

Ensuring Suitability of Ground Support Equipment: The Role of AMC in Maintenance Supervision

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Abstract

The decision of Apron Movement Control (AMC) to supervise the feasibility of Ground Support Equipment (GSE) is critical to ensuring safe and efficient airport operations. This study develops a structured decision-making model for assessing GSE feasibility using the Analytical Network Process (ANP). The research was conducted at Yogyakarta International Airport, Indonesia, incorporating multiple criteria and sub criteria, including engine condition, safety features, and vehicle operation licensing. ANP was selected for its capability to model complex interdependencies among assessment elements. Data were collected through expert questionnaires involving relevant aviation stakeholders and analyzed to determine the relative weights and priorities of each criterion. The results indicate that document validity, corrective actions, and leakage conditions exert the greatest influence on GSE feasibility assessments. The proposed model provides a systematic and transparent framework to support AMC supervision activities, contributing to improved GSE safety standards and operational efficiency at airports. Furthermore, the findings demonstrate the applicability of the ANP method for feasibility evaluation and broader managerial decision-making processes within the aviation industry.

Keywords: suitability, ground support equipment, analytical network process, Apron Movement Control.

1. Introduction

Aircraft ground handling is a critical component of air operations, directly affecting both flight punctuality and safety. It comprises a range of services provided to aircraft while on the ground during arrival, departure, or turnaround phases, including refueling, baggage handling, cabin cleaning, catering, passenger boarding, de-icing, towing, and maintenance inspections (Skorupski et al., 2020). Effective coordination of these activities is essential and involves multiple ground personnel, such as ground handlers, maintenance crews, and airport operations staff.

One key airport operational unit is Apron Movement Control (AMC). AMC personnel are licensed airport authorities responsible for controlling and supervising all movements within the apron area, including aircraft, vehicles, personnel, and goods. AMC oversees airside operational services, airside cleanliness, and the safe movement of aircraft, vehicles, passengers, and cargo on the apron (Jati & Pradana, 2023).

The role of AMC includes monitoring aircraft movements, vehicle traffic, airside cleanliness, and the management of Ground Support Equipment (GSE) within the apron area. AMC is responsible for airside supervision, ground-based flight service operations, vehicle and passenger traffic control, aircraft maneuvering oversight, cargo handling, airside cleanliness, and the placement, arrangement, and supervision of GSE (Adyuta Daniswara & Abdusshomad, 2024) (Muhamad Ihsan Saputra, 2022).

To ensure safe and orderly apron operations, AMC supervises apron markings and signage that guide vehicle and aircraft movements. These markers provide standardized guidance

to enhance safety for both passengers and ground personnel. Service roads, in particular, represent critical apron infrastructure elements supporting controlled vehicle movement (Augusta & Purnama, 2024). Aircraft ground handling activities significantly influence airport traffic safety, with human factors frequently cited as primary contributors to incidents. GSE operators are often directly or indirectly involved in such events (Skorupski et al., 2020). In addition to operators, effective GSE maintenance plays a vital role, aiming to ensure equipment safety, reliability, and serviceability while minimizing cost and downtime, in compliance with airport operational regulations (Ur Rahman & Akbar, 2023).

Given the broad scope of AMC responsibilities covering airport administration, ramp services, baggage handling, aircraft towing, and refueling enhancing operational safety and efficiency is essential for overall airport performance. Aircraft movements, including taxiing, towing, pushback, and apron maneuvering, represent complex operational processes requiring precise coordination (Buelta et al., 2024). AMC guides the movement of airside vehicles, such as buses, service vehicles, handling equipment, and fuel trucks, while ensuring compliance with designated operational zones reserved for aircraft and ground vehicles (Postorino et al., 2006).

AMC performance is closely linked to ground handling reliability. Aircraft failures, GSE malfunctions, and operator errors can all contribute to operational delays, with a single delay potentially triggering cascading disruptions across airport operations (Skorupski & Żarów, 2021). AMC also coordinates with Air Traffic Control (ATC), which supports trajectory prediction, conflict detection, and situational awareness for pilots and controllers (Ali et al., 2015). However, many existing ATC systems are reaching the end of their operational lifecycles and struggle to accommodate increasing air traffic volumes, particularly in remote, low-altitude, and maritime regions (Ali et al., 2015).

Beyond operational challenges, ground operations contribute significantly to environmental impacts. Emissions generated during taxiing, takeoff, and landing represent major pollution sources, supplemented by emissions from auxiliary power units (APUs), ground power units (GPUs), and servicing vehicles during aircraft turnaround processes (Padhra, 2018). Aircraft movements within airport operational areas substantially affect fuel consumption, emissions, labor costs, and departure punctuality. While runway, terminal, and control capacities are typically considered in slot allocation, climate-sensitive and movable operational constraints are often overlooked (Park & Kim, 2023). Notably, during the COVID-19 pandemic, environmental impacts temporarily decreased due to widespread aircraft grounding (Adrienne et al., 2020).

Considering the increasing complexity of apron operations, the risks associated with GSE utilization, and the potential for cascading delays due to inadequate supervision, this study aims to examine how AMC can ensure the feasibility and suitability of GSE through effective maintenance supervision, thereby enhancing safety, efficiency, and operational continuity.

This research focuses on Ground Support Equipment (GSE) and the supervisory role of AMC across three primary factors affecting apron performance: operational document validity, operator competency, and equipment condition. Failure in any of these dimensions increases the risk of incidents and disrupts apron operations. To address this challenge, the study proposes an Analytic Network Process (ANP) model that integrates all dimensions of GSE feasibility and quantitatively prioritizes their interrelationships, providing an objective and implementable decision-making basis for AMC.

This research contributes in three key ways. First, it introduces a comprehensive ANP-based decision model for GSE feasibility, offering a systematic and transparent framework for AMC decision-making. Second, it proposes a conceptual model that quantitatively identifies

critical priorities previously assessed only qualitatively. Third, it strengthens the role of AMC as a GSE feasibility supervisor through a scientifically grounded approach.

Recent studies indicate that apron safety is strongly influenced by GSE technical condition, operator compliance, and document validity, alongside the need for integrated oversight and technological systems. However, existing research has not fully synthesized all GSE feasibility dimensions such as mechanical condition, safety features, and document legality into a scalable decision-making framework.

This study addresses this gap by developing an integrated ANP-based framework that captures interdependencies among criteria and provides practical decision support for AMC supervision.

2. Methodology

This study employs the Analytic Network Process (ANP) to develop a decision-making model. ANP was selected due to its ability to handle complex interactions among criteria and sub-criteria. The method analyzes relative influence through assumption-based problem structuring and decomposes complex decision problems into interrelated elements. Priority scales are used to identify the most influential factors while accounting for dependency and feedback relationships. Decision-making within the ANP framework is based on validated empirical judgment (T. L. Saaty & Vargas, 2006).

The most critical components of the research process for assessing the sustainability and viability of ground operations in the aviation sector are the defined alternatives and evaluation criteria. The study is conducted in three stages: model development, quantification, and data synthesis and analysis. Expert judgments are aggregated using the geometric mean, as expressed in Eq. (2-1):

$$(\prod_i^n = 1a_i)^{1/n} = \sqrt[n]{a_1 a_2 \dots a_n} (\prod_i^n = 1a_i)^{1/n} = \sqrt[n]{a_1 a_2 \dots a_n} \quad (2-1)$$

where $a_i a_i$ represents the pairwise comparison value provided by the ii -th respondent, and nn denotes the total number of respondents.

To ensure a comprehensive understanding of the problem, the study first conducted in-depth interviews and collected supporting data from the ground handling company. Subsequently, respondents were requested to complete pairwise comparison questionnaires to support the ANP analysis (Rusydiaana & Devi, 2013).

The study informants consisted of practitioners with demonstrated expertise in the relevant field. Informants were selected based on their knowledge and experience in evaluating the feasibility of GSE. Data collection was conducted through interviews to obtain in-depth insights into the research object. The number of respondents was set at a minimum of five individuals holding supervisory positions.

Table 1 presents the comparison scale used in this study. The scale ranges from 1 to 9, where each value represents a level of dominance or preference between criteria. Intermediate values of 2, 4, 6, and 8 are applied when judgments between two adjacent importance levels are required. This scale facilitates structured and objective evaluation in the ANP analysis.

Table 2-1: 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)

3. Result and Analysis

Based on the analysis, an ANP network structure was constructed to represent the relationships among the research goal, evaluation criteria, and decision alternatives.

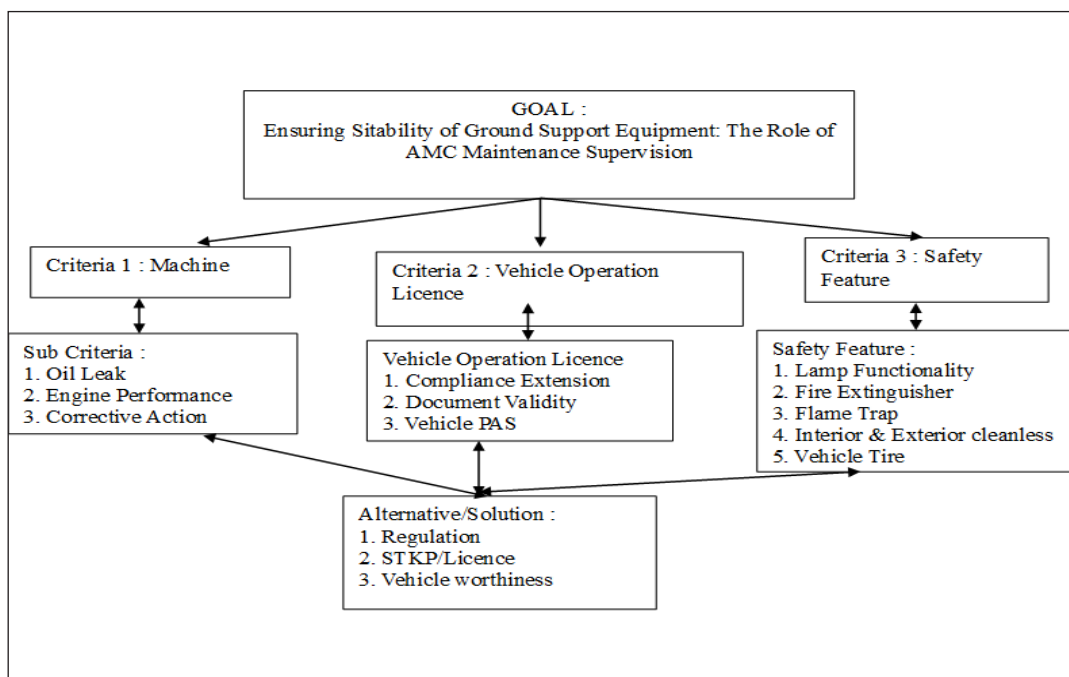


Figure 3-1: ANP Network Structure.

Figure 3-1 shows that the feasibility of ground support equipment is primarily influenced by three main criteria: engine condition, vehicle operating license, and safety features. Engine condition is characterized by indicators such as oil leakage potential, engine performance, and corrective actions for identified defects. The vehicle operating license criterion reflects regulatory compliance and is assessed through permit processing speed, document validity, and the use of vehicle identification cards for airside operations. Safety features are evaluated based on lighting functionality, fire extinguisher availability, flame trap presence, detection systems, and tire condition.

The results highlight the critical role of AMC in supervising GSE operations to ensure both safety and regulatory compliance. Effective AMC oversight ensures that GSE units operate within acceptable technical and legal standards, thereby reducing operational risks on the apron.

Based on the ANP results, several alternative strategies emerge as effective measures for improving GSE feasibility, including strengthened regulatory enforcement, competency enhancement through licensing and structured training programs, and systematic vehicle fitness inspections. These alternatives collectively support the primary objective of ensuring reliable and safe GSE operations through effective maintenance supervision.

Furthermore, the established ANP model provides a structured framework for evaluating GSE feasibility and identifying priority supervision strategies. The findings demonstrate that integrating technical condition, regulatory compliance, and safety considerations within a single decision-making framework can improve the effectiveness of AMC supervision and contribute to safer and more efficient ground operations.

Table 3-1: Priority Criteria

Respondent	Criteria 1. Machine	Criteria 2. Vehicle Operation License	Criteria 3. Safety Feature
P1	0.30253	0.38937	0.3081
P2	0.27216	0.39311	0.33472
P3	0.29899	0.40152	0.29949
P4	0.32204	0.32334	0.35462
P5	0.25213	0.40854	0.33933

Table 3-1 and Figure 3-2 show the weight comparison of the main evaluation criteria with a total weight value (W) of 1.08. At assessment point P1, the Engine criterion has a weight of approximately 0.30, the Vehicle Operating Licence approximately 0.38, and Safety Features approximately 0.30. At P2, the Engine remains at about 0.30, the Vehicle Operating Licence increases to approximately 0.41, and Safety Features decrease to approximately 0.27. At assessment point P3, the Engine weight increases to about 0.32, the Vehicle Operating Licence reaches approximately 0.42, and Safety Features increase to approximately 0.36. At P4, the Engine weight decreases to about 0.26, while the Vehicle Operating Licence and Safety Features have weights of approximately 0.32 and 0.35, respectively. Finally, at assessment point P5, the Engine has a weight of approximately 0.29, the Vehicle Operating Licence approximately 0.41, and Safety Features approximately 0.34.

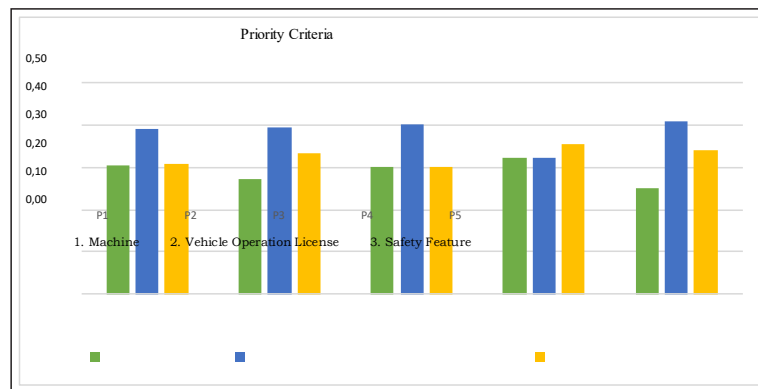


Figure 3-2: Criteria Results from Participants.

The results indicate that the Vehicle Operating Licence consistently has the highest weight across all assessment points (P1-P5), demonstrating that it is considered the most important criterion in this evaluation. Safety Features generally rank as the second most important criterion, except at P1, where the Engine criterion slightly exceeds it. The Engine criterion consistently has the lowest weight, indicating that it is considered the least important among the three criteria.

Overall, these results show that in an evaluation with a total weight of 1.08, the Vehicle Operating Licence is regarded as the most critical factor, followed by Safety Features and Engine condition or performance. This prioritization reflects the importance of regulatory compliance and safety in the decision-making process related to Apron Movement Control and Ground Support Equipment eligibility. Orderly and safe GSE traffic on the airside, particularly in movement areas and service roads, requires effective socialization among GSE operators and the implementation of traffic discipline sanctions to reduce violations (Utami & Endrawijaya, 2018).

Table 3-2: Priority of Machine Sub-Criteria

Respondent	1. Oil Leak	2. Engine Performance	3. Corrective Action
P1	0.27429	0.25039	0.47532
P2	0.23041	0.29056	0.47903
P3	0.35667	0.30232	0.34101
P4	0.47984	0.2302	0.28997
P5	0.38399	0.24183	0.37418

Table 3-2 and Figure 3-3 present the weight comparison of the Engine sub-criteria with a total weight value (W) of 0.96. At assessment point P1, the weight of Oil Leakage is approximately 0.30, Engine Performance approximately 0.25, and Maintenance History approximately 0.50. At P2, Oil Leakage has a weight of about 0.25, Engine Performance approximately 0.30, and Maintenance History approximately 0.50. At P3, Oil Leakage and Maintenance History each have weights of approximately 0.35, while Engine Performance is approximately 0.30. At P4, Oil Leakage becomes dominant with a weight of approximately 0.50, Engine Performance decreases to approximately 0.20, and Maintenance History is approximately 0.30. At P5, Oil Leakage and Maintenance History again have comparable weights of approximately 0.35, while Engine Performance is approximately 0.25.

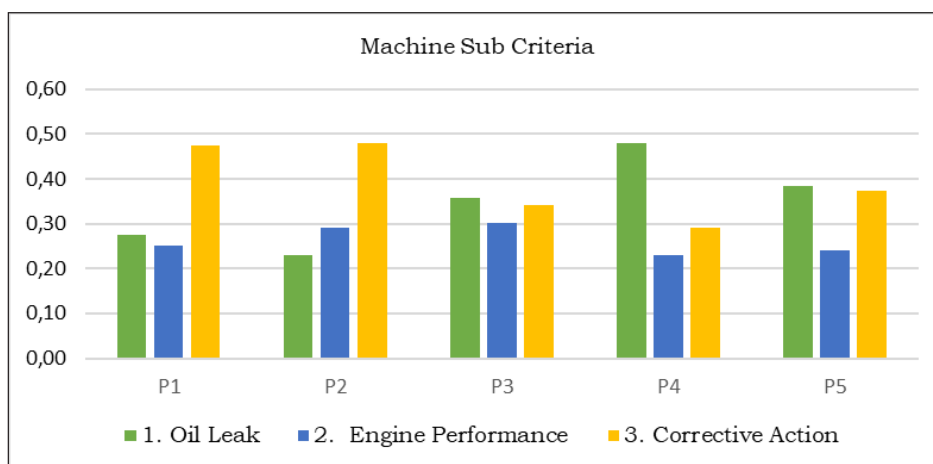


Figure 3-3: Sub Criteria of Participants.

These results show that Maintenance History has the highest weight at most assessment points (P1, P2, P3, and P5), indicating that it is considered the most important Engine sub-criterion. Oil Leakage also receives a relatively high weight, particularly at P4 and P5, highlighting its importance in engine condition assessment. Engine Performance consistently receives the lowest weight across most assessment points. This prioritization emphasizes the importance of maintenance records and the absence of oil leakage in evaluating engine feasibility for supporting GSE operations. Aircraft movement on the airside is managed by the Apron Movement Control unit, which determines aircraft parking positions based on coordination with the Aerodrome Control Tower unit (Hermawan, 2021).

Table 3-3: Priority of Vehicle Operation License Sub-Criteria

Respondent	1. Compliance With Document Validity Extension	2. Document Validity	3. Vehicle PAS
P1	0.33844	0.31004	0.35152
P2	0.28769	0.4643	0.24801
P3	0.32222	0.4706	0.20719
P4	0.46285	0.292	0.24515
P5	0.33321	0.48061	0.18618

Table 3-3 and Figure 3-4 present the scores of the Vehicle Operating Licence Sub-criteria Document Validity Renewal Compliance, Document Validity, and Vehicle Pass across five assessment points (P1–P5). At P1, Document Validity Renewal Compliance and Document Validity both have values of approximately 0.25, while Vehicle Pass is slightly lower at approximately 0.20. At P2, Document Validity increases significantly to approximately 0.45, while Document Validity Renewal Compliance and Vehicle Pass have values of approximately 0.20 and 0.25, respectively. A similar pattern is observed at P3, where Document Validity reaches approximately 0.40, followed by Document Validity Renewal Compliance at approximately 0.25 and Vehicle Pass at approximately 0.20. At P4, Document Validity Renewal Compliance becomes dominant with a value of approximately 0.35, while Document Validity and Vehicle Pass are approximately 0.25 and 0.15, respectively. At P5, Document Validity again has the highest value at approximately 0.40, followed by Document Validity Renewal Compliance at approximately 0.25 and Vehicle Pass at approximately 0.15.

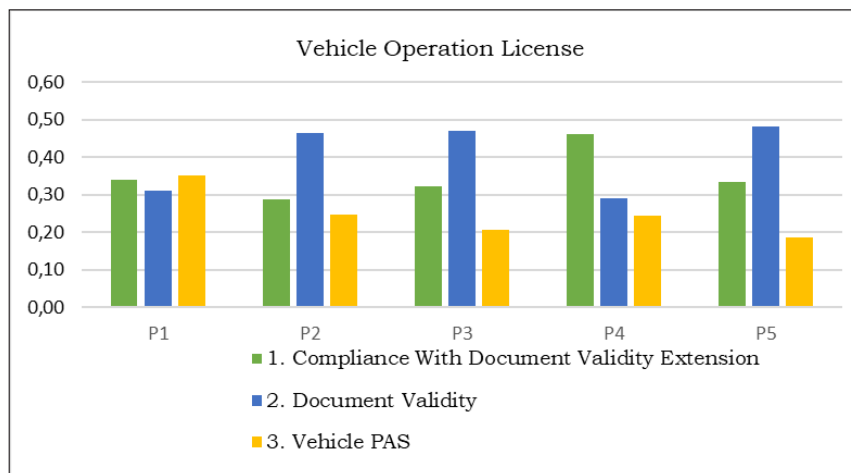


Figure 3-4: Results of Vehicle Operation License Sub-Criteria from Participants.

The total weight obtained from these sub-criteria is 0.72, indicating a strong overall contribution of Vehicle Operating Licence to the evaluation. Document Validity consistently emerges as the most important sub-criterion, while Vehicle Pass shows the lowest contribution and therefore requires improvement to enhance the overall Vehicle Operating Licence score. Apron Movement Control conducts continuous surveillance to ensure discipline in GSE activities on the airside, where safety is a primary concern (Fitriatmoko, 2022).

Table 3-4 and Figure 3-5 show the weight comparison of Safety Feature sub-criteria with a total weight (W) of 1.08 across five participants (P1–P5). The evaluated sub-criteria include lamp functionality, fire extinguisher (minimum 5 kg), flame trap, interior and exterior cleanliness, and vehicle tire condition.

Table 3-4: Priority of Safety Feature Sub-Criteria

Respondent	1. Lamp Functionality	2. Fire Extinguisher (Min.5kg)	3. Flame Trap	4. Interior & Exterior Cleanliness	5. Vehicle Tire Condition
P1	0.36457	0.12421	0.18017	0.08295	0.2481
P2	0.30673	0.13509	0.21942	0.13723	0.20152
P3	0.27048	0.12196	0.17529	0.06707	0.3652
P4	0.25266	0.15644	0.22342	0.07154	0.29594
P5	0.34829	0.20871	0.18041	0.08426	0.17833

At P1, lamp functionality has the highest weight (0.35), followed by flame trap (0.20), interior and exterior cleanliness (0.10), vehicle tire condition (0.05), and fire extinguisher (0.02). At P2, lamp functionality remains dominant at 0.30, followed by flame trap (0.20), interior and exterior cleanliness (0.10), fire extinguisher (0.07), and vehicle tire condition (0.05). At P3, vehicle tire condition becomes the highest priority with a weight of 0.35, followed by lamp functionality (0.25), flame trap (0.20), fire extinguisher (0.15), and interior and exterior cleanliness (0.05). At P4, lamp functionality again has the highest weight (0.30), followed by vehicle tire condition (0.25), flame trap (0.20), interior and exterior cleanliness (0.15), and fire extinguisher (0.10). A similar pattern is observed at P5, where lamp functionality has the highest weight (0.30), followed by vehicle tire condition (0.25), flame trap (0.15), interior and exterior cleanliness (0.10), and fire extinguisher (0.05).

These results indicate that lamp functionality is generally the top priority in vehicle safety assessment, except at P3, where vehicle tire condition is prioritized. Fire extinguishers consistently receive the lowest weight across all assessments, reflecting variations in safety focus depending on vehicle condition and operational requirements.

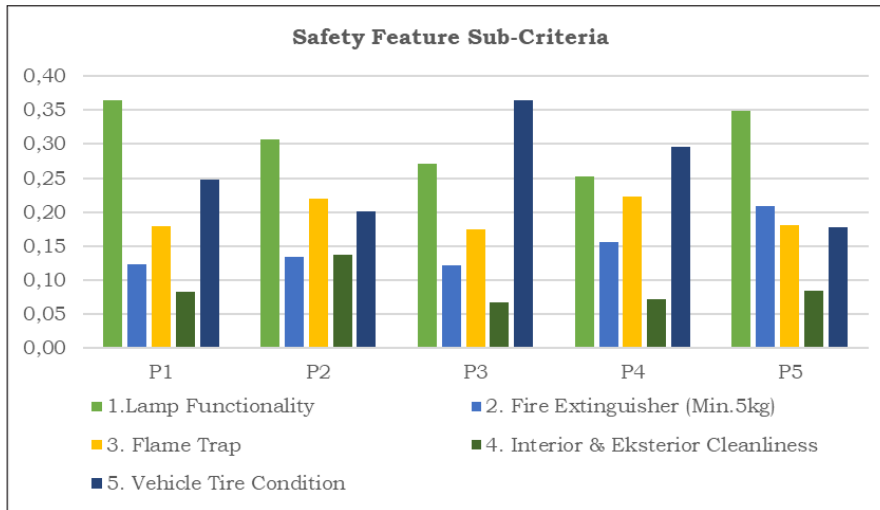


Figure 3-5: Results of the Safety Feature Sub-Criteria from Participants.

Table 3-5 and Figure 3-6 present the comparison of alternative sub-criteria weights with a total value (W) of 0.86 across P1–P5. The evaluated alternatives include regulation, vehicle registration/licence (STTKP/Licence), and vehicle eligibility. Across all assessment points, vehicle eligibility consistently receives the highest weight, followed by STTKP/Licence, while regulation has the lowest weight. This pattern indicates that physical vehicle readiness is prioritized over regulatory aspects in alternative evaluation. STTKP/Licence shows relatively stable weighting across all participants.

Table 3-5: Alternative Priority

Respondent	1. Regulation	2. STTKP/License	3. Vehicle Worthiness
P1	0.2412	0.34182	0.41698
P2	0.28604	0.2529	0.46107
P3	0.32157	0.27082	0.40761
P4	0.25442	0.23827	0.50731
P5	0.17285	0.34085	0.4863

These findings reflect operational conditions in which GSE equipment parking facilities are not optimally utilized, resulting in irregular placement of equipment in apron and service road areas and reducing overall operational efficiency (Fitriatmoko, 2022).

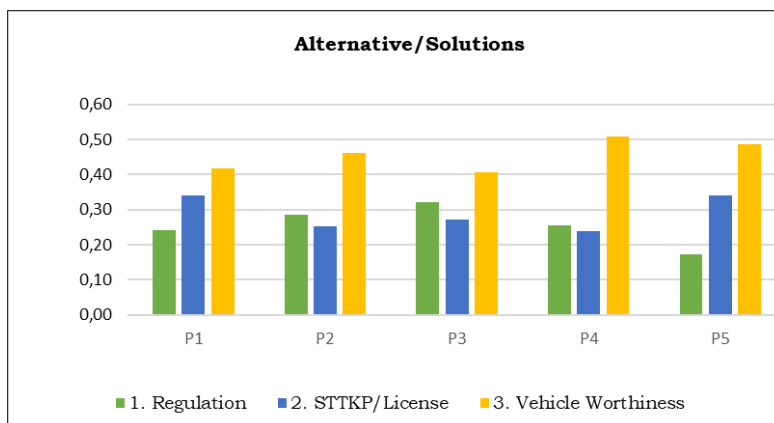


Figure 3-6: Alternative results from participants.

Table 3-6 and Figure 3-7 illustrate the combined prioritization of all sub-criteria. Vehicle eligibility has the highest priority value (approximately 0.45), followed by Oil Leakage and Compliance, each with values around 0.30. Engine Performance and Maintenance History have lower priority values (below 0.20), while Document Validity remains an important regulatory factor. Lamp Functionality and Vehicle Tire Condition show moderate priority values, highlighting their relevance to operational safety. Fire extinguisher availability (minimum 5 kg) has a priority value of approximately 0.25, while Flame Trap has the lowest priority, below 0.10. Interior and Exterior Cleanliness also receives attention with a priority value of approximately 0.20.

Table 3-6: Combined Priority of Sub-Criteria Elements

Name	Priority of Sub-Criteria Elements
1. Oil Leak	0.35834
2. Engine Performance	0.25428
3. Corrective Action	0.38738
1. Compliance with Document Validity Extension	0.34801
2. Document Validity	0.46796
3. Vehicle PAS	0.18403
1. Lamp Functionality	0.28114
2. Fire Extinguisher (Min.5kg)	0.11615
3. Flame Trap	0.24147
4. Interior & Exterior Cleanliness	0.05501
5. Vehicle Tore Condition	0.30622

Overall, this combined prioritization provides clear guidance on key focus areas for vehicle maintenance and safety management. Vehicle eligibility is identified as the most critical factor, followed by Oil Leakage and Compliance. Although other sub-criteria have lower priority values, they remain important for ensuring safe, compliant, and efficient GSE operations. This is particularly relevant for Indonesian airports, where GSE includes aircraft tractors, passenger stairs, baggage towing vehicles, lavatories, ground power units, air starter units, water service trucks, and non-motorized equipment. Environmental challenges further highlight the need for adopting electric GSE to reduce emissions and promote sustainable airport operations.

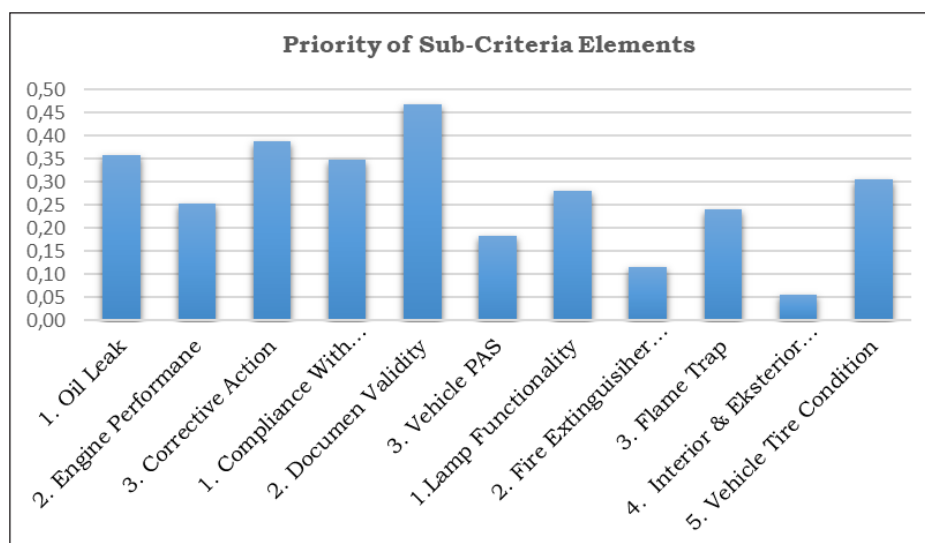


Figure 3-7: Results of the Combined Sub-Criteria.

4. Conclusions

The Analytic Network Process (ANP) method was applied to develop a decision-support model for Apron Movement Control (AMC) in supervising the feasibility of Ground Support Equipment (GSE) at Yogyakarta International Airport. By identifying relevant criteria and sub-criteria, constructing the ANP network, and collecting data through pairwise comparison matrices, the proposed model effectively evaluates and prioritizes key factors influencing GSE supervision.

The final ANP results indicate that Document Validity is the highest-priority sub-criterion, followed by Corrective Actions and Oil Leakage. In contrast, sub-criteria such as APAR (minimum 5 kg) and Interior and Exterior Cleanliness receive lower priority values. These findings demonstrate that regulatory compliance and timely corrective maintenance actions are the most critical aspects for ensuring GSE suitability during inspections conducted by AMC personnel.

Overall, the developed ANP model proves effective in providing structured and reliable decision recommendations, thereby supporting improvements in safety and operational efficiency at Yogyakarta International Airport. The model can serve as a practical reference for decision-makers in optimizing future GSE supervision and maintenance strategies.

Air transport operations are characterized by stringent safety requirements and high service continuity standards compared to other modes of transportation. In this context, GSE plays a vital role in ensuring the smooth and safe flow of air transport operations (Ur Rahman & Akbar, 2023).

In relation to regulatory implementation, existing Standard Operating Procedures (SOPs), such as those applied at Kalimantan Airport, Berau, mandate firm enforcement by airport management against operational violations. However, despite the availability of SOPs governing airside safety and order, irregularities persist. Observations reported in previous studies indicate issues such as improper placement of GSE, the absence of Equipment Staging Area (ESA) markings on the apron, and insufficient supervision by Apron Movement Control (AMC) personnel (Salsabilla et al., 2020). These findings reinforce the relevance of the proposed ANP-based decision model as a tool to strengthen supervision effectiveness and regulatory compliance in airside operations.

Contributorship Statement

MS conceptualized the study, designed the method, analyzed the results, and prepared the manuscript; VP conducted the ANP modeling and supported data analysis; AS contributed to the literature review and assisted in manuscript preparation.

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