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Identifying Practical Green Logistics Strategies for Indonesia Using AHP

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Abstract

Although green logistics has become a global concern, its implementation in Indonesia remains challenging due to the high operational cost and limited readiness of logistics companies. Many companies are aware of sustainability issues. However, they still face uncertainty regarding which green logistics strategy should be prioritized under limited resources and infrastructure constraints. This condition indicates the need for practical choice framework that can assist logistics stakeholders in determining the most feasible and impactful sustainability strategy. In tackling climate change Indonesia has 2 agenda which are FOLU Net Sink 2030 and Net Zero Emission 2060. To support agenda FOLU Net sink 2030 has only 4 years left, that's why this research is important to do. Indonesia needs a clear of which strategies of green logistics is practically implemented in Indonesia, without massive initial investment. This study uses the Analytic Hierarchy Process (AHP) to identify a feasible green logistics strategy for Indonesia based on the judgement of 12 logistics practitioners and experts. Four criteria were considered: government support, technology readiness, operational efficiency that include implementation cost, and environmental sustainability. Seven alternatives were assessed: route optimization, digital carbon monitoring, fleet electrification, eco driving, renewable energy, green warehousing, and ESG reporting. The results show that technology readiness is the most important criterion (0.292), while Digital Carbon Monitoring is the highest priority strategy with a weight of 0.3989 (39.89%). The consistency ratio (CR = 0.0339) indicates that the aggregated pairwise comparison matrix is acceptable. To connect the AHP result with practice, the study uses the ANL Logistics Carbon Calculator powered by Cocoon Carbon UK as a proof of concept. The paper contributes a practical decision framework for logistics managers who need to begin green transformation through measurable, lower infrastructure, and economical actions.

Keywords
Green logistics, Digital carbon monitoring, Carbon calculator, Indonesia.

1. Introduction
Indonesia's logistics sector is the backbone for Indonesia economic growth, with hundred islands across the country, transportation becomes significantly important and high volumes on inter island distribution. In practice, this sector depends heavily on road freight, port connectivity, warehousing, and multimodal movements between industrial corridors and islands. These operational logistics also create environmental pressures from diesel fuel use, congestion, inefficient routing, and energy intensive warehouse activities.

The transport sector is one of the most significant sources of carbon emissions in Indonesia. The Institute for Essential Services Reform reported that Indonesia's transport sector emitted approximately 150 MtCO2 in 2022, with road transport contributing around 90% of transport emissions with road freight contributing around 20% of road transport emissions (Institute for Essential Services Reform 2024). For logistics operators, this issue is directly relevant because many freight activities still rely on diesel trucks, conventional route planning, and limited emissions monitoring.

These problems could be identified in daily logistics operations. In the Jakarta – Cikarang - Karawang industrial corridor, congestion, waiting time, and delivery delays often increase fuel consumption. In inter island heavy equipment logistics, operators frequently deal with long routes, fragmented transport arrangements, and limited modal alternatives. Many warehouses also still use conventional energy systems. These realities suggest that green logistics in Indonesia must be approached in a practical way, cost friendly and user friendly.

In some previous studies have discussed several green logistics strategies, including route optimization, eco driving, fleet electrification, renewable energy, green warehousing, and ESG reporting. But many logistics managers still face a practical dilemma: which strategy should be started first when resources are limited? This study responds to that problem by applying AHP to prioritize feasible strategies and by using the ANL Logistics Carbon Calculator as a proof of concept for applying the highest ranked strategy.

1.1 Objectives

In this study has four objectives, first, to identify relevant criteria for evaluating green logistics strategies, second, to prioritize practical strategy alternatives using AHP, third, to test the consistency of the expert judgement, and fourth, to show what strategy would be highest ranked.

2. Literature Review

Green logistics refers to the effort to reduce the environmental impact of logistics activities while maintaining service reliability and operational efficiency. Rodrigue (2020) links green logistics with freight efficiency, energy optimization, route planning, modal choice, and low emission technologies. Christopher (2016) also notes that sustainability has become a strategic logistics concern because companies are expected to reduce environmental impact without weakening responsiveness and competitiveness.

In the wider sustainable supply chain literature, green logistics strategies are usually discussed as operational, technological, or managerial actions. Route optimization and eco driving may reduce fuel use and delivery inefficiency. Digital carbon monitoring and ESG reporting improve visibility and decision quality. Fleet electrification and renewable energy can support deeper emission reduction, but they usually require higher investment, infrastructure readiness, and stronger organizational capability (Srivastava 2007, Kannan et al. 2014, Govindan et al. 2015).

In this study, implementation cost is treated as part of cost efficiency. This distinction is important because a strategy may look feasible from an environmental perspective but remains hard to adopt if it requires high initial investment or major infrastructure change. Cost efficiency could be done by proper fleet maintenance or shortening route option. This could be run by logistic company in Indonesia, where many logistics companies operate with small margins.

The Indonesia's logistics context is very complicated. The country's archipelagic geography, uneven infrastructure, limited manpower resources about green logistics knowledge, high competition on selling price, and dependency on road transport make green logistics transformation more difficult. Transportation decarbonization still requires investment, policy support, and technological improvement (Asian Development Bank 2022, International Energy Agency 2022). For this reason, first stage strategies should be doable, realistic and fit the current condition.

In tackling climate change global issue, Indonesia has 2 agendas which are FOLU Net Sink 2030 and Net Zero Emission 2060 that provide important policy context for this study. Indonesia's Enhanced Nationally Determined Contribution increased its 2030 emission reduction ambition to 31.89% unconditionally and 43.20% conditionally with international support (Government of Indonesia 2022). Although FOLU primarily concerns forestry and land use, logistics and transportation remain relevant because freight movement directly affects fuel consumption, carbon emissions, and supply chain sustainability.

Digital carbon monitoring refers to the use of digital systems to collect, calculate, monitor, and report emissions from logistics activities. The data may include shipment distance, weight of the cargo, transport mode, and type of fleet. The GHG Protocol Corporate Standard provides a widely used basis for corporate greenhouse gas accounting and reporting (World Resources Institute and World Business Council for Sustainable Development 2004).

Carbon calculator is a tool made by a UK based company, which can be used for door to door shipment. In this sense, digital carbon monitoring is not only a reporting tool, but it can also help companies identify the level of emissions that have been produced, which helps the managers decide what actions should come next, as part of the overall green logistic strategy.

The Method in this study is the Analytic Hierarchy Process (AHP), introduced by Saaty (1980), is a multi criteria choice method, that converts expert judgement into priority weights. AHP is suitable for this study because green logistics decisions involve compromise between environmental impact, feasibility, cost, technology readiness, and policy support. It also includes a consistency test, which helps evaluate whether expert judgements are rationally acceptable.

3. Methods

This study adopts a quantitative approach using AHP. The hierarchy contains one goal, four criteria, and seven strategy alternatives. The goal is to identify the most feasible green logistics strategy for Indonesia. The criteria are government support, technology readiness, operational efficiency, and environmental sustainability. The alternatives are route optimization, digital carbon monitoring, fleet electrification, eco driving, renewable energy, green warehousing, and ESG reporting.

The pairwise comparison matrix followed Saaty's reciprocal logic, where a_ij = 1/a_ji. The priority vector was calculated using the column normalization and row average method. Each column was first normalized using N_ij = a_ij / sum(a_ij). The priority weight was then calculated as W_i = sum(N_ij) / n, where n is the number of alternatives. Consistency was tested using CI = (lambda_max - n) / (n - 1) and CR = CI / RI. For n = 7, RI = 1.32, and a CR value below 0.10 was considered acceptable.

The alternative matrix was based on the responses of 12 experts, not on the judgement of a person. Every respondent compared the practical of the seven alternatives in relation to Indonesia's logistics conditions. The individual judgements were combined into one group matrix using the geometric mean, because AHP comparisons are ratio based and the geometric mean helps preserve reciprocity. After the group matrix was formed, the final priority weights were calculated using column normalization and row averaging. The consistency ratio was also calculated from this aggregated group matrix (Figure 1).

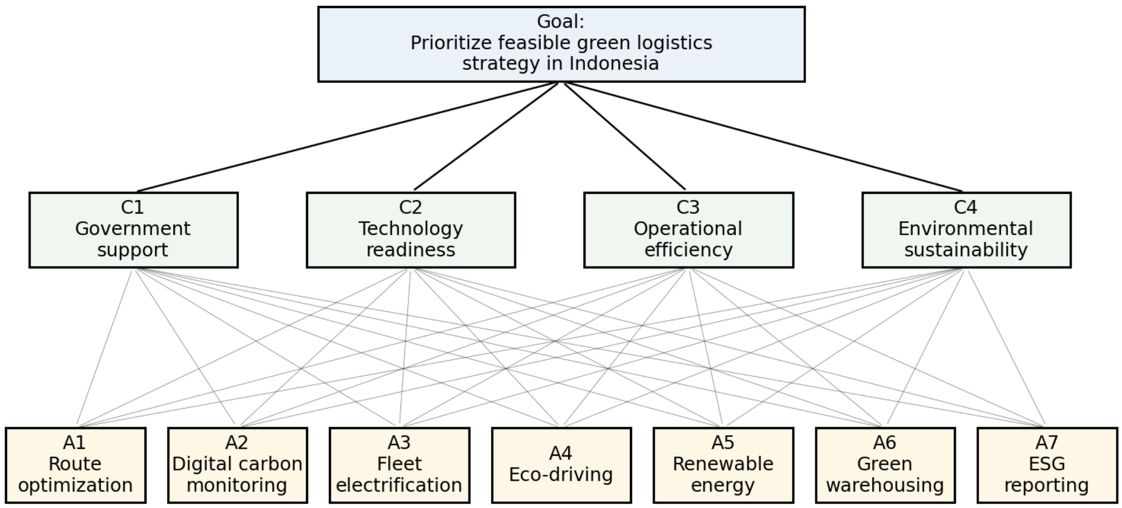

Figure 1. AHP hierarchy for green logistics strategy prioritization

4. Data Collection

Data was collected from 12 experts (logistic practitioners) described in Table 1. Purposive sampling was used because AHP requires informed judgement from people who understand the decision problem, rather than responses from a random population. Table 2 shows 4 criterion and 7 alternatives.

Table 1. Respondent profile

Respondent profile	Result
Total respondents	12
Forwarder / 3PL	66.7% (8 respondents)
Land transport	16.7% (2 respondents)
Warehousing	16.7% (2 respondents)

Table 2. AHP criteria and alternatives

Code	Criteria / Alternative	Basis or description
C1	Government support	Regulations, incentives, supervision, and policy support
C2	Technology readiness	Digital systems, real time monitoring, energy efficiency, and system integration
C3	Operational efficiency	Cost efficiency, implementation cost, resource use, delivery performance, route and fleet optimization
C4	Environmental sustainability	Emission reduction, green fleet, energy efficiency, waste reduction, and environmental commitment
A1	Route Optimization	Operational route and load efficiency
A2	Digital Carbon Monitoring	Digital measurement, dashboard, and carbon visibility
A3	Fleet Electrification	Low emission or electric vehicle transition
A4	Eco Driving	Driver behavior and fuel-efficient driving
A5	Renewable Energy	Renewable energy use in logistics facilities
A6	Green Warehousing	Energy efficient and sustainable warehousing
A7	ESG Reporting	Carbon disclosure and ESG reporting system

5. Results and Discussion

5.1 Numerical Results

The numerical result shows how the four evaluation criteria were weighed before the strategy alternative were ranked. Implementation cost was included within the operational efficiency criterion as a cost efficiency consideration. As presented in Table 3 below, the technology readiness received the highest weight. This suggests that for Indonesian logistic practitioner, a green logistics strategy needs to be supported by digital readiness and make sense operationally.

Table 3. Criteria weight calculation

Criterion	Average score	Weight	Rank
Technology readiness	5.43	0.292	1
Operational efficiency	4.96	0.266	2
Environmental sustainability	4.64	0.249	3
Government support	3.60	0.193	4
Total	18.63	1.000	-

The AHP figures in Table 4 were developed from the aggregated judgement of the 12 experts described in Table 1. The pairwise comparison form was completed by respondents with high level experience in logistic decisions, including forwarding/3PL, land transport, and warehousing industry. Because AHP uses ratio scale comparisons, the individual responses were aggregated using the geometric mean rather than a simple arithmetic average. This produced one reciprocal group matrix representing the collective expert judgement. The priority weights in Table 5 were calculated from this aggregated matrix using column normalization and row averaging. The consistency ratio in Table 6 was also calculated from the aggregated group matrix, so the reported CR reflects the consistency of the combined expert judgement rather than the judgement of one person.

Table 4. Reciprocal pairwise comparison matrix for strategy alternatives

Strategy	A1	A2	A3	A4	A5	A6	A7
A1 Route Opt	1.000	0.333	3.000	3.000	5.000	3.000	2.000
A2 Digital Carbon	3.000	1.000	7.000	5.000	7.000	5.000	3.000
A3 Fleet Electric	0.333	0.143	1.000	2.000	2.000	2.000	0.333
A4 Eco Driving	0.333	0.200	0.500	1.000	3.000	1.000	0.500
A5 Renewable Energy	0.200	0.143	0.500	0.333	1.000	0.500	0.333
A6 Green Warehousing	0.333	0.200	0.500	1.000	2.000	1.000	0.500
A7 ESG Reporting	0.500	0.333	3.000	2.000	3.000	2.000	1.000

Table 5. Alternative priority weights

Rank	Code	Strategy	Priority weight	Percentage
1	A2	Digital Carbon Monitoring	0.3989	39.89%
2	A1	Route Optimization	0.2007	20.07%
3	A7	ESG Reporting	0.1373	13.73%
4	A3	Fleet Electrification	0.0845	8.45%
5	A4	Eco Driving	0.0729	7.29%
6	A6	Green Warehousing	0.0667	6.67%
7	A5	Renewable Energy	0.0390	3.90%

Table 6. Consistency test result

Indicator	Result
n	7
lambda_max	7.2686

CI	0.0448
RI	1.32
CR	0.0339
Decision	Consistent (CR < 0.10)

The result indicates that Digital Carbon Monitoring is the highest priority strategy, with a priority weight of 39.89%. This suggests that practitioners see carbon visibility and digital measurement as a realistic entry point for green logistics transformation. The consistency ratio is 0.0339, which is below the 0.10 threshold, therefore, the aggregated pairwise comparison matrix is acceptable for AHP analysis.

5.2 Graphical Results

Figure 2 shows that Digital Carbon Monitoring ranks clearly above the other alternatives, followed by Route Optimization and ESG Reporting. This suggests that application system and data driven strategies are seen as more feasible at the early stage than high capital investment solutions such as fleet electrification and renewable energy.
The result also explains that fleet electrification and renewable energy may provide strong long term environmental benefits, but their feasibility is limited by higher investment needs, infrastructure readiness, and longer payback periods. By contrast, Digital Carbon Monitoring can begin with data that many logistics companies already collect, such as shipment, fuel, route, and vehicle information. This makes it more suitable for companies that need to balance sustainability goals with cost control and operational continuity.

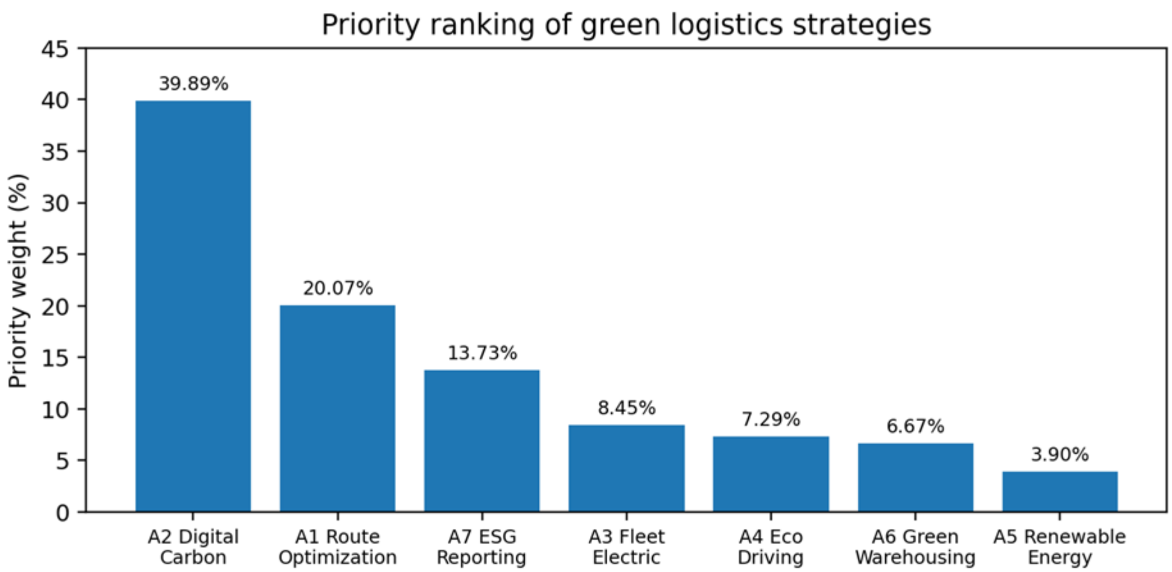

Figure 2. Priority weights of green logistics strategy alternatives

5.3 Proposed Improvements

Based on the AHP ranking, the proposed improvement is to introduce Digital Carbon Monitoring as a first step in green logistics strategy. The implementation can start with purchasing a calculator then collecting activity data, calculating emissions, visualizing results through a dashboard, and reviewing the findings for management decisions to do carbon offset in supporting FOLU Net sink 2030 NZE targets. In this study, the ANL Logistics Carbon Calculator is used as a proof of concept to show how digital carbon calculation could be done at any time and start implementing green logistics strategy. The calculator translates the AHP recommendation into a practical operations process: data capture, calculation, carbon offsetting, reporting, and continuous improvement.

From a cost efficiency perspective, this improvement is very efficient because the carbon calculator can be implemented using monthly or annual subscription, without massive investment in software or hardware. By calculating carbon emissions in every shipment, the company can identify where cost saving actions should be prioritized, such as route optimization, reduced idle time, reduced empty fleet, improved vehicle maintenance, or eco driving. Implementation cost is therefore not treated as a separate issue from feasibility, it is part of cost efficiency, to assess whether a strategy can generate operational value while supporting emissions reduction.

5.4 Validation: ANL Logistics Carbon Calculator Proof of Concept

The ANL Logistics Carbon Calculator powered by CocoonCarbon UK is used as proof of concept to show how the highest ranked strategy can work in practice. The validation is intentionally kept as an operational illustration, not as a commercial product evaluation. It's to show that Digital Carbon Monitoring can be applied in an Indonesian logistics setting using existing operational data.

The proof of concept validates feasibility by showing that routine logistics data can be converted into useful carbon information. Relevant data may include shipment ID, origin and destination, route distance, transport mode, fuel or activity data, vehicle type, cargo weight, and trip frequency. Using the general logic CO2e = activity data x emission factor, the calculator can support shipment-level carbon visibility, customer reporting, Scope 3 disclosure, and management decisions related to route optimization and fuel-efficiency improvement (Table 7).

Table 7. Proof of concept validation of digital carbon monitoring

Validation element	Practical role in ANL Logistics	Link to AHP result
Operational data availability	Uses existing shipment, route, mode, vehicle type, cargo weight, and frequency data.	It shows that digital carbon monitoring can start without large infrastructure investment.
Carbon calculation logic	Converts logistics activity data into estimated CO2e using relevant emission factors.	Supports measurable and evidence based green logistics decisions.
Decision support output	Identifies high emission routes, supports customer reporting, and informs future improvement actions.	Links the AHP priority to route optimization, ESG reporting, and cost-efficiency decisions.

This validation does not claim that emission reductions have already been achieved. Its purpose is to show that the AHP result can be translated into a workable measurement process.

6. Conclusion

This study applied AHP to prioritize feasible green logistics strategies for Indonesia. The criteria analysis shows that technology readiness is the most important criterion, followed by operational efficiency, environmental sustainability, and government support. The alternative evaluation identifies Digital Carbon Monitoring as the highest priority strategy, with a priority weight of 39.89%. The consistency ratio of 0.0339 confirms that the aggregated expert judgement matrix is acceptable.

The findings suggest that Indonesia's green logistics transformation should begin with carbon monitoring / calculating. The ANL Logistics Carbon Calculator supports this conclusion by showing how shipment data can be converted into carbon indicators through a practical digital tool. The proof of concept demonstrates how digital carbon monitoring can support ESG reporting, Also the logistic company can immediately start practicing green logistic strategy and ESG value with offsetting carbon emissions that they produce during their business activity. It's an easy way to start in pathway toward supporting FOLU Net Sink 2030 and Net Zero Emission 2060. The result also confirms that implementation cost should be understood within cost efficiency, because it determines the size of the initial investment you need to make.

This study has several limitations. The ANL Logistics Carbon Calculator is presented as proof of concept. Future research should test this approach with logistics companies to see if carbon monitoring can reduce fuel consumption and support emissions reduction.

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