Ecological Footprint Model of Soekarno-Hatta International Airport from the Perspective of the Local Community

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Abstract. Soekarno-Hatta International Airport is prone to various environmental problems. The problem of population growth has an impact on increasing economic activity which directly impacts the environment. In every production activity from the environmental side, it will bring up the carrying capacity of the environment and the carrying capacity of the environment or ecological footprint. The problem will be difficult if it turns out that the ecological footprint that occurs exceeds the capacity of the existing environmental carrying capacity, also for airport problems. This will result in the airport being unsustainable. This article will discuss the model of the airport environmental footprint that is currently occurring at Soekarno-Hatta International Airport by utilizing the opinions of respondents who live and have activities around the airport. The factor analysis method is used to process the respondent's data to obtain the factors that influence the environmental footprint and then through these findings a model can be developed which is expected to be able to abstract the current conditions. The research results show that the dominant environmental footprint at Soekarno-Hatta airport is overload airport activities impact, operational slot time optimization, and renewable of airport energy, which can then be built as an instrument to evaluate, build and develop airport control policies that are environmentally friendly and sustainable.

Keywords: Airport, ecological footprint, factor analysis, sustainable development, carrying capacity.

1. Introduction

Along with population development followed by an increase in economic activity, airports must be equipped with an environmental impact analysis in accordance with the regulations of the International Civil Aviation Organization (ICAO) where the demands for aviation safety are getting higher. The socio-cultural conditions of the community around Soekarno-Hatta airport have an impact on airport operations, for example:

1. The development of residential areas around the airport fence
2. The number of livestock roaming in the airport area
3. There are social activities around the airport
4. Development of buildings at the end of the runway which is expected to disrupt flight operations
5. Increased business activities around airports which may have an impact on airport operations
6. Activities related to community culture that can endanger flight operations, such as raising kites and releasing hot air balloons.

Soekarno-Hatta International Airport is the largest airport in Indonesia. Soekarno Hatta Airport is Indonesia’s main gateway from the international world so it has a very important role in the mirror of the Indonesian State. The name Soekarno Hatta Airport is taken from two national hero figures as well as the President and First Vice President of Indonesia, namely Soekarno and Mohammad Hatta, as shown in Figure 1.

![Figure 1. Soekarno-Hatta Airport, Banten - Indonesia](image1)

Source: Angkasa Pura, 2020

And the growth in the number of passengers for Soekarno-Hatta International Airport is very significant when compared to Juanda Surabaya Airport and Denpasar Ngurah Rai Airport, as shown in Figure 2.

![Figure 2. Domestic Aircraft Passenger Indonesia](image2)

Source: Angkasa Pura, 2020

In accordance with Law Number 23 of 1997 concerning Environmental Management in article 6, Soekarno-Hatta International Airport continues to strive to increase its activities. To anticipate any complaints (complaints) from the community around the airport and the people of Tangerang in
general, Soekarno-Hatta International Airport conducts environmental management / monitoring of activities / activities that have environmental impacts and analyzes related to operational flight activities, as shown in Figure 3.

Figure 3. Airport Operation Activities [31]

2. Literature Review

2.1. Airport

Airport or airport is one of the public buildings that have a major contribution to the economy of a region. This large contribution is inseparable from the magnitude of environmental problems and social impacts that may arise in the long term. Airport development must consider important indications related to environmental impacts in the future, both those arising in and around the airport environment due to ongoing airport operations [1].

2.2. Carrying Capacity

Environmental carrying capacity is the number of populations or communities that can be supported by the resources and services available in an ecosystem [2]. Factors that affect the limitations of an ecosystem to support the livelihoods of humans and other living creatures are the amount of available resources, the number of populations, and the patterns of resource consumption. The concept of the carrying capacity of the physical environment and facilities refers to the size of the human population that can be supported by certain facilities in an area or land that is physically limited. According to [3], the carrying capacity of the environment is defined as the maximum number of people that the earth can support with the available resources. The maximum amount is the upper limit that does not cause environmental damage so that life on earth can continue [4]. The quality of the environment is largely determined by the carrying capacity of the environment. The occurrence of damage to the ecosystem or a decrease in the quality of the environment indicates that the resources consumed to meet the needs of human life have exceeded a certain threshold of environmental carrying capacity [5].

2.3. Environmental Capacity

Based on Law no. 32 of 2009, the carrying capacity of the environment is the ability of the environment to accommodate or absorb substances, energy and/or other components that enter or are included in it. Environmental capacity is more anthropocentric or gives priority to how much human life needs in a certain area or land that can be accommodated. The concept of environmental carrying capacity is closely related to the amount of resources consumed to meet or serve human needs. According to [6] Machhub (2010), environmental carrying capacity is defined as the ability of an environment to accept a number of resource utilization loads as input in order to meet the needs of the human population. Environmental capacity needs to be made in an analysis that takes into account the quality of the resources provided. Environmental carrying capacity analysis can be used as a tool to evaluate the quality of the environment and as an indicator of controlling the amount of resource consumption that exceeds the standard (overconsumed).

Capacity is classified into 4 (four) types of criteria, namely maximum, subsystem, suboptimum, and optimum as shown in Figure 4. [7] (Darmaputra, 2015a). The explanation of the four criteria is:
Maximum environmental carrying capacity, occurs when the available resources have been used to the maximum extent and have exceeded the environmental carrying capacity of the resources to meet the needs of the resident population or humans. 

Capacity of the Subsystem Environment, if the utilization of resources has exceeded the carrying capacity of the environmental resources, but the population is not maximum so that the resources used are still classified as exceeding the needs of the human population.

Suboptimum Environmental Capacity, if the utilization of available resources is still below the average human population needs or has not exceeded the carrying capacity of the resource environment, even though the human population is close to the maximum.

Optimum Environmental Capacity, if the utilization of available resources or the environmental carrying capacity of the resources has a tendency to be below the average human population needs with the number of human populations that are not maximum.

![Figure 4. Criteria for Environmental Capacity [7]](image)

2.4. Ecological Footprint

The ecological footprint theory was first introduced in the early 1990s by Mathis Wackernagel and William Rees. The Ecological Footprint is one of the first comprehensive efforts made to measure the capacity or carrying capacity of human needs. The measured carrying capacity of human needs is equivalent to the number of planet Earth needed to support human needs for resources within a certain period of time [2]. Based on research, since the mid-1980s, human needs have exceeded the carrying capacity of planet Earth. In 2008, human needs were recorded to have exceeded the carrying capacity of the planet Earth (biocapacity) with an achievement percentage of 44% [8]. According to [9], ecological footprint is a tool for planning toward sustainability or a tool for calculating the estimation of human needs for resource consumption in a number of human populations. According to [10], ecological footprint is an area-based indicator that can measure the sustainability of resource consumption patterns, both on an individual, local, national, and global scale. According to [11], ecological footprint is also defined as a method used to measure or evaluate environmental impacts resulting from human activities in a certain area. According to [12], ecological footprint is closely related to indicators of economic value. The use of resources for the survival of humankind in the world will gradually reach a stage of deprivation and even scarcity if it continues to be used beyond the carrying capacity of the planet earth. Therefore, the ecological footprint of the use of resources to meet human needs needs to be further analyzed and calculated. Ecological footprint analysis is one of the tools for planning sustainable environmental development [13]. Ecological footprint analysis is used to measure the level of human resource consumption in relation to the carrying capacity of the environment. Ecological footprint analysis is implemented with the aim of managing the use of the resources of an area to be more efficient so that environmental sustainability can be realized. Man-made environmental development tends to be unsustainable [14]. An airport is an example of an
artificial environment which in its operation and service utilizes resources on a large scale. Therefore, airports need to be managed with the concept of an ecological footprint analysis. According to [15], the airport environmental footprint can be classified into 4 (four) types, namely energy, noise, congestion, and emission. The airport's ecological footprint related to energy comes from 3 (three) sources, namely the total terminal energy consumption, waste energy from buildings, and power supply and distribution system losses. The total terminal energy consumption and power supply and distribution system losses are related to electrical energy. The ecological footprint theory of electric energy which is suitable for this study is the total terminal energy consumption. The total terminal energy consumption is the total amount of electrical energy used to operate electrical equipment to support flight service activities at the airport terminal building, especially related to artificial coolers (air conditioners). The elements of an airport's ecological footprint are presented in Figure 5.

![Figure 5. Elements of an Airport Ecological Footprint [15]](image)

3. Methodology
This study uses a descriptive method with the convenience sampling technique through a survey of respondents, with the following stages: [16]:
From the concept can be construct some factors and also can be determine some indicatots, and base on the literature review we also can be completed every indicator with some references coming form journals until we get research statement and summarizing until we have research instrument or questionnaire. The relation between Concept/Theory – Construct – indicators – references can be shown as Table 1.
Table 1. Research Instrument Development

| Factor                | Indicator                                      | Ref. # |
|-----------------------|------------------------------------------------|--------|
| Energy (EN)           | Power Supply & Distribution Loses (EN1)        | [17]   |
|                       | Waste Energy from Building (EN2)               | [18]   |
|                       | Total Terminal Energy Consumption (EN3)        | [19]   |
| Emission (ES)         | Landslide Vehicle Emissions (ES1)              | [20]   |
|                       | Airslide Vehicle Emissions (ES2)               | [21]   |
|                       | Aircraft (ES3)                                 | [22]   |
|                       | Wetlands Loss (ES4)                            | [23]   |
|                       | Storm Water Contamination (ES5)                | [24]   |
| Noise (NO)            | Aircraft Operations (NO1)                      | [25]   |
|                       | Nighttime Operations (NO2)                     | [26]   |
|                       | Engine Run Up and Testing (NO3)                | [27]   |
| Congestion (CG)       | Passengers Vehicle Traffic (CG1)               | [28]   |
|                       | Truks and Commercial Traffic (CG2)             | [29]   |
|                       | Aircraft Congestion and Delay (CG3)            | [30]   |

4. Results and Discussion.

A number of indicators cluster to form a new first variable called \textit{overload airport activities impact}, these indicators are:

1. Aircraft Congestion and Delay (CG3) = Delay aircraft during landing and take off process.
2. Passengers Vehicle Traffic (CG1) = Passenger activities during pre-flight and post-flight
3. Truks and Commercial Traffic (CG2) = Aircraft supporting operational activities.
4. Airslide Vehicle Emissions (ES2) = emissions from delivery or pick-up cars
5. Engine Run Up and Testing (NO3) = Aircraft maintenance and engineering site location, very near with airport.
6. Aircraft (ES3) = Technical aspect of aircraft around aircraft noise and emission.

A number of indicators cluster to form a new second variable called \textit{operational slottime optimization}, these indicators are:

1. Nighttime Operations (NO2) = empowerment of production time
2. Aircraft Operations (NO1) = Airport production and utilization
3. Storm Water Contamination (ES5) = Outcome sustainable emission

A number of indicators cluster to form a new third variable called \textit{renewable of airport energy}, these indicators are:

1. Total Terminal Energy Consumption (EN3) = Minimize accumulated energy requirement at the terminal.
2. Waste Energy from Building (EN2) = Recycling Energy and waste to energy processes.

The relation between variables can be shown in Figure 6. Furthermore, from the results of data processing with the regression method, can be shown in Figure 7.
From the results of this analysis, it can be seen that the first factor contributes to a negative value of 0.026 which indicates a quality limitation on the impact of excessive airport activities and must be immediately above. Meanwhile, for the second factor, the optimization of operational time slots has a positive contribution value of 0.062 which indicates that quality improvement with the indicators contained in this second factor can increase respondents' understanding of the airport's ecological footprint. For the third factor related to the quality of airport renewable energy, it also gives a positive contribution value of 0.345 which means that the increase in the quality of this factor will affect the increase in respondents' understanding of the airport's ecological footprint related to the optimization of energy use. Furthermore, the above model is built using regression analysis method and then it can be simulated to find an optimal solution that can be implemented, here is a description in the form of a mathematical model:

$$Y = 7.260 - 0.026 X_1 + 0.062 X_2 + 0.345 X_3$$

With the contrains:

- $-2.383 \leq X_1 \leq 2.392$
- $-2.597 \leq X_2 \leq 1.923$
- $-3.170 \leq X_3 \leq 2.767$

The optimum value of the ecological footprint can be shown as Tabel 2.

| Variable          | Condition  | $Y$    | $\beta_0$ | $X_1$ | $X_2$ | $X_3$ |
|-------------------|------------|--------|-----------|-------|-------|-------|
| Current           |            | 7.260  | 7.260     | 0     | 0     | 0     |
| Un-expected       |            | 4.494  | 7.260     | 2.392 | -2.597| -3.170|
| Optimum           |            | 8.393  | 7.260     | -2.383| 1.923 | 2.767 |
5. Conclusions.

From the results of research on the Ecological Footprint Model of Soekarno-Hatta International Airport From the Perspective of The Local Community can be conclusion that:

1. Found three new factors that influence the Ecological Footprint Model, namely overload airport activities impact, operational slot time optimization, and renewable of airport energy.

2. The three new factors formed can be represented as factors
   1. **Overload airport activities impact** which consists of several indicators namely the Aircraft Congestion and Delay, Passengers Vehicle Traffic, Truks and Commercial Traffic, Airslide Vehicle Emissions, Engine Run Up and testing, and Aircraft. The value of this variable can reduce to make the optimum of ecological footprint.
   2. **Operational slot time optimization** which consists of several indicators namely Nighttime Operations, Aircraft Operations, and Storm Water Contamination. The value of this variable can be increase to make the optimum of ecological footprint.
   3. **Renewable of airport energy** which consists of several indicators, namely Total Terminal Energy Consumption, and Waste Energy from Building. The value of this variable can be increase to make the optimum of ecological footprint.

3. Models that illustrate the Ecological Footprint Model of Soekarno-Hatta International Airport From the Perspective of The Local Community.

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