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Exploring Sustainability Decisions for Ground Operation in Indonesia Airports

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Abstract

This study aims to investigate sustainability decision-making processes for ground operations in Indonesian airports utilizing Analytical Networking Process (ANP). Employing both qualitative and quantitative methodologies, data were gathered through interviews with key stakeholders, including ground handling personnel, airport authorities, and airline experts. Analysis was conducted using ANP facilitated by Super Decision tools, a mathematical theory aiding problem-solving. Ten respondents from ground handling, airport authorities, and airlines identified criteria for sustainability, including digitalization of aircraft, adoption of electric vehicles, implementation of robotic baggage systems, automation of operational processes, and enhancement of operational efficiency. Proposed alternative solutions encompass artificial intelligence tools, innovation initiatives, and data development strategies. These criteria and alternative solutions align with the International Air Transport Association (IATA) guidelines for sustainable ground operations and Indonesian governmental regulations outlined in No. 111 of the year 2022 concerning sustainable development goals.

Keywords: *sustainability, digitalization, ground operation.*

1. Introduction

The global pursuit of reducing emissions has intensified efforts to develop vehicles with minimal environmental impact, as the transportation sector contributes nearly one quarter of total energy emissions worldwide (Cihat Onat et al., 2020). Among industries, the automotive sector stands out for its substantial investment in research and development to diminish reliance on fossil fuels, with electric vehicles (EVs) emerging as a prominent solution to mitigate emissions amidst rising energy costs and climate change concerns (Tseng et al., 2013)(Granovskii et al., 2006)

While electric mobility holds promise for fostering sustainability, challenges abound, including the high cost of EVs, societal adjustments, limited driving range, and prolonged recharging times. Implementing EVs on a systemic level necessitates comprehensive infrastructure, integrated charging solutions, and grid enhancements within urban environments (Silvester et al., 2013).

Aviation emissions come from a variety of sources other than aircraft propulsion systems. Ground support activities require a variety of vehicles and equipment, many of which are

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powered by fossil fuels and release significant amounts of pollution. These emissions include vehicles used for passenger transportation, shuttle services, and ground support equipment (GSE), which is required for aircraft ground operations. Notably, emissions are caused by power supplied to machinery, the fixed airport power source, and parked aircraft at terminal gates, necessitating the use of auxiliary power units (APUs) to ensure autonomous ground operations and onboard equipment functionality in the absence of engine operation (Federal Aviation Administration, 2015).

Furthermore, emissions come from the combustion of gasoline in cars, trucks, and other vehicles that operate on airport grounds. While airplane engines mostly emit CO2 and H2O, they also emit a variety of pollutants such as NOx, SOx, CO, HC, particulate matter, and trace chemicals. Despite accounting for a small proportion of total emissions, these contaminants have a considerable impact on air quality (Federal Aviation Administration, 2015).

Atmospheric emissions from ground vehicles are a major source of concern at airports, as they have a negative impact on nearby air quality. Addressing this issue requires investigating alternatives such as switching from diesel to electric vehicles, as advocated by (Fontela et al., 2007).

This integrated approach to understanding aircraft emissions emphasizes the multidimensional character of the aviation industry's environmental concerns, highlighting the need for comprehensive mitigation solutions to promote sustainability and reduce environmental impact.

Ground operations at airports encompass a range of activities crucial for aircraft handling, including towing, pushback, and operational safety measures (SKyBrary, 2018).). Strategies like fuel conservation, optimized towing procedures, and engine shutdown during taxiing contribute to emissions reduction and operational efficiency (Gelinas & Fan, 2012).

While the aviation industry's contribution to global emissions remains relatively modest, emissions released at higher altitudes possess significant climatic implications, underscoring the need for sustainable aviation practices (Federal Aviation Administration, 2015). Embracing global initiatives such as the Sustainable Development Goals (SDGs) aligns with the aim of promoting economic welfare, social sustainability, and environmental preservation (Indonesia Government Regulations No.111, 2022).

Aviation emissions have a substantial impact on global climate and air quality, yet their proportion to overall emissions is relatively low when compared to other industries concerned with global warming and air pollution. However, the majority of aircraft emissions disperse at high altitudes in the upper troposphere and lower stratosphere, possibly having far-reaching climate consequences (Federal Aviation Administration, 2015).

Aligned with larger environmental imperatives, the Sustainable Development Goals (SDGs) provide a comprehensive framework for eradicating poverty, improving wellbeing, and protecting the planet by 2030. The SDGs prioritize sustainable economic growth, social well-being, environmental quality, and inclusive development, which are supported by governance practices that promote intergenerational increases in quality of life (Indonesia Government Regulations No.111, 2022).

Anticipating future trends, air traffic management is ready for revolution, with less human intervention and increased information flow among trustworthy operators. Higher levels of automation and autonomy, such as unmanned aircraft, are expected to be integrated by 2045. This transition involves a move from a human-centric air traffic management paradigm to one characterized by growing system autonomy, with management primarily carried out by exception. Full autonomy denotes a situation with little human interference, indicating the evolution of aviation operations toward higher efficiency and safety (International Air Transport Association (IATA), 2023).

2. Research Methods

The Analytic Network Process (ANP) is used in the study as a mathematical theory for studying influence using a structured assumption-based problem-solving technique. ANP facilitates solution formulation by decomposing and synthesizing complex issues, as well as using a priority scale to systematically identify the most significant aspects. This strategy clarifies the interdependence of components and their feedback loops, hence improving decision-making through empirical validation and experiential considerations (T. L. Saaty & Vargas, 2006).

The identification of alternatives and criteria is critical to the study process for evaluating sustainability in ground operations in the aviation industry. The research is divided into three stages: model construction, quantification, and data synthesis and analysis. The geometric mean, expressed by the following formula, is a crucial tool for identifying tendencies or values within the data:

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

n = Respondent 1…….. n

i = Pairwise 1……i

In order to fully comprehend the issues at hand, the study first conducts an extensive interview in addition to preserving data from the ground handling company. Before resolving the issues, the second meeting's requirements were to complete pairwise questionnaires (Rusydiana & Devi, 2013).

Fifteen participants from the airline industry, airport administration, and ground handling company make up the total population. The generally used scale, whose value indicates the intensities of judgment, was employed in the interview to measure each of the statements. The range was selected using the stimulus-response theory, and its efficacy has been verified by both the theoretical rationale for the scale that will be used to produce comparable elements as well as by some individuals.

The basic value scale that will be used to express the range of judgment intensities

Table 1. Comparison Scale

Scale Level	Definition	Explanation
1	Like significant	Two activities influence equally to the objective
3	Relative significant	Experience and judgment prefer one activity more than another
5	Solid significant	Ability and assessment strongly support one activity with another
7	Precise significant	Very strong activity, proven by practice
9	Excessive significant	The evidence favoring one activity over another
2,4,6,8	For an agreement between the above values	Need to add a numerical assessment because there is no right word to describe it

Sources : (R. Saaty, 2016)

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 1.

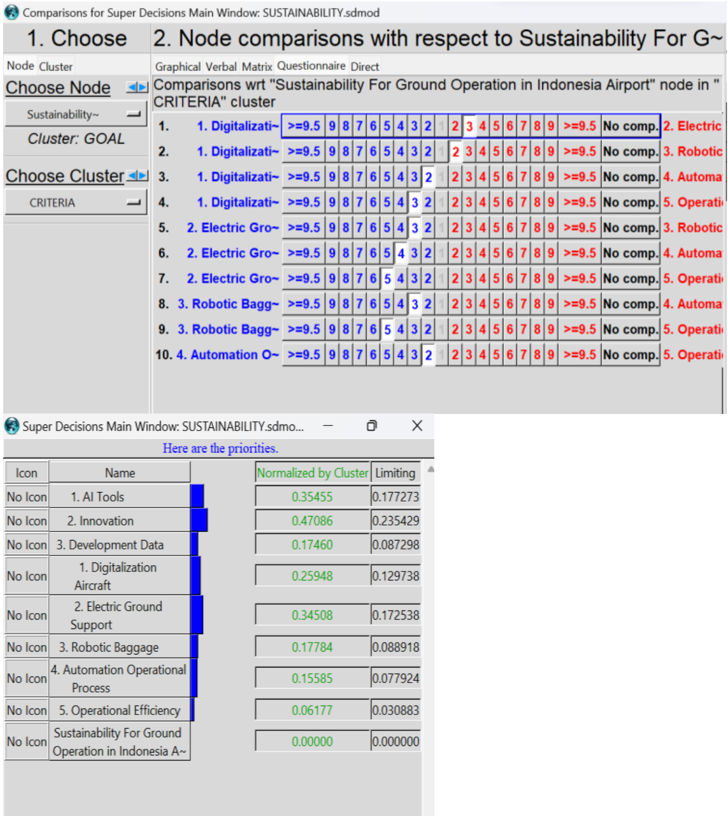

Figure 1. Sampel Questionnaires for pairwise comparison

3. Result and Discussion

The conceptual model for integrating electric ground support equipment in Indonesian ground handling activities highlights the importance of emissions requirements to stakeholders. Stakeholders from airlines, airports, and ground handling professionals see adherence to emissions requirements as critical, lobbying for regulatory compliance with Indonesia Government Regulation No. 55 of 2019, which is consistent with IATA and CORSIA norms (Sari et al., 2021).

In terms of sustainability, ground operations target four essential areas: people, planet, profitability, and connections. These include developing long-term strategies to address issues such as labor shortages, personnel retention, and the use of environmentally friendly methods in managing Ground Support Equipment (GSE) operations. Digitizing ground operations, streamlining procedures, and improving operational efficiency are all critical components of sustainable practices. Notably, the continued growth of the economy is dependent on the digitalization and automation of ground operations, as well as process innovation (International Air Transport Association, 2024).

Ground operations' key development projects include digitalizing load control and aircraft turnaround procedures, automating operational processes, and modernizing GSE with enhanced/electric models, including the shift to autonomous vehicle operations. Furthermore, integrating robotics for luggage and airline loading is a critical step toward improving operational efficiency and sustainability in the aviation industry (International Air Transport Association, 2024).

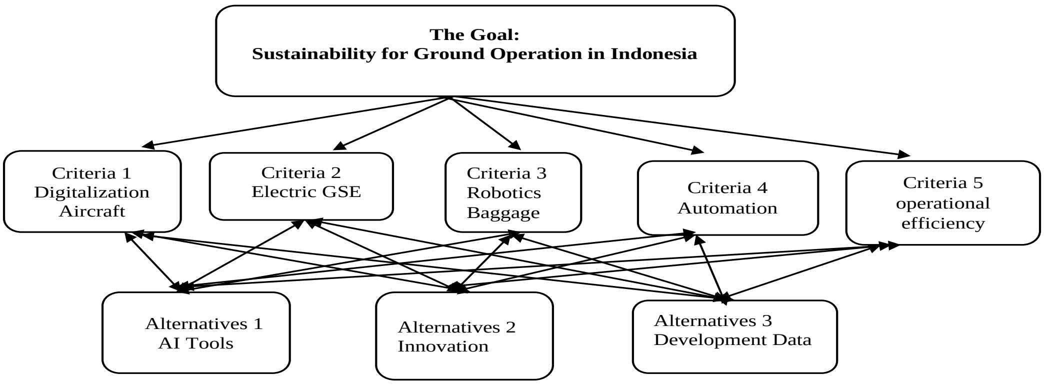

Figure 2. Structure model for ANP

The sustainability framework model for ground operations at Indonesian airports was formulated through comprehensive research involving 10 respondents from various sectors including ground handling, airport management, and airline expertise. These respondents provided diverse perspectives, contributing to the development of the framework.

3.1 Perspective from Ground Handling

The findings from interviews conducted with ground handling experts, including general managers, station managers, and operational managers, revealed significant insights. According to Figure 3, the most crucial aspect for sustainability in ground operations at Indonesian airports is the adoption of electric ground support, indicated by a geometric mean (GMK) value of 0.309. Following closely is the digitalization of aircraft, with a GMK value of 0.261, while robotic baggage ranks third with a GMK of 0.210. Automation of operational processes occupies the fourth position with a value of 0.142, and operational efficiency is identified as the least prioritized factor, with a value of 0.075.

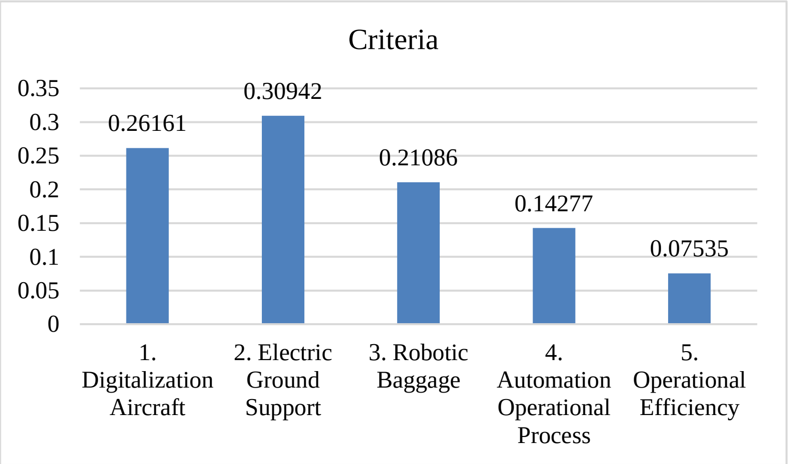

Figure 3. The criteria from ground handling expert

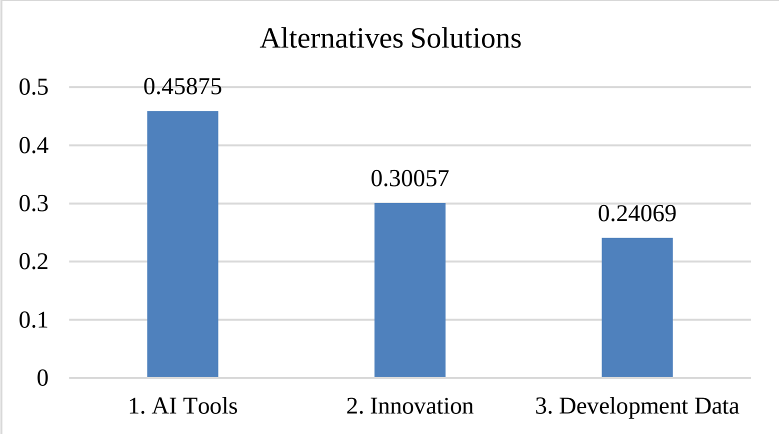

Figure 4. The alternative solution from ground handling expert

According to ground handling experts, three alternative alternatives for sustainability in ground operations in Indonesia are available: AI Tools, Innovation, and Data Development. Figure 4 shows that AI Tools emerged as the most important choice, with a geometric mean (GMK) of 0.458. Innovation came in second with a value of 0.300, while Development Data was last with a value of 0.240.

3.2 Perspective from Airport Experts

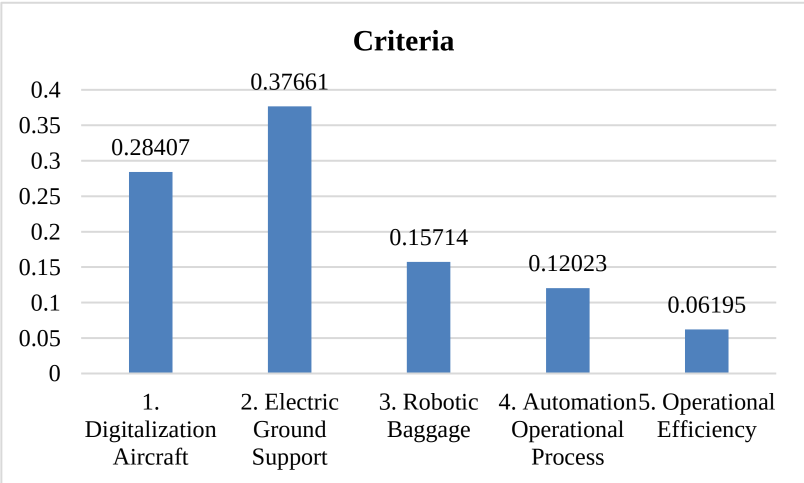

Figure 5. The criteria from Airport Authority Expert

The interview conduct from airport experts is General Manager, Officer in Charge, and Station Manager. Figure 5 showed the critical geometric mean (GMK) value is 0.376 for electric ground support equipment. The second sequence is digitalization aircraft with value is 0.284. Finally, the value comes out is 0.157 robotic baggage.

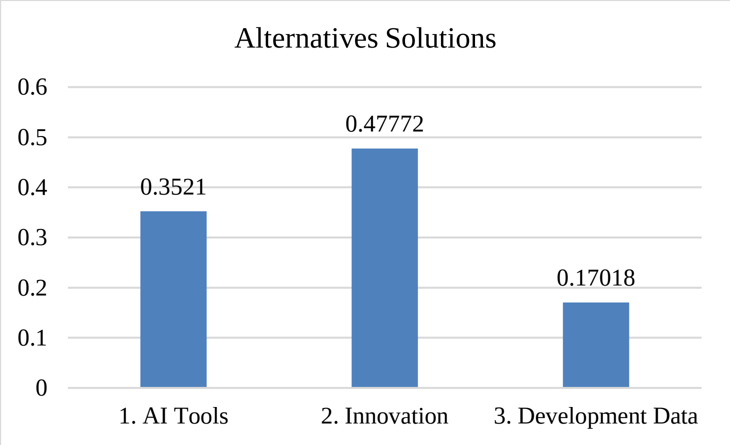

Figure 6. The alternative solutions from Airport Expert

In terms of alternative solutions for sustainability in ground operations as perceived by airport authority experts, Figure 6 reveals that innovation emerged as the most significant option, with a substantial value of 0.477. AI Tools followed closely with a value of 0.352, while development data ranked last with a value of 0.170.

3.3 Perspective from Airline Experts

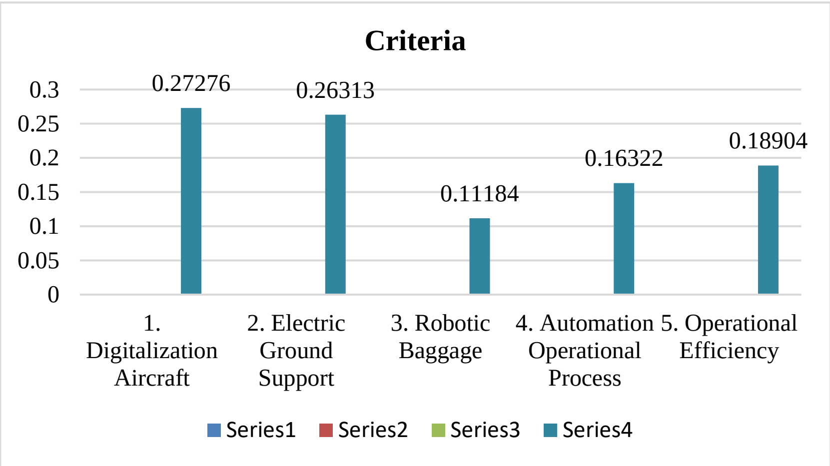

Figure 7. The criteria from airline experts

The next criteria are from the airline perspective with involve the pilot, station manager, and operational manager. The figure 7 showed the most important for sustainability is digitalization aircraft with geometric mean value is 0.272. The second sequence is electric ground support with geometric mean value is 0.263, follow by operational efficiency with value 0.189.

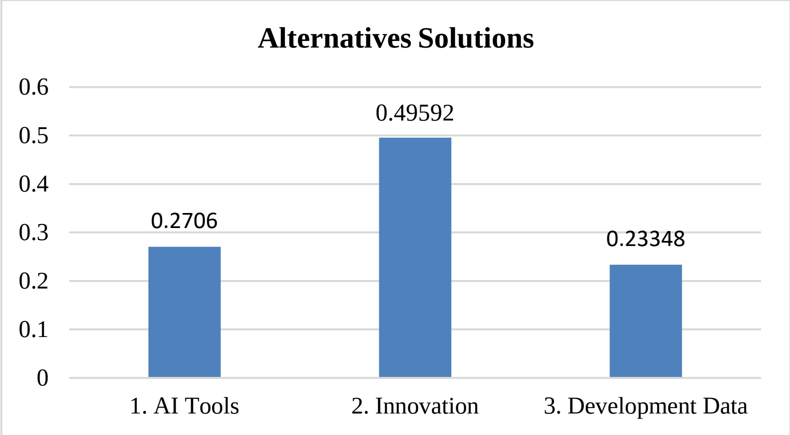

Figure 8. The alternative solutions from airline experts

Meanwhile the figure 8 showed alternative solution for the sustainability in ground operation from airline expert is innovation with significant value is 0.495, followed by AI Tools is 0.270, and the last is 0.233 for development data.

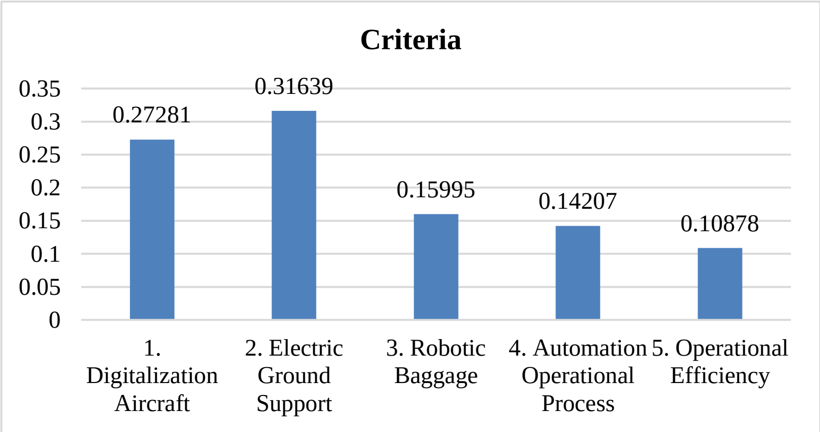

Figure 9. Summary of criteria from the ground handling, airport and airline experts' perspective.

Figure 9 showed summary from three stakeholder where the most criteria for sustainability for ground operation is electric ground support with geometric mean value is 0.316 and followed by digitalization with value is 0.272. The following order is robotic baggage with value 0.159, the fourth sequence is automation operational process, and finally is operational efficiency with geometric mean value is operational efficiency.

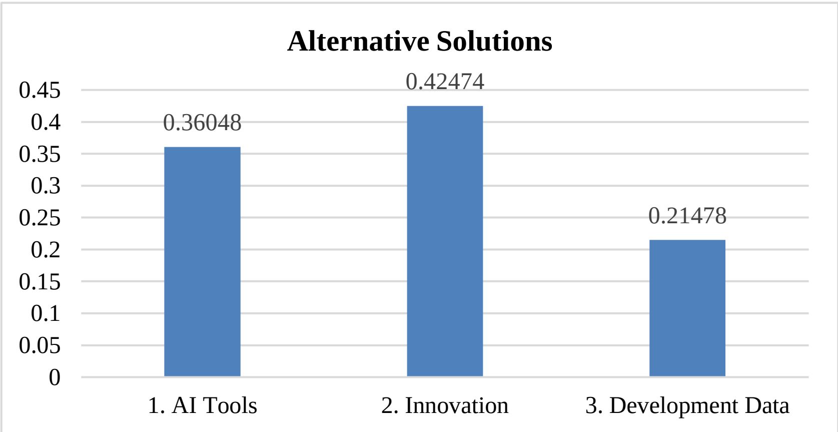

Figure 10. Summary of alternative solution from the ground handling, airport and airline experts' perspective.

According to Figure 10, alternative solutions for sustainability in ground operations highlight innovation as the most significant option, with a geometric mean value of 0.424. Artificial intelligence (AI tools) follows closely in second place, with a value of 0.360. Lastly, development data ranks third with a value of 0.214.

3.4 Discussion

The research on air transportation sustainability employs the Analytic Hierarchy Process (AHP) to analyze airport efficiency modeling, focusing on sustainability aspects. A sustainable airport efficiency model was devised using data from passenger, cargo, and aircraft movement outputs, alongside estimations of taxiing times and emissions produced per landing and take-off (LTO) cycle, based on taxiing times (Güner, 2021).

Efficient ground handling at airports is pivotal for air travel sustainability. A collaborative decision-making system facilitates online fleet assignment to ground handling tasks and promotes information exchange within airports (Alonso Tabares et al., 2021).

Electric vehicles are deemed essential in the automotive industry for sustainable development, contributing to lower greenhouse gas emissions, reduced air pollution, and creating new job opportunities. However, the integrated impact of electrified powertrains on automotive industry supply chain sustainability and passenger car fleet development remains underexplored (Günther et al., 2015).

Aircraft turnaround efficiency refers to executing required operations within a stipulated time frame to ensure punctual flight departures. Coordination among service providers such as ground handlers, fuel, and catering suppliers is critical for an efficient turnaround (Malandri et al., 2019).

Environmental conditions pose sustainability-based risk factors, affecting employee health and job satisfaction. Measures to mitigate physical effects of environmental factors, especially in ramp operations where personnel face adverse weather conditions, are crucial for maintaining efficiency (Yazgan et al., 2022).

Artificial intelligence (AI) facilitates cognitive tasks, benefiting governments and corporations worldwide through data processing and algorithmic analysis. Its popularity has surged with the abundance of data generated by the internet (Iyer, 2021).

The use of external electric towing during aircraft taxiing offers potential to reduce ground-based carbon dioxide emissions. However, further data and feedback from stakeholders are needed to assess cost-effectiveness and refine modeling techniques for efficient implementation (Salihu et al., 2021).

Analytic Network Process (ANP) and AHP methods are instrumental in transport and sustainability research. In the context of sustainability for ground operations in Indonesia, these methods are applied to incorporate expert opinions from ground handling, airports, and airlines. Parameters from IATA regulations, FAA, and Indonesian government regulations are integrated to develop a conceptual model for sustainable decision-making in Indonesian airport ground operations.

In terms of ground operations sustainability in Indonesia, the Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP) techniques are critical, leveraging expert views from ground handling, airports, and airlines to build a conceptual model. These methods allow for systematic decision-making by incorporating priorities and parameters from authoritative sources such as the International Air Transport Association (IATA), the Federal Aviation Administration (FAA), and Indonesian government regulations, specifically Regulation No. 111 of 2022, which addresses sustainable development goals. The sustainability framework designed assures comprehensive and successful ground operations for Indonesian airports by incorporating multiple views and matching with existing requirements.

4. Conclusion

The prioritization reveals a deliberate focus on particular standards and potential remedies, offering insights into the crucial areas that stakeholders think would have the most impacts on sustainability in ground operations—both internationally and in Indonesia particularly. Based on expert opinions from three stakeholders, the prioritization of criteria for sustainability in ground operations indicates that the implementation of electric ground support equipment holds the highest importance, where the usage of electrically driven equipment in ground operations is emphasized, indicating a shift towards greener and more ecologically friendly technologies. This might apply to ground-level machinery and electric cars. following by digitalization of aircraft, robotic baggage, automation of operational processes, and finally operational efficiency. In terms of alternative solutions for sustainability in ground operations in Indonesia, innovation emerges as the top priority, followed by AI Tools, with development data ranking last. Innovation is the key to attaining sustainability in Indonesian ground operations. This all-encompassing phrase may refer to the creation and application of fresh and innovative methods, tools, and techniques to deal with environmental issues in aircraft ground operations.

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