CONCEPTUAL MODEL FOR THE IMPLEMENTATION OF ELECTRIC GROUND SUPPORT EQUIPMENT IN GROUND HANDLING ACTIVITIES IN INDONESIA

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ABSTRACT

This research aims to develop a model for the implementation of electric ground support equipment (E-GSE) in Indonesia. It employed the qualitative and quantitative method. Data were collected through interviews with airport stakeholders including ground handling, airline and airport experts. The data analysis used the Analytical Network Process (ANP) with Super Decisions software tools. The ANP is a mathematical theory that can be used to analyze the influence of approaches and assumptions used to solve related problems. The key stakeholders from the airlines, ground handling, and airport authority agreed that the critical criteria to implement electric ground support equipment (E-GSE) are emissions standards, pollution sources, limit value, employee exposure, and stationary measurements. The alternative solutions are regulation, company finance, and infrastructure. Those criteria and alternative solutions are in line with the Indonesian government's regulation, supported by provision of the governor, concerning vehicle tax incentives for electric battery vehicles to support ground handling companies investment in electric ground support equipment (E-GSE) to reduce emissions in airports.

Keywords*:* emission; regulations; electric vehicle; ground operation

1. Introduction

An airport is a place for runways and takeoffs, landings and aircraft maintenance. The aviation industry is strongly influenced by air traffic conditions, service disruptions, weather, and mechanical disruptions (Wei & Gosling, 2013). More than 2 billion passengers travel around the world on airplanes and airports are part of a country's development that has socio-economic and environmental impacts.

Due to the increasing demand for air transportation, the aviation industry is predicted to continue to grow. Higher funding, development, repair and maintenance of airports need to be maintained (Sameh & Scavuzzi, 2016). Airport operators are responsible for providing the facilities and services of the air transportation industry. These responsibilities include service terminals, land transportation facilities, the provision of train terminals and cargo transportation between flight terminals and passenger terminals. They are also responsible for managing commercial airports, land or airport transportation, parking infrastructure, airport entry access, and other related factors outside the airport terminal boundaries (Graham, 2009).

Ground handling helps the fleet of aircraft on the ground. Accuracy, speed, safety, security and cost-effectiveness are crucial to minimize turnaround time. Ground handling also coordinates the movement of aircraft at the terminal gate during the time of departure. Equipment on land such as a ground power unit, pushback car, cargo and passenger boarding stair are known as ground support equipment (GSE). All these ground handling vehicles use diesel in their operations to cut costs; however, they create more pollution in the area during operation. Consequently, emissions planning for equipment at airports is very important. Multiple companies have attempted to switch their focus to fuel operation or be updated for ground operating vehicles (Aerospace, 2012).

The main environmental problems associated with airport transfers are emissions, noise, land use, and energy consumption (Sameh & Scavuzzi, 2016). Air transportation contributes greatly to air pollution, accounting for 12 percent of total emissions, while human-caused carbon emissions account for 26.4 percent (ICAO, 2010).

Air pollution comes from diesel fuel and dust when aircraft are on the ground. Emissions from diesel fuel occur when an airplane refuels and departs and varies based on the type of aircraft. Emissions from dust originate from brakes, tires and asphalt (Nadia & Mantecchini, 2014).

The main sources of air pollution in air transportation are aircraft engines and ground support equipment that use diesel fuel, such as nitrogen oxides (NOx), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), sulfur dioxide (SO2), and other materials (Kristensen et al., 2012).

The invention of electric vehicles is an effective method for lowering carbon emissions in the transportation sector. However, completely replacing fossil fuels with electricity or battery power is a challenge for the transportation industry. By employing the Vehicle to Grid (V2G) concept, electric transportation can deliver stored energy to the electric grid. Electric vehicles can be classified into the following categories: Battery Electric Vehicles (BEV), Hybrid Electric Vehicles (HEV), Plug-In-Hybrid Electric Vehicles (PHEV), and Extended Range-Electric Vehicle (EREV) (Yuan et al., 2017).

Electric batteries that are below the speed of 40 miles per hour with zero emissions can be applied to cars. PHEV are similar to HEV with the additional feature of a charging

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port, which is usually plugged into an electrical outlet. Some of the features of PHEV are improved fuel efficiency and lower emissions. BEV are fully electrically-operated, and the electrical outlet charging feature makes it a vehicle without emissions. An EREV is a combination of a battery electric vehicle and a plug-in hybrid electric vehicle with better efficiency (Shaukat et al., 2018).

For many years, because of the need of countries to improve the economy and lives of their inhabitants, fossil fuels such as petroleum, coal and gas have been used on a large scale. However, fossil fuels are one of the main culprits causing ozone depletion and air pollution. One solution to reducing pollution is the use of electric vehicles because electric fuel produces zero emissions. (Feng & Wang, 2000).

Emissions are generated from local power plants that use electricity to provide power to vehicle equipment at airports. These emissions are often released when using land support equipment. Equipment to support aircraft activities on the ground that use diesel fuel significantly contribute to pollution at airports (Airport Cooporative Research Program, 2012).

In Indonesia, aircraft handling procedures consist of catering, interior handling, refueling, maintenance, passenger handling, transportation, and others. One effort that can be made to achieve high performance is the improvement of maintenance performance (Nugroho et al., 2012). Despite several policies, mainland implementation companies do not have proper regulations regarding the use of environmentally friendly fuels. In airport activities, diesel ground support equipment can cause pollution, so the invention of electric ground support equipment can reduce pollution at airports (Kusnoputranto & Kristanto, 2014).

In response to climate concerns and a rising interest in electric vehicles, the transportation sectors of Southeast Asian countries are shifting towards the electric vehicle (EV) industry and ecosystem. The popularity of electric cars has encouraged a transition away from fossil fuels and has spread to Indonesia, where electric power adoption is on the rise. The countries have established comprehensive electric vehicle policies that take a holistic approach to developing the entire EV ecosystem by promoting demand and incentivizing private investment.

Currently, there are 30 electric vehicle charging ports at Soekarno Hatta Airport, around 200,000 aircraft passengers and 50,000 workers and visitors (non-passengers) who arrive every day, making this airport a strategic location for a campaign for the use of electric cars. The airport authority and Indonesia power will provide the infrastructure for charging electric car batteries known as public electric vehicle charging stations.

The transportation minister has released a statement restricting the use of ground support equipment to support airline activities on the ground. The challenge of this regulation arises from the limit on the age of the GSE because it costs a large amount of money for ground handling companies to rejuvenate their equipment (Sucipto, 2017).

Electric vehicles have a bright future in Indonesia. In recent years, the Indonesian government has made a concerted effort to increase the use of electric vehicles in the country. Electric vehicles are used in some airports, such as taxis, buses, skytrains, and

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ground support equipment. Despite the numerous benefits of using electric vehicles in airports, there is no plan in place in Indonesia to use electric ground support equipment.

2. Research method

First, an in-depth interview was conducted to gain a comprehensive understanding of the problems, and data were collected from the ground handling company. Next, comprehensive pairwise questionnaires were conducted before coming to conclusions (Rusdiyana & Devi, 2013). The population was chosen based on non-probability as well as a purposive sampling technique**.**

The total population consisted of ten respondents from the airlines, airport authority and a ground handling company. The interview utilized a scale that is commonly applied to measure statements, and the selected value represents the intensity of the judgment. The range has been chosen based on the stimulus-response theory and validated for effectiveness.

Table 1
Ultimate measure of the complete amount

Strength of Importance	**Description**	**Justification**
1	Likely significant	Two activities equally influence the objective
3	Relatively significant	Experience and judgment prefer one activity more than the other
5	Solidly significant	Ability and assessment strongly support one activity over the other
7	Precisely significant	Very strong activity, proven by practice
9	Excessively significant	Evidence favors one activity over the other
2,4,6,8	Agreement between the above values	Need to add a numerical assessment because there is no right word to describe it

Source : (Saaty, 2016)

The Analytical Network Process (ANP) is the tool for analysis, and the process utilizes Super Decisions tools. The ANP is a mathematical theory that can analyze the influence of approaches and assumptions to solve related problems. The ANP method thoroughly explains the representation of related factors and responses. The method involves three steps. First, questionnaires are distributed and in-depth interviews with experts are conducted to identify essential significant factors. Second, the results are collected and an ANP network is created to develop a questionnaire. Third, the analysis is applied to create alternative solutions, priorities and strategic policies (Haura et al., 2016).

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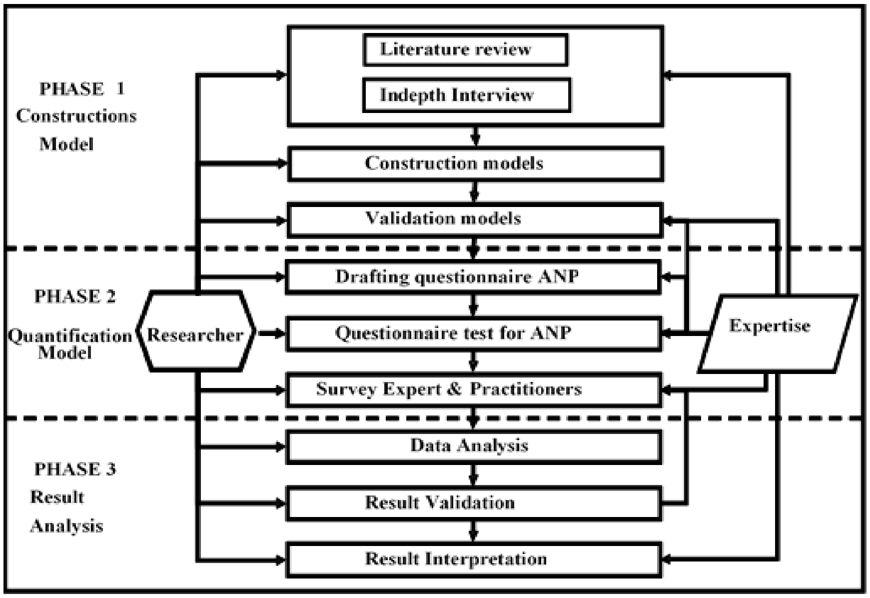

Figure 1 Analytic Network Process (Ascarya, 2011)

For the research process**,** the criteria and alternatives are the most important for the feasibility of using E-GSE in the aviation industry, and the research stages will be carried out as shown in Figure 1, such as cluster and criteria (node). There are three phases or stages of research to be conducted, namely; construction of the model, quantification of the model, synthesizing and analyzing the data. The geometric mean is a type of average calculation that shows a certain tendency or value, and has the following formula:

$$\left(\prod_i^n = 1 a_i\right)^{1/n} = \sqrt[n]{a_1 a_{2,,} a_n}$$

n = Respondent 1……… n
i = Pairwise 1……..i

To make a pairwise comparison, Super Decisions software version 2.10.0 was used. This software is commonly used in ANP research. Examples of questionnaires for conducting pairwise comparisons are shown in Figure 2.

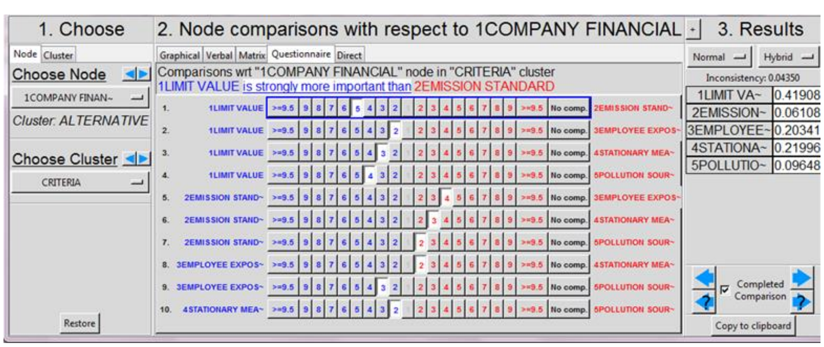

Figure 2 Sample questionnaire for pairwise comparison

3. Results and discussion

The survey was processed for each informant using the ANP Super Decisions software, and produced three super-matrices that prioritozed the order of significant problems and their respective solutions. Furthermore, the results were divided into groups of practitioners, academics, and regulators to produce the order of priority.

The average value and pattern were used to determine the priority order. Clusters were divided into three categories of goal, criteria, and alternatives. The goal was the use of electric vehicle equipment in the airline industry, while criteria and nodes were the limit values, emissions standards, employee exposure, stationary measurements, and pollution sources. The alternatives referred to company finances, regulations, and infrastructures.

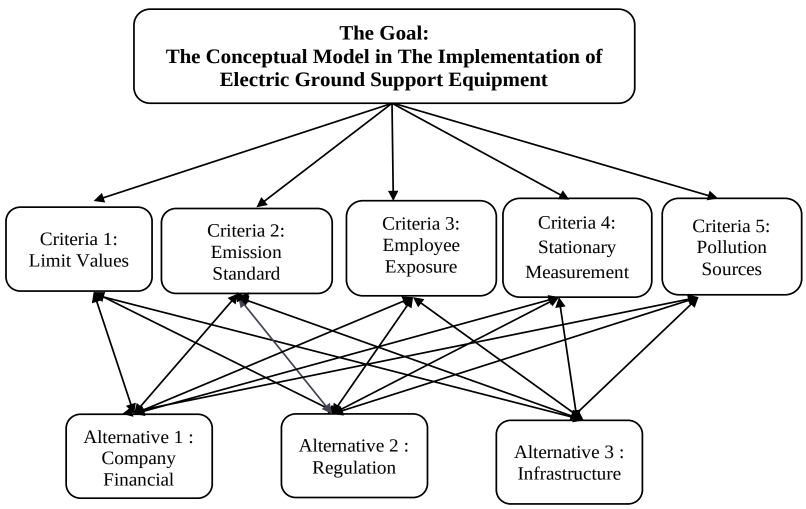

Figure 3 Structure model ANP

The results from the survey were processed for each respondent using the ANP framework to decipher the important criteria and alternatives for the use of electric vehicle equipment in the airline industry. The framework model also formed the basis of the questionnaires, and the data that were processed produced two matrices that gave priority order and appropriate alternatives from the perspective of each respondent.

In this study, there were ten respondents with airline, ground handling, and airport expertise who had different ideas and perspectives. Therefore, the ANP in the Super Decisions software presented the results that determined the overall priority order, which was then divided into three groups (clusters) of experts, namely the aviation industry, a ground handling company, and the airport authority.

3.1 Expert perspective from the aviation industry

In this discussion, the first research question will be answered regarding the most important criteria for the feasibility of using the E-GSE in the aviation industry from the perspective of the airlines. The results show that the obtained criteria are divided into five categories, namely, the limit values, emissions standards, employee exposure, stationary measurements, and pollution sources**.** Figure 4 shows the result of the interviews with airlines experts with the positions of pilot, corporate analyst, and operations manager.

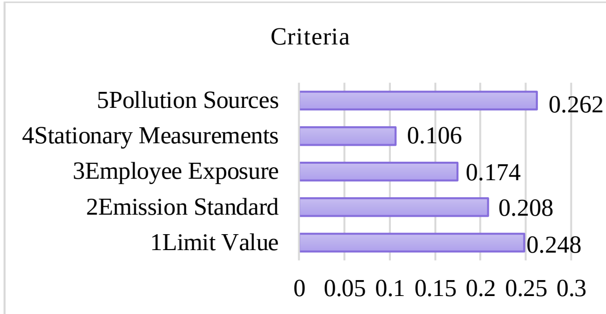

Figure 4 Criteria from airlines experts

The results showed that the essential geometric mean (GMK) value is 0.262 for the pollution sources category, which becomes an important issue for the feasibility of using the E-GSE from the perspective of an airlines expert. The second rank for the problem of E-GSE use is the limit value with a geometric mean score of 0.248, while that in the third place is emissions standards at 0.208. Furthermore, employee exposure is in fourth place with a value of 0.174, and in last place is stationary measurements with a geometric mean value of 0.106.

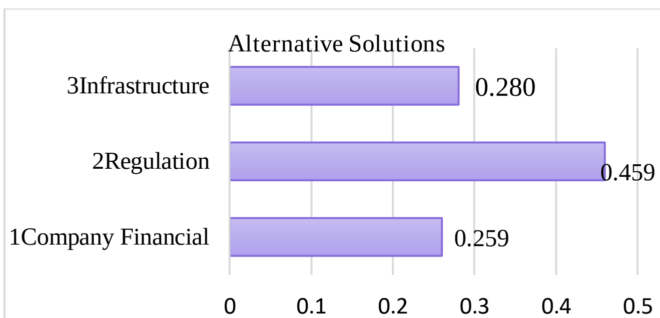

Figure 5 Alternative solution from airlines experts

Meanwhile, the alternative solutions related to the feasibility of using E-GSE in the aviation industry from the perspective of the airlines are divided into three alternatives, namely, company finance, regulation, and infrastructure. The results showed that the crucial geometric mean (GMK) value is 0.459 in regulation for the feasibility of using the E-GSE from the perspective of the airlines. The second ranked alternative is infrastructure with a value of 0.280, and the ultimate alternative solution is company finance with a geometric mean value of 0.259.

3.2 Expert perspective from the ground handling perspective

After discussing the related criteria and alternative solutions, the next important criteria will be addressed regarding the feasibility of using E-GSE in the aviation industry from the combined perspective of four ground handling experts.

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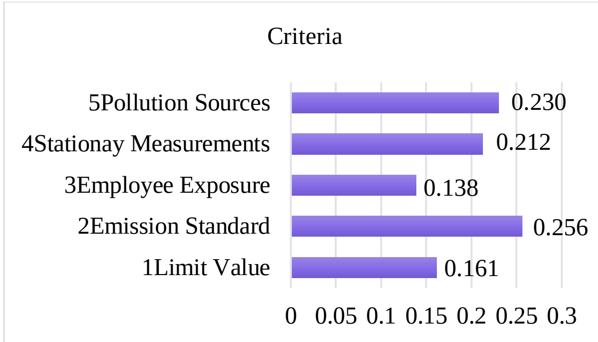

Figure 6 Criteria from ground handling experts

The results showed that the most critical geometric mean (GMK) value is 0.256 in the emissions standards category. The second ranked criterion is pollution sources with a mean geometric value of 0.230, while the third priority criterion is stationary measurement with a mean geometric value of 0.212. The fourth ranked criterion for the E-GSE feasibility problem from the perspective of ground handling experts is the limit value with a geometric mean value of 0.161, which is similar to employee exposure with a value of 0.138.

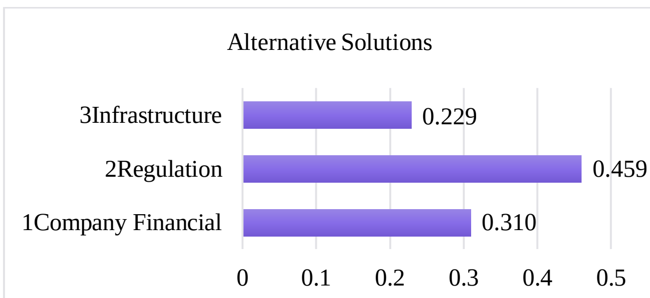

Figure 7 Alternative solutions from ground handling experts

Meanwhile, the alternative solutions from the perspective of ground handling experts show the essential geometric mean (GMK) value as 0.459 in the regulation category. This is similar to the result from the perspective of the airlines. The second ranked alternative is company finance with a mean geometric value of 0.310, and the last alternative solution is the infrastructure with a geometric mean value of 0.229. However, this result is essential and ranks second when compared to the element of company finance.

3.3 Expert perspective from the airport authority

The next criteria will be addressed regarding the feasibility of using the E-GSE in the aviation industry from the perspective of the airport authority. The results showed that the priority of each criterion is divided into five categories, namely, limit values, emissions standards, employee exposure, stationary measurements, and pollution sources**.**

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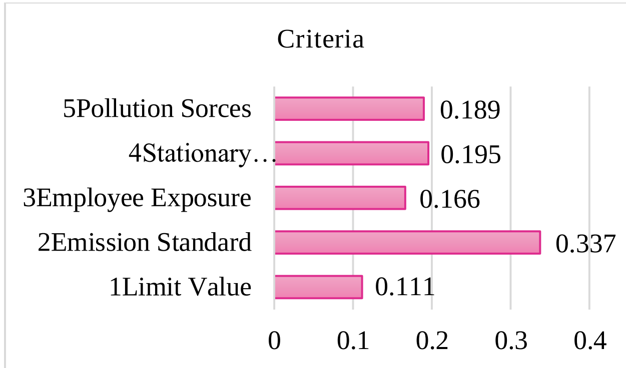

Figure 8 Criteria from airport authority experts

The results showed that the most important geometric mean (GMK) value is 0.337 in the emissions standards category, which is therefore an important issue in the feasibility of using the E-GSE in the aviation industry and is similar to the ground handling perspective. The second ranked criterion is stationary measurement with a geometric mean value of 0.195, while the third priority criterion is the pollution source with a value of 0.189. The fourth ranked crtierion from the perspective of airports is employee exposure with a geometric mean value of 0.166, and the last is the limit value of 0.111.

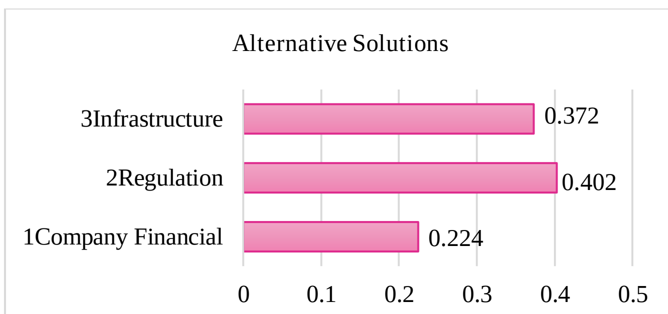

Figure 9 Alternative solutions from airport authority expert

Meanwhile, for the alternative solutions related to the feasibility of using E-GSE from the airport authority perspective, the most important geometric mean (GMK) value is 0.402 in the regulation category. These results are similar to all the experts opinions. The second ranked E-GSE feasibility solution is infrastructure with a geometric mean value of 0.372, and company finance has a geometric mean value of 0.224. These are relatively similar to the results from the airlines perspective, whereby infrastructure is essential and ranks second when compared to company finance.

Figure 10 Summary of criteria from the airlines, ground handling, and airport authority perspectives

Figures 10 and 11 give a summary of the three stakeholder's perspectives for the criteria. The highest rank is for emissions standards with a value of 0.57 and the alternative solution, regulation, has a value of 1.05. The emissions standards and regulation criteria are the most important for the conceptual model for the implementation of the use of electrical ground support equipment at Soekarno Hatta Airport, Jakarta, Indonesia.

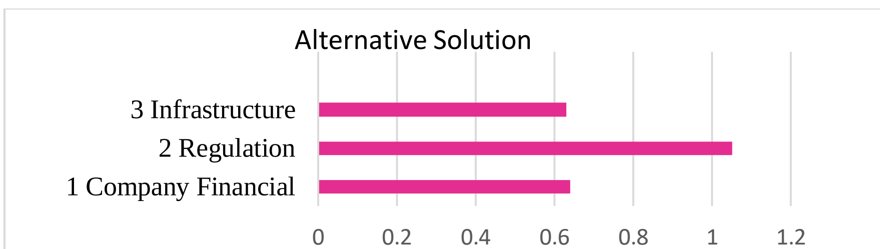

Figure 11 Summary of alternative solutions from the airlines, ground handling, and airport authority perspectives

3.4 Discussion

According to Scheelhaase (2018), it is essential to review the sources of emissions from aircraft operations. These emissions are carbon dioxide (CO2), nitrogen oxides (NOx), sulfur oxides (SOx), water vapor (H2O), and aerosols. Currently, international and domestic market measures only regulate CO2 emissions in aviation. The intention of Carbon offsetting and Reduction Scheme for International Aviation (CORSIA) and European Emissions Trading Scheme (EU ETS) for air transportation is to reduce CO2 emissions in aviation. However, there are other criteria, such as emissions measuring instruments at airports that companies need to invest in for the long-term according to Corsia and IATA standards (Scheelhaase, 2018).

From an economic perspective, the costs are very high. Fuel costs for an internal combustion engine (ICE) GSE are an important variable. For large airports, the use of land support equipment is significant and a large amount of fuel is used; therefore, the emissions released are substantial. The investment in land supporting equipment is growing for large airports (Morrow et al., 2007).

The ground handling experts suggest that to solve pollution-related problems, control and

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management should be in line with Presidential law no.55.This law states that Indonesia is committed to encouraging the acceleration of the battery-based motor vehicle program to support the reduction of greenhouse gas emissions; increase energy efficiency, energy security, and energy conservation in the transportation sector; realize clean energy and clean air; and encourage acceleration of use.

Airlines are undergoing some challenges such as cost pressures, compliance, and operational issues caused by competition and growth in the industry. Ground support equipment (GSE) are directly affected by these challenges, including the rising cost of fuel and pressure to reduce air pollutants. Many airlines, power utilities, and other GSE industry stakeholders are examining the cost-effectiveness of using E-GSE versus the alternatives of gasoline and diesel-fueled internal combustion engine (ICE) (Morrow et al., 2007).

Research on airports shows that they are responsible for the pollution generated at the local level which contributes to global warming. Local air pollution is determined by the amount of gases emitted by aircraft during their landing and takeoff period, according to ICAO Annex 16, Volume 2. The latter is divided into four stages, according to ICAO standards: take–off (0.7 minutes), climb (2.2 minutes to 3,000 feet above ground), approach (four minutes from 3,000 feet to landing), and idle (when the aircraft is taxiing or standing on the ground with engines on) (Grampella et al., 2017).

The Analytic Hierarchy Process and Analytic Network Process can be applied to the study of transportation even though the method is not specific to the feasibility of using electric ground support equipment. In this study, the Analytical Network Process (ANP) method was used to develop the conceptual model for the implementation of using electric fuel for ground support equipment by interviewing several people who are experts in the airlines, ground handling, and the airport authority. This method is considered appropriate for the subject under study because it creates a concept model that explains the global idea of involvement of individuals or groups and its development.

The most important parameters in this conceptual model are pollution requirements, and the most important alternative approach is regulation. Regulation is based on Presidential regulation No. 55 from 2019, and emissions standards are based on the International Air Transport Association (IATA) and Carbon offsetting and Reduction Scheme for International Aviation (CORSIA) standards.

4. Conclusion

The three stakeholders from the airlines, ground handling, and airport authority concluded that the most critical criteria for the implementation of electric ground support equipment are emissions standards, followed by pollution sources, limit value, stationary measurements, and employee exposure. The ranked alternative solutions are regulation, company finance, and infrastructure. To support airports, the airlines and ground handling agents in the implementation of the use of electric hevicles in ground support equipment, the government provided Presidential Regulation No.55 in 2019 outlining the fast track program for battery-powered electric vehicles for road transportation. The provision of the regulation from the governor discusses vehicle tax duty incentives for motorized battery-based vehicles (BEV) since their usage will decrease pollution.

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REFERENCES

Aerospace. (2012). *Reducing the environmental impacts of ground operations and departing aircraft: An industry code of practice*. Practice working group.

Airport Cooperative Research Program (ACRP) (2012). *Airport Ground Support Equipment (GSE): Emission reduction strategies,inventory, and tutorial*. Washington, DC: The National Academies Press. https://doi.org/10.17226/22681.

Ascarya. (2011). The persistence of low profit and loss sharing financing in Islamic banking: The case of Indonesia. *The 4th Bank Indonesia's Islamic Banking Reserch Forum*. Doi: https://doi.org/10.13033/isahp.y2009.087

Feng & Wang. (2000). Performance evaluation for airlines including the consideration of financial ratios. *Journal of Air Transport Management*, *6*(3), 133–142. Doi: https://doi.org/10.1016/s0969-6997(00)00003-x

Graham, A. (2009). *Managing the airports, an international perspective* (Third Ed). Butterworth-Heinemann.

Grampella, M., Martini,G., Scotti, D.,Tassan, F., Zambon, G. (2017). Determinants of airports' environmental effects. *Transportation Research*, *50*, 327–344. Doi: https://doi.org/10.1016/j.trd.2016.11.007

Haura, A., Baga, L.,Tanjung, H. (2016). Analysis of cash waqf management on Sharia financial service cooperation. *Analytical Network Process Approach, 3*(1), 89–105.

ICAO. (2010). *ICAO Environment Report*.

Kristensen, K.,Brogaard, L.,Jacobsen, J., Ellerman, T. (2012). Air pollution in airports. *The Danish Eco Counci*, *1*(1).

Kusnoputranto & Kristanto. (2014). Capacity evaluation of environmental noise for airport sustainability through Eco-airport. *Research Journal of Science & IT Management*, *03*(03), 20–27.

Morrow, K., Hochard, D., Franchort, J. (2007). *Cost benefit analysis modeling tool for electric vs . ICE Airport Ground Support Equipment — Development and results*. Doi: https://doi.org/10.2172/911917

Nadia, M., & Mantecchini, L. (2014). A transport carbon footprint methodology to assess airport carbon emissions. *Journal of Air Transport Management*, *37*, 76–86. Doi: https://doi.org/10.1016/j.jairtraman.2014.03.001

Nugroho, I. A., Riastuti, U. H., & Iridiastadi, H. (2012). Performance improvement suggestions for ground handling using lean solutions approach. *Procedia - Social and Behavioral Sciences*, *65*(ICIBSoS), 462-467. Doi: https://doi.org/10.1016/j.sbspro.2012.11.149

Rusdiyana & Devi. (2013). Challenges in developing Baitul Maal Wat Tamwil (BMT) in Indonesia using Analytic Network Process (ANP). *Business & Management*, *4*(2), 51–62. Doi: https://doi.org/10.29244/jam.1.2.107-118

Saaty, R. (2016). *Decision making in complex environments*. Pittsburgh, PA, USA: Katz Graduate School Of Business.

Sameh & Scavuzzi. (2016). Environmental sustainability measures for airports. *Centre of Research in Air and Space Law*, *7*, 1–12.

Scheelhaase, J. D. (2018). How to regulate aviation's full climate impact as intended by the EU council from 2020 onwards. *Journal of Air Transport Management*, *75*, 68–74. Doi: https://doi.org/10.1016/j.jairtraman.2018.11.007

Shaukat, N., Khan, B., Ali, S. M., Mehmood, C. A., Khan, J., Farid, U.,Ullah, Z., Anwar, M. (2018). A survey on electric vehicle transportation within smart grid system. *Renewable and Sustainable Energy Reviews*, *81*, 1329–1349. Doi: https://doi.org/10.1016/j.rser.2017.05.092

Sucipto. (2017). Indonesia aviation outlook 2017. *Signature*, 219.

Wei, W., & Gosling, G. D. (2013). Strategies for collaborative funding of intermodal airport ground access projects. *Journal of Air Transport Management*, *32*, 78–86. Doi: https://doi.org/10.1016/j.jairtraman.2013.07.006

Yuan, K., Song, Y., Mu, Y., Andri, I., Pina, A., Ferrão, P., Fournier, J., Lacarrière, B., & Corre, O. Le. (2017). A load forecast method for fast charging stations of electric a load forecast method for fast on charging stations of electric vehicles on the freeway considering the information interaction. *9th International Conference on Applied Energy, ICAE2017*. Doi: https://doi.org/10.1016/j.egypro.2017.12.584