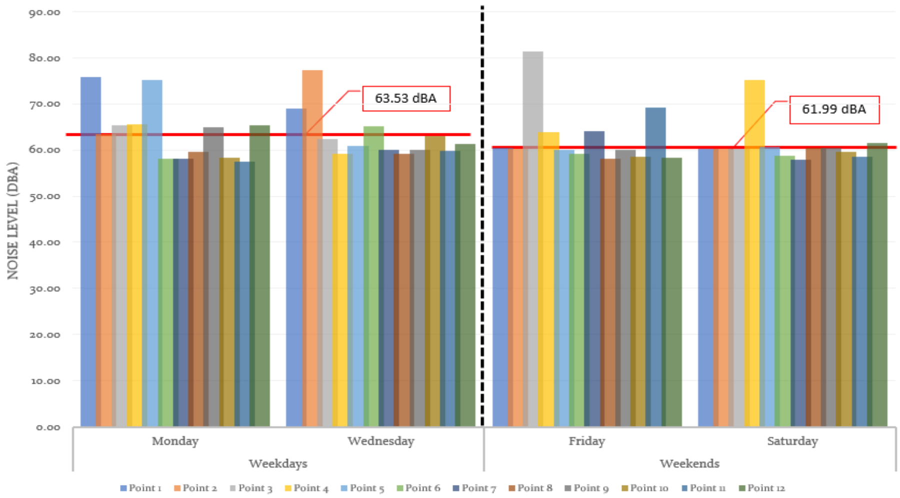

Figure 4. Mapping of noise due to flight activities at Radin Inten II International Airport

By averaging the noise level measurements from all points on the same day (showed by various colors of bar chart in Figure 4), it is found that the difference in average noise for weekdays has a higher value, namely 63.53 dBA when compared to the average noise measured on weekends only reached 61.99 dBA. This study, carried out during the COVID-19 pandemic, showed that flight activities in pandemic conditions were relatively less noisy. It can be seen from the relatively similar noise level between weekdays and weekends, where the difference in noise levels is below 3%. Noise mapping is done by overlaying the base map in raster data, with the results of noise level measurements being visualized with contour lines. The prediction model for the distribution of noise levels uses the krigging method for zones that are not measured. Krigging method is one of several methods for interpolating using linear predictor. Krigging weighting system are calculated based on the distance. The smaller distance to a known point the greater its weight. The contour map visualization of the noise levels distribution at Radin Inten II International Airport is in Figure 5a.

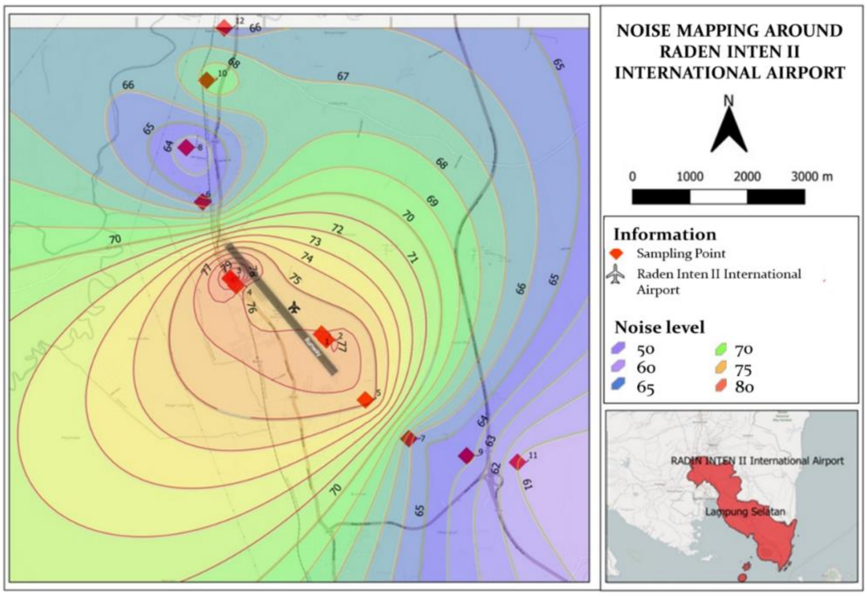

Figure 5a. Noise mapping due to flight activities

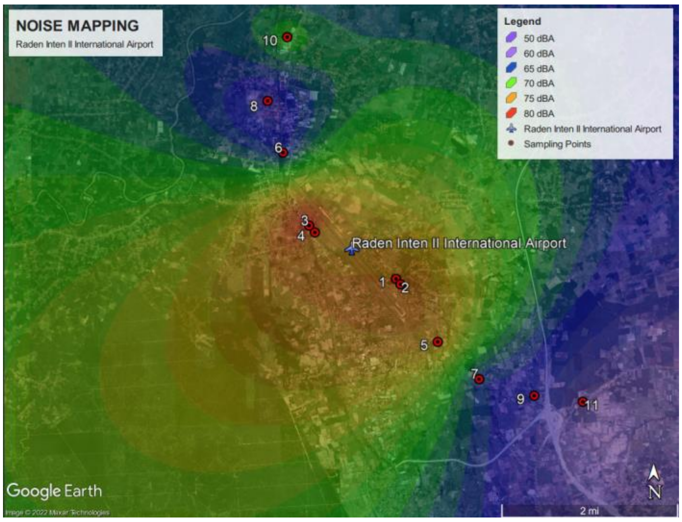

Figure 5b. Noise mapping due to flight activities overlayed with Google Earth map

From the results of noise mapping as shown in Figure 5a and 5b, the two zones most affected by noise are the zones around the runway zone which, when viewed from satellite imagery, are quite dense settlements. From Figure 6, dense settlements around the airport within 600 m experience high noise exposure, reaching 70–80 dBA. Another review at a distance of 1-2 km from the end of the runway shows the measured noise level is in the range of 60-70 dBA. Settlements at a distance of 3-4 km from the new runway are deemed to meet the noise level quality standards for residential zones. The airport is an economic center where its development will be an attraction for the surrounding community to live in the location with the hope of improving economic life (Susanto, 2020). Airport activities will then change the land use around the airport into a fairly dense settlement (Aryany & Pradoto, 2014). Based on the mapping, the reduced comfort of living due to the noise of aviation activities is a consequence of the economic improvement that the community around the airport may feel.

3.2 Identification of Noise Zone

In evaluating the noise zone around the airport, the WECPNL index is calculated, which is calculated from the Leq value obtained from each point of the entire sampling period. A level 3 noise zone can be stated if the noise index value exceeds 80 WECPNL. It is referred to as a level 2 noise zone if the noise index is greater than 75 and less than 80 WECPNL. Then it is called a level 1 noise zone if the noise index is more than 70 and less than 75 WECPNL. However, if the noise value is less than 70 WECPNL, the zone is outside the noise zone classification (Table 3).

Table 3 WECPNL index value and noise zone classification of each point

Point	WECPNL Index Point (dBA)	Noise Zone
1	79.2	Level 2
2	82.1	Level 3
3	86.3	Level 3
4	80.4	Level 3
5	78.8	Level 2
6	68.3	Non-Noise Zone
7	70.5	Level 1
8	67.8	Non-Noise Zone
9	68.9	Non-Noise Zone
10	74.1	Level 2
11	65.4	Non-Noise Zone
12	68.4	Non-Noise Zone

Based on the measurement results, three sampling points are included in the level 3 noise zones: points 2, 3, and 4. The three locations are sampling locations within 300 m from the runway. Based on Table 1, these three regions are zones with a WECPNL index of more than 80 dBA. This zone is intended to build airport facilities equipped with sound insulation. This zone can be used for green lines or other means of environmental control and agriculture that do not invite birds. The noise zone is under its designation based on land use at points 2 and 3. However, based on observations, at point 2, it can be seen that there are residential residents on Jl. Brantiraya has the potential to be exposed to noise from airport activities. For the level 2 noise zone, there are two sampling points (point 1 and 5) whose noise index is known to be in the 75-80 dBA range. Meanwhile, the level 1 noise zone is measured at 2 points, namely point 6 and 11, where the distance range from the runway is between 600-3,000 m. Land classified as level 2 and 1 noise zones can be used for various activities except for school buildings, hospitals, and residential houses. The measurement results found that the zone not included in the noise zone is the sampling point with a distance of more than 3,000 m from the runway. Although at point 10, there is a local source of noise that makes that point included in the noise level zone 2. Mapping of noise level zones 1, 2, and 3 after modeling using the kriging method obtained an image as shown in Figure 6. Based on the mapping of the noise zone in Figure 6 from modeling using the kriging method, the level 3 noise zone is in a radius of less than 500 m and the level 2 zone is at a radius of 500-1,500 m. Noise is more spread to the community in southwest of the airport.

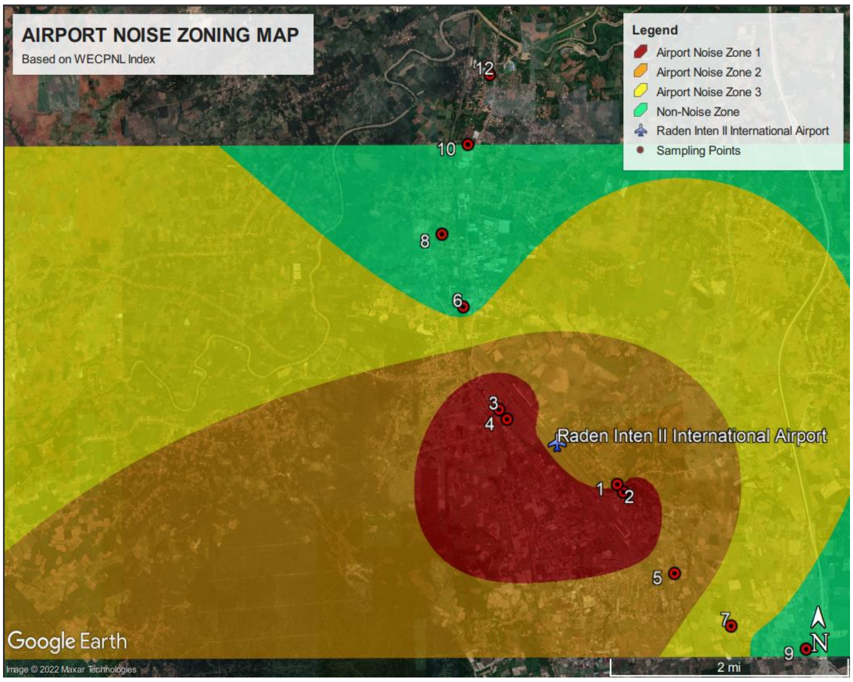

Figure 6. Mapping of the noise zone around Radin Inten II International Airport

Noise management that shall be applied in level 3 noise zone is to evaluate and enforce the suitable land use in accordance to the regulation and the airport is expected to install noise monitoring system to ensure monitoring environmental acoustic and public health problem caused by aircraft noise (Vogiatzis, 2012). Based on observations; several existing buildings need to install proper insulation to reduce the impact of noise from aviation activities. In many countries, residential insulation program for properties located in zones 1 or 2 are provided by the airport management cooperate with local government. The program includes insulation improvement for doors, windows, and ventilation system and education about noise and its effect to human health.

4. Conclusions

There are 12 noise sampling points around Radin Inten II International Airport, which are based on the flight path and the radius of the runway (300-4,000 m) following the provisions of the International Civil Aviation Organization (ICAO). The Leq measurement results in this study were in the range of 60.4-81.4 dBA with an average value of 69.8 dBA. The distance factor to the noise level is known to have a strong negative correlation indicated by the Spearman correlation test value (ρ), reaching -0.753. Activities that contribute the highest to the noise around the airport are take-off, landing, taxiing, and engine testing activities, all of which are in the airport zone. The COVID-19 pandemic has reduced flight frequency so that the number of flights on weekdays and weekends is not significantly different. Noise levels between weekdays and weekends are relatively no different. Comparative studies between pandemic and normal condition shall be carried thus it can show the reduction of noise level due to COVID-19 lockdown. In the future, this research improved by comparing the impact of noise on different groups of people (age, economy, education, occupation, gender). In order to assess the accuracy of the measured noise data, future research will take into account integrating additional noise sources (such as road traffic, construction, etc.) during field measurements.

Noise mapping shows that the zones most affected by noise are dense settlements located at a distance of about 600 m from the runway, which are quiet dense settlements. Settlements within 3-4 km from the new runway are deemed to meet the noise level quality standards for residential zones. The consequence of increasing the community's economy around the airport is a decrease in the comfort level of life due to noise. The level of the noise zone is a method used by policymakers to determine a good land allocation for the zone around the airport. The WECPNL index is a tool used to determine the noise level of the zone. From the calculation results, the three locations are known to be included in the noise level zone 3, and 2 locations based on the WECPNL index are included in the noise level 1 and 2. Some community activities such as hospitals and schools in these locations need to be evaluated regarding the installation of standardized insulation to minimize the impact of activity noise. Based on the WECPNL index mapping, the non-noise zone is within a radius of more than 2.5 km from the runway. The zone has low noise, so it can be designated as a settlement, school, or hospital.

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