Development of Eco-Airport Model to Measure Environmental Noise Footprint in Supporting Airport Sustainability

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Abstract. Among a set of tools to emerge in recent years in environmental management, one appears to meet the criteria necessary to bridge this gap is the environmental footprint analysis based on biophysical reality of sustainable living, people must use natural renewable products and services not sooner than they are replaced and produces no waste faster than nature can absorb. The purpose of this study is to develop a model of noise environment footprint toward sustainability airport with the environmental assessment at Soekarno-Hatta International Airport. The results showed that the airport ecological footprint of the model can be built through the factors analysis that can give an idea of the influence of ecoairport. The conclusion of this study is to obtain the noise ecological footprint provides a method for the total impact of air transport to be assessed, the ecological footprint can be used as a communication and awareness tool to inform communities about the impact they make. It can lead to shifts to public transport for airport access, ecological footprint can be used by airports and airlines to identify operations where energy efficiency measures can be made and where resource consumption can be reduced.

Keywords: ecological footprint, eco-airport model, noise, sustainability, factor analysis

1. Introduction
In accordance with Law Number 23 of 1997 concerning Management Environment in article 6, Soekarno-Hatta International Airport continues to increase its activities. To anticipate complaints from the community around the Airport and the Tangerang community in general, Soekarno-Hatta International Airport carries out environmental management/monitoring of activities/activities that cause environmental impacts and its analysis has been carried out and compiled in the Environmental Impact Analysis Document, Environmental Management Plan and Plan Environmental monitoring. According to the World Health Organization (WHO), exposure to noise pollution may even increase...
the risk of heart attack. Not surprisingly, urban communities have a 46 percent risk of heart attack compared to people who live in quiet areas.

In fact, it is not only far away in Germany that people are exposed to the dangers of noise pollution. Indonesian people are also aware or not also experience health hazards due to pollution on this one. The proof, Indonesia is included in the top four countries with the most cases of hearing loss in Asia.

The greater the global outlook the greater the ecological footprint. The greater the ecological footprint, it means that natural resources are used freely, without good design. This is because the demand for natural resources is too much to overcome the earth's ability to produce the original material that has been used. Therefore, the ecological footprint is a concept that is closely related to sustainable development and the application of the concept of an intimate natural life. Development that is designed and prioritizes the concept of intimate nature is a hint of low ecological footprint. Every aspect will be taken to develop the economic sector such as the power used, the use of land space, as a result of the use of natural resources, and the steps to adjust or maintain and maintain to maintain the ecological balance for generations to come. International standards regulate noise from new aircraft production by International Civil Aviation Organization (ICAO). The current standard refers to Chapter 3 Annex 16 of 1977. Since 1991 a major study has been carried out in the ICAO Committee for Aviation Environmental Protection (CAEP) which has recently led to a more stringent noise definition 4 Chapter boundary.

As the main outcome of the above process, a balanced approach is recommended that includes four elements:
1. noise reduction,
2. land use,
3. noise control procedures, and
4. restrictions on aircraft operations.

Very significant technological advancements in the aviation world in the last two decades, still leave the problem of aircraft and airport noise that must be resolved immediately by the air transportation industry as a whole if current growth is to be sustained. Government and stakeholders as well as policy makers are faced with very challenging challenges, while operationally it must reduce noise at sources that are generally growing rapidly, especially related to the evolution of the concept of machinery, and the need to be economical, but must keep trying to overcome the needs of the global airline fleet to accommodate the expected traffic growth without the cost of having to damage the environment. Figure 1 shows aircraft noise metrics.
Airport development and development has an impact on people's lives, both in the form of positive and negative impacts, especially in areas where major international airports are operated, it can be understood that the growth of air transportation can be seen as an economic benefit, for example by operating a jumbo jet, the tourism sector began to increase to become a large industry.

For people who live around the airport area, the environmental impacts of airport operations and are the most obvious environmental load capacities are noise, noise effects, and implications related to other environmental issues, such as:

1. Aircraft noise can affect quality of life. Increased air traffic and aviation technology advancements can affect individual tranquility and worsen climate noise at airports.
2. Sleep disturbance increases, aggravation increases, and health impacts occur due to aircraft noise.
3. Aircraft noise can inhibit airport expansion, unless substantial noise reduction can be made.

Because noise can have a significant impact on the community, it is necessary to control noise around the airport area by controlling the level of noise that occurs, so that it is compatible with the carrying capacity of the environment that supports it, so that the sustainability of an environmentally friendly or eco-friendly airport which covers social aspects, economic aspects, and environmental aspects can be achieved.

2. Literature Review

One component of the impact of transportation on the environment is the noise caused by traffic both on roads, railways and airports. The problem of transportation noise impacts is unique compared to other pollution, noise occurs spontaneously and arises at any time due to the movement of means of transportation in this case is an aircraft. If the movement has moved away from a location, then this form of pollution leaves no impact at all. Noise is an unwanted form of sound or a form of sound that is not appropriate to the place and time. The sound is undesirable because it interferes with human speech and ears, which can damage hearing or human comfort. In general, noise can be interpreted as a sound that is detrimental to humans and the environment, including on livestock, wildlife and systems in nature [1].

Simply stated, noise can be defined on the basis of a number of basic elements: namely the source of the sound, during the spread of sound and the receiver. Sound is a vibration or change in pressure in an elastic medium that causes auditory sensation that can be captured by the ear [2].

Airplanes taking off and taking off are the main sources of flight noise. Over the past 30 years, flight frequencies have begun to increase [3]. The result is increased aircraft noise causing increased public awareness about this. In special directions, the problem of increasing noise is important and has become the dominant complaint at several airports. In addition, for people who live and have activities near the airport area, various noise originating from sources at the airport such as airplane taxis, aircraft engine tests, generators or traffic sides of transportation vehicles traveling to the airport, especially private vehicles can also make a significant contribution to noise around the airport.

Several sources of noise can be grouped in [4]:

1. Noisy traffic, this noise is caused by the sound of transportation, for example trains, airplanes, buses and others and is felt more by the people around the traffic lane.
2. Noise industry, coming from large industries that operate machines that produce sounds up to about 100 dB. This industrial noise is felt by the employees and residential communities around the industry.
3. Noisy household, usually comes from household activities and is usually not too noisy.
Figure 2. Movement of aircraft sound sources[12]

Based on the provisions of the ICAO, because the source of aircraft noise is following the movement of the aircraft, the aircraft noise model is divided into 3 parts, namely: final approach, ground roll, and initial climbing as illustrated in Figure. 2.

Specifically [5] stated that the main sources of noise on airplanes were:
1. Turbojet Engine Noise, i.e., the noise emitted from engine movement and accelerates with outside air through the nozzles.
2. Turbofan Engine Noise, i.e., the noise produced by compressors and turbines,
3. Aerodynamic Noise, i.e., the noise produced by the flow of air under the fuselage of the aircraft, the cavities of the aircraft, landing gear and the surface of the aircraft.
4. Propeller Aircraft Noise, i.e., noise that comes from the power of the gas in the turbine or from the work of the aircraft engine piston

Factor analysis. In carrying out factor analysis, the variables analyzed are said to be feasible to be factored if the KMO-MSA value is >0:5 and significant value (sig) or opportunity (p) <0:05. Based on the results of data processing, can be determined the KMO-MSA value [6].

It is also known that the Bartlett’s Test value is 0.000. This shows that the data collected has the right to be factored.

Anti-Image Correlation, variables can be used as a joint component or cannot be determined based on the value of the anti-image correlation with the following conditions.
MSA = 1, variables can be predicted without errors from other variables.
MSA ≥ 0.5, variables can still be predicted and need to be analyzed further.
MSA < 0:5, variable cannot be edited and cannot be analyzed further.

3. Methodology
Experimental research has been carried out to produce a model of environmental noise traces at airports. Factor analysis is done to see the impact of the environmental footprint caused by aircraft movement and its implications on society. The framework of the study is presented in Figure 3.

Through factor analysis study of environmental capacity is expected to note the implications of the environmental footprint of the airport, which can then be modeled to determine the calculation of the potential environmental footprint area of the airport and can be used by the government to build the policy instruments in the context of the standard-setting eco-friendly airport.

The stages of this research start from literature and field observations, followed by analysis of the social and environmental surroundings aerodrome area until terminated by the establishment of a
model potential environmental footprint. Systematics research the conceptual framework presented in Figure 3.

![Diagram of Airport Sustainability](image)

**Figure 3. Research Framework**

4. **Results and Discussion.**

Soekarno-Hatta International Airport has a total area of about 1800 acres, consisting of two parallel runways. The First Runway have a 3660 m long runway and the second runway has a runway length of 3600 meters. The geographic location of Soekarno-Hatta located at the coordinates 06° 07’ 25” South Latitude and 106° 39’ 40” East Longitude, as outlined in Figure 4.

The views of stakeholders on environmental capacity through interviews with stakeholders show little consensus on the implementation of the environmental footprint as part of the framework of the environmental carrying capacity. While some industry groups are excited that the elements of costs and benefits can be included in the interpretation of the carrying capacity of the environment (which requires the application of monetary decision criteria), the Society supports the implementation of the management of its environmental footprint. Following the definition and interpretation of environmental carrying capacity that can be captured from the processed data that represents the expression of respondents [7].

Environmental impacts occur in the form of energy is wasted due to the use of electricity or fuel, the impact of the existing source for this comes from the operating activities of the airport (aircraft on ground, offices, terminals, cargo and supporting facilities). Management of impacts on the energy component is to use the GPU, Building Automatic System (BAS), energy saving and the use of alternative energy such as bio diesel/vegetable oil, zoning designation, air conditioning, electricity and water, the Setup utility systems (water, lighting, noise), Selection of the use of materials, building in
service, air conditioning and electricity usage settings corresponding dimensions of space and shape space. The location of the building and the position of the points of the compass, determination of the type of air conditioning for each part of the building.

Development of eco-airport models to measure environmental noise footprint in supporting airport sustainability with simulation shown five new factors. That five factors can affect to the model performance through potential implementation, these are the factors: noise annoyance ($X_1$), noise disturbance ($X_2$), noise impact ($X_3$), noise management ($X_4$), and noise sensitivity ($X_5$). After the discovery of new factors that affect the noise footprint of an airport environment, the next step is to build a model using regression analysis by utilizing the factor scores generated during the process with the factor analysis method carried out to obtain a model that is able to describe the relationship between the new factors above with environmental noise footprint in supporting airport sustainability...The regression equation result has been shown below:

$$Y = 4.812 + 0.094 X_1 + 0.110 X_2 + 0.215 X_3 - 0.019 X_4 - 0.180 X_5 \quad (1)$$

Where constrain are:

- $-2.863 \leq X_1 \leq 1.935$
- $-2.552 \leq X_2 \leq 1.965$
- $-2.385 \leq X_3 \leq 1.256$
- $-2.924 \leq X_4 \leq 2.213$
- $-2.989 \leq X_5 \leq 2.029$

**Implications for noise annoyance ($X_1$)**

Factors implication of noise annoyance $n$ is positive, this shows that the higher the level of noise that occurs it will have implications for increasing the level of aggravation.

Aircraft noise can be a source of irritation because it interferes with sleep, interferes with conversation, and interferes with human activities, subjective experience irritation is a common reaction to noise and each respondent can show different reactions to the same noise level and differences in respondents can be ascribed to some differences in noise sensitivity.

**Implications for noise disturbance ($X_2$)**

The noise disturbance implication factor is positive, this indicates that the higher the noise level that
occurs it will have implications for the increase in noise disturbance. Noise can cause disturbances and endanger health, at higher levels can cause deafness or deafness due to noise (Noise Induced Hearing Loss), noise disturbance factor is the most dominant disturbance variable in research the relationship between noise level and health disorders [8] and the implication of aircraft noise is the emergence of negative impacts on health and life stress and can damage quality of life [9].

**Implications for noise impact (X₃)**
The noise impact implication factor is positive, this indicates that the higher the noise level that occurs it will have implications for increasing noise impact. On the implications of noise impact, respondents' answers clustered on the problem of the noise situation of the airport area, the presence of particles, dust, and smoke as well as odors as an impact of airport operational activities, were felt by most respondents who made the calculation of the accumulated number of noise implications.

Implications for noise management (X₄)
The implication factor of noise management is negative, this indicates that the higher the noise level that occurs, the indicated noise management must be optimal, or it is necessary to improve noise management efforts. By looking at the results of this study for this negative value, then this noise management factor becomes very important to be a concern and needs to be improved because it will have a direct impact on reducing the noise level and impact on the reduction of noise source noise.

**Implications for noise sensitivity (X₅)**
The noise sensitivity implication factor is negative, this shows that the higher the noise level that occurs it will result in a decrease in noise sensitivity, or it can also be interpreted to mean the community is immune to noise.

How noise sensitivity influences noise aggravation and noise disturbance is the implication of noise has also been carried out by previous researchers, basic biological investigation studies of noise sensitivity show noise sensitivity has a heritability of 40% [10], and noise sensitivity shows sensitive individuals have distinctive patterns of brain activity that distinguish them from insensitive individuals and differences in noise sensitivity most likely reflect greater strain on cognitive processes. By looking at the results of research for this factor is negative, then the noise sensitivity factor is very important to be a concern because it will have a direct impact on the decrease in individual sensitivity and impact on health problems due to noise.

5. **Conclusions.**
Finding the factors that can affect to the eco-airport models to measure environmental noise footprint at the airport operational activities, production activities that occur will cause environmental footprint that will affect various aspects of community life includes social, economic, and environmental aspects. Of all existing facilities to serve the transport of passengers and goods/cargo in activity at the airport, will also potentially impact the environment, the attention to some things like the following to be important to follow up:

1. Air transport includes many different activities carried out by different industries with consumers.
2. Growth in airports is expected to increase each year in line with population growth.
3. Increased consumption of environmental resources in the area of the airport and the potential of waste generated, would increase greenhouse gas emissions are a significant factor in global climate change.
4. Concerns about environmental issues and sustainable development needs in the area of the airport needs to be addressed.

In the end, the balance between the carrying capacity of the environment and environmental capacity, it is very important to note that the creation of environmentally friendly airport can happen, and continuity can be maintained to be eco-airport.

From the previous explanation, the potential model of ecological footprint development can be concluded with:
Y = 4.812 + 0.094 X₁ + 0.110 X₂ + 0.215 X₃ - 0.019 X₄ - 0.180 X₅

Where constrain are:
-2.863 ≤ X₁ ≤ 1.935
-2.552 ≤ X₂ ≤ 1.965
-2.385 ≤ X₃ ≤ 1.256
-2.924 ≤ X₄ ≤ 2.213
-2.989 ≤ X₅ ≤ 2.029

The factor of noise annoyance, noise disturbance, noise impact, noise management, and noise sensitivity are the implication of noise in the airport environment and is a capacity to accommodate the noise load must be supported by the carrying capacity of its environment.

REFERENCES

[1]. Ya Ling Yang. (2020). Comparison of public perception and risk management decisions of aircraft noise near Taoyuan and Kaohsiung International Airport. Journal of Air Transport Management. Volume 8, Article 101797

[2]. Paul Davidovits. (2019). Chapter 12: Waves and sound. Physics in Biology and medicine (Fifth Edition) Pages 173-192

[3]. Heesup Han, Jongsik Yu, Wansoo Kim. (2019). An electric airplane: Assessing the effect of travelers' perceived risk, attitude, and new product knowledge. Journal of Air Transport Management. Volume 7. Pages 33-42

[4]. Jin Zhang, Giacomo Squicciarini, David J. Thompson. (2019). Implications of the directivity of railway noise source for their quantification using conventional beamforming. Journal of Sound and Vibration. Volume 459. Article 114841

[5]. Christine Erbe, Rob Williams, Miles Parsons, Sylvia K. Parsons, I. Made IwanDewantama. (2018). Underwater noise from airplane: An overlooked source of ocean noise. Marine Pollution Bulletin. Volume 13. Pages 656-661

[6]. Wahyu Sardjono and Faldhi Firdaus, (2020). Readiness Model of Knowledge Management Systems Implementation at the Higher Education. ICIC Express Letters. ICIC International. ISSN 1881-803X Volume 14, Number 5

[7]. Marcus Sutcliffe, Paul Hooper and Ros Howell. (2007). Can Eco-Footprinting Analysis Be Used Successfully to Encourage More Sustainable Behaviour at the Household Level?. Sustainable Development Sust. Dev. (in press). Published online in Wiley InterScience (www.interscience.wiley.com)

[8]. Webb L. (2002). Measuring Your Eco-Footprint or Weighing Your Eco-Rucksack. WWF Website. 2002a. Ecological Footprinting: a Guide for Local Authorities.

[9]. Haberl H, Erb KH, Krausmann F. (2001). How to calculate and interpret ecological footprints for long periods of time: the case of Austria 1926–1995. Ecological Economics 38(1): 25–45.

[10]. Robert KH, Schmidt-Bleek B, Aloisi de Larderel J, Basile G, Jansen JL, Kuehr R, Price Thomas P, Suzuki M, Hawken P, Wackernagel M. (2002). Strategic sustainable development – selection, design and synergies of applied tools. Journal of Cleaner Production 10 (3): 197–214.

[11]. National academies of Sciences, Engineering, and Medicine. (2009). Aircraft Noise: A Toolkit for Managing Community expectations. Washington, DC: The National Academis Press. https://doi.org/10.17226/14338

[12]. Antonio Filippone. (2014). Aircraft noise prediction. Progress in Aerospace Sciences. Volume 68. July 2014. Pages 27-63