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THE STRATEGIC ROLE OF ECO-FRIENDLY FLEETS, ECO-FRIENDLY HUBS, AND OPERATIONAL SUSTAINABILITY IN DRIVING DISTRIBUTION EFFICIENCY: AN EMPIRICAL STUDY AT PT POS INDONESIA

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Abstract: This research aims to deepen insights into the influence of Environmentally Friendly Fleets (EFF), Green Logistics Hubs (GH), and Sustainable Operations (SO) on Distribution Efficiency (DE) within the logistics industry, which is increasingly challenged by fierce competition and environmental demands. A survey with 80 practitioners who work directly in supply chain management and logistics was used to collect data. A technique that is appropriate for examining intricate relationships between latent components, partial least squares structural equation modeling (PLS-SEM), was used to evaluate the suggested framework. With relative path coefficients of 0.984, 0.580, and 0.672, the results show that EFF, GH, and SO significantly improve distribution efficiency. The model exhibits good explanatory ability, as seen by the R^2 value of 0.809, which indicates that it explains about 81% of the variance in distribution efficiency. The results' trustworthiness was further guaranteed by the fact that every measuring indicator met validity and reliability standards. These outcomes emphasize the strategic role of sustainability-oriented initiatives in daily operations. For logistics firms, reinforcing eco-friendly practices not only enhances efficiency and competitiveness but also supports the development of greener and more resilient distribution networks over time.

Keywords: Eco-Friendly Fleet, Eco-Friendly Hub, Operational Sustainability, Distribution Efficiency.

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1. Introduction

The transformation of the logistics sector toward more efficient and environmentally responsible systems has become a strategic agenda in many countries, including Indonesia. Logistics activities—particularly freight transportation and courier services—are recognized as major contributors to carbon emissions and fossil fuel consumption (Rauf & Sari, 2024). The rapid expansion of e-commerce has intensified pressures on distribution infrastructure and delivery fleets. In Indonesia, transportation accounts for over 27% of total greenhouse gas emissions, with land-based logistics representing a significant portion (Ministry of Environment and Forestry, 2023). Heavy reliance on imported fuels also poses a fiscal challenge, with fuel subsidies reaching IDR 64 trillion annually during 2015–2020. These conditions underscore the urgency for a logistics system that is not only reliable and fast but also environmentally sustainable (Whulanza, 2023).

One global approach addressing these challenges is green logistics, which integrates environmental considerations into logistics systems through the deployment of eco-friendly vehicles, route optimization, energy management, and renewable energy utilization (Zhang, Zhao, & Li, 2021). In Indonesia, several logistics companies have begun adopting such initiatives. PT Pos Indonesia (Persero), the nation's oldest state-owned logistics enterprise, has introduced electric fleets and solar panel installations at selected branches—such as in Bali and Tambun (Bekasi)—since 2021 as part of its transition toward a green industry. These measures are expected to reduce operational costs while cutting emissions from fossil fuel usage.

Most research in Indonesia still tends to emphasize customer satisfaction and overall company performance. For example, Fadli et al. (2024) explored how green logistics affects customer satisfaction and loyalty at JNE in Jakarta, while Aziz et al. (2025) examined its impact on service quality and trade in the context of DHL Global Forwarding. In a similar vein, Akubia et al. (2024) studied the role of green logistics practices in driving sustainability outcomes among manufacturing companies in both Indonesia and Ghana. Despite these contributions, there is still limited empirical evidence on how green logistics improves distribution efficiency, especially at the regional scale and beyond Java.

Medan, a key logistics hub in Sumatra, plays a vital role in Indonesia’s supply chain. With a city population of over 2.4 million and a metropolitan population exceeding 4.75 million, it represents a strategic logistics center in North Sumatra. Given its unique geographical, demographic, and infrastructural conditions compared to western Indonesia, applying green logistics concepts in Medan requires further investigation. The Main Branch Office of PT Pos Indonesia in Medan holds considerable potential to serve as a model for renewable energy–based distribution systems. Yet, empirical studies evaluating the extent to which electric fleets and locally sourced renewable energy (e.g., solar panels) can improve operational efficiency remain limited.

In this context, the present study focuses on examining the influence of environmentally friendly vehicle fleets and renewable energy–based hub strategies on the distribution efficiency of PT Pos Indonesia’s Medan Main Branch. The research further aims to uncover both the advantages and obstacles associated with adopting green logistics in regional operations across Indonesia. A quantitative design was employed, utilizing structural modeling with SmartPLS for data analysis.

From an academic perspective, the study contributes novelty by integrating two key strategies—electric vehicle fleets and locally sourced renewable energy—in assessing their combined effects on regional logistics efficiency. In addition, the use of quantitative methods supported by field-based structural modeling enriches methodological development in Indonesian green logistics research. The results are expected to provide valuable input for policymakers and practical guidance for industry stakeholders, especially in advancing environmentally sustainable logistics practices at regional as well as national scales.

2. Literature Review

Eco-Friendly Fleet

An eco-friendly logistics fleet—such as electric vehicles or low-emission transport—is considered a key innovation for strengthening efficiency in logistics distribution systems. The adoption of electric vehicles has been shown to lower operating expenses, reduce dependence on fossil fuels, and enhance the speed as well as reliability of urban deliveries (Srivastava, 2020).

According to Luthfi & Ramadhani (2022), logistics firms that consistently employ green fleets experience measurable improvements in distribution efficiency, especially regarding delivery times and resilience against fuel price volatility. These benefits arise from lower energy use per kilometer, reduced maintenance costs, and the ability of electric vehicles to operate in restricted or low-emission zones.

Eco-Friendly Hub

Hub strategies that utilize locally generated renewable energy—such as solar installations, micro-hydro plants, and other clean sources—are playing an increasingly vital role in enhancing distribution efficiency. By becoming energy self-reliant, logistics hubs can lower electricity costs, maintain uninterrupted services, and speed up sorting as well as dispatching processes (Zhang et al., 2021).

According to Rauf & Sari (2024), renewable-powered distribution centers also gain resilience against power outages, achieve faster inventory turnover, and minimize logistical expenses. Moreover, the integration of automation systems supported by clean energy strengthens operational efficiency by improving process precision and reliability (Gusti Agung Candra Maha Fitri & Mulyati, 2025).

Distribution Efficiency (DE)

DE refers to the ability of a logistics system to deliver goods rapidly, accurately, and with minimal resource use (Putra Wijaya et al., 2025). Indicators of this efficiency include travel time, fuel consumption, delivery accuracy, and optimal routing. Tjiptono & Diana (2019) emphasize that efficient distribution significantly influences customer satisfaction and long-term business sustainability.

Yuliasih & Nurlaili (2021) note that Indonesia's distribution efficiency is challenged by geographical complexity, traffic congestion, and uneven infrastructure. As such, technological and innovative measures—such as electric fleets and renewable-powered hubs—offer promising solutions to improve performance.

Operational Sustainability

Operational sustainability in logistics encompasses environmental, economic, and social dimensions, ensuring that business activities remain efficient while addressing long-term resilience and ecological responsibility. This approach extends beyond short-term gains, emphasizing environmental impact reduction and business continuity (Srivastava, 2020).
Whulanza (2023) explains that achieving sustainability in logistics relies on three main strategies: emission reduction, energy efficiency, and the integration of eco-friendly technologies. In practice, sustainability is often evaluated by measuring carbon reductions, renewable energy adoption, and improvements in resource utilization and cost efficiency.

Hypothesis Development

Role of Eco-Friendly Fleet on Distribution Efficiency

The implementation of green logistics fleets—such as electric or hybrid vehicles—has a direct impact on operational efficiency (Purnomo et al., 2024). Energy-efficient and low-emission fleets contribute to reduced fuel and maintenance costs over time (Luthfi & Ramadhani, 2022). Furthermore, their ability to access emission-regulated zones enhances delivery smoothness. Srivastava (2020) argues that companies adopting green transportation often achieve distribution gains through reduced travel time, cost savings, and improved customer trust.
H1: Eco-friendly logistics fleets have a direct positive effect on distribution efficiency.

Role of Eco-Friendly Hub on Distribution Efficiency

Green hub strategies integrate renewable energy, waste management, and efficient digital systems. Facilities equipped with solar panels, energy-saving cooling systems, and warehouse automation allow for lower energy consumption and reduced reliance on external power (Zhang, Zhao, & Li, 2021). This contributes to faster, more accurate, and cost-efficient distribution. Whulanza (2023) confirms that distribution efficiency improves substantially when hubs are designed and operated with sustainability principles in mind.

H2: Eco-friendly hub strategies have a direct positive effect on distribution efficiency.

Role of Operational Sustainability on Distribution Efficiency

Operational sustainability reflects an organization's ability to continue business activities efficiently while addressing environmental, social, and economic concerns. In logistics, this includes compliance with environmental regulations, maintaining a green reputation, stakeholder support, and resilience against energy crises or supply chain disruptions (Srivastava, 2020).

Firms that consistently adopt sustainability practices often build distribution systems that are more adaptive and resilient. Zhang, Zhao, & Li (2021) suggest that strong operational sustainability enhances supply chain effectiveness and accelerates goods distribution through energy efficiency and risk management. Tjiptono & Diana (2019) further stress that sustainability is not merely an ethical or regulatory concern, but also a tangible operational advantage, leading to more precise, cost-effective, and customer-oriented deliveries.

H3: Operational sustainability has a direct positive effect on distribution efficiency.

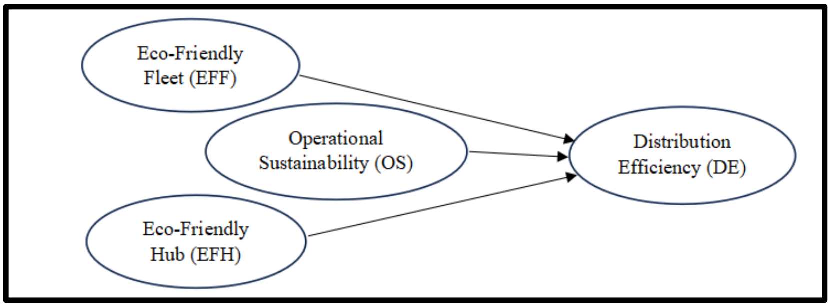

Figure 1: Research Model

3. Method

Research Design

This study applies an explanatory quantitative approach aimed at testing causal relationships among independent, mediating, and dependent variables within the framework of sustainable logistics transformation. The core objective is to evaluate how Eco-Friendly Fleet, Eco-Friendly Hub Strategy, and Operational Sustainability (independent variables) affect Distribution Efficiency (endogenous variable).

The SmartPLS program is used in this work to do Partial Least Squares–Structural Equation Modeling (PLS-SEM). PLS-SEM was chosen because it is reliable when working with non-normal data distributions or relatively small to medium sample sizes, and it is appropriate for evaluating complicated frameworks including a large number of latent variables and measurement items.

Data Sources and Sampling Technique

Employees of PT Pos Indonesia (Persero), Medan Main Branch, were given structured questionnaires to complete in order to gather primary data. A five-point Likert scale, with 1 denoting "strongly disagree" and 5 denoting "strongly agree," was used to assess responses. The measuring indicators were taken from well-known research in the field.

The population consisted of staff directly engaged in logistics, fleet operations, energy management, and distribution planning. Sampling followed a purposive non-probability technique, targeting respondents with direct knowledge and involvement in logistics operations. Criteria included: (1) at least one year of work experience, (2) active involvement in logistics, fleet, or energy facility operations, and (3) familiarity with branch-level distribution processes. Minimum sample size was determined based on Hair et al. (2017), which recommends five to ten times the number of indicators. With 20 indicators, at least 100–200 respondents were required.

Data Analysis Procedure

The analytical process involved three main stages:

a. Measurement Model Assessment

The assessment began with tests of construct validity and reliability. Average Variance Extracted (AVE > 0.5) was used to demonstrate convergent validity, while cross-loading analysis and the Fornell-Larcker criterion were used to confirm discriminant validity. Cronbach's Alpha scores over 0.6 and Composite Reliability (CR > 0.7) were used to gauge reliability.

b. Structural Model Assessment

The explanatory power of the model was measured using R2 values, and path coefficients were examined to assess the strength and direction of correlations. Through bootstrapping, the significance of the hypotheses was assessed, with t-statistics exceeding 1.96 and p-values falling below 0.05 as the thresholds. In addition, the study examined both direct effects and indirect (mediated) effects of Operational Sustainability in linking Eco-Friendly Fleets and Eco-Friendly Hub Strategies with Distribution Efficiency.

c. Goodness-of-Fit Evaluation

Model fit was evaluated through the Standardized Root Mean Square Residual (SRMR), where values under 0.08 signified an acceptable level of fit. This assessment confirmed that the observed data were well aligned with the proposed research model.

4. Result and Discussion

Respondent Demographi5cs

Table 1. Respondent Demographics

Category	Criteria	F	%
Gender	Male	60	75
	Female	20	25
Age (Years)	<25	1	1
	25 - 34	22	28
	35 - 44	39	49
	45 - 54	18	23
Years of Service	1 – 3	5	6
	4 – 6	5	4
	> 6	72	90

Category	Criteria	F	%
Division	Operation	39	49
	Business	30	38
	Finance	11	14
Position Level	Staff/Non Managerial	41	51
	Assistant Manager	5	6
	Manager	34	43
Education	Senior High School	30	38
	D1/D2/D3	18	23
	S1/D4	32	40

A total of 80 participants took part in this study, representing the operations, business, and finance divisions. The majority were male (75%) and within the productive age range of 25–44 years. Most respondents held a bachelor's degree (40%) and had over six years of work experience (90%), indicating a strong level of professional maturity in their respective fields. Their positions varied across staff/non-managerial, assistant manager, and managerial levels. These demographic attributes suggest that the respondents are both relevant and credible sources of information for the objectives of this research.

Outer Structural Model Results

As shown in Table 2, as evidenced by factor loadings over 0.7 and Average Variance Extracted (AVE) values above 0.5, the results show that all indicators satisfy the requirements for convergent validity. This strengthens the validity of the measurement model (outer model) and guarantees that the instrument appropriately captures the targeted study concepts by confirming that each indication consistently reflects its corresponding construct.

The Fornell–Larcker criteria was used to further investigate discriminant validity (Table 3). Construct uniqueness is confirmed and multicollinearity issues are ruled out when the analysis reveals that the square root of each construct's AVE is greater than its correlations with other latent variables. Additionally, dependability was confirmed; both Composite dependability and Cronbach's Alpha values were above 0.70, confirming that the measuring tool meets recognized reliability standards and showing good internal consistency.

Table 2. Validity and Reliability of Research Variables

Variable	Indicator	FLo	Cr_α	(Cops_Re)	AVE
Eco-Friendly Fleet (EFF)			**0.847**	**0.897**	**0.685**
X1.1	Electric vehicles are proportionally used in logistics operations.	0.795			
X1.2	Eco-friendly fleets are routinely deployed in distribution processes.	0.878			
X1.3	Operating costs of green fleets are lower compared to conventional vehicles.	0.849			
X1.4	The use of eco-friendly fleets reduces carbon emissions in delivery.	0.784			
Eco-Friendly Hub (EFH)			**0.847**	**0.864**	**0.896**
X2.1	Distribution hubs utilize renewable energy such as solar panels or micro-hydro.	0.780			
X2.2	Facilities implement efficient and low-emission energy management.	0.885			

Variable	Indicator	FLo	Cr_α	(Cops_Re)	AVE
X2.3	Waste management systems at the hub follow eco-friendly principles.	0.809			
X2.4	Logistics hubs apply automation and digitalization supporting green practices.	0.831			
Operational Sustainability (OS)			**0.874**	**0.914**	**0.728**
X3.1	The company consistently complies with environmental regulations and policies.	0.886			
X3.2	The firm's reputation for environmental responsibility is improving.	0.892			
X3.3	Operations remain stable despite energy crises.	0.800			
X3.4	Stakeholders fully support the implementation of green logistics.	0.830			
Distribution Efficiency (DE)			**0.822**	**0.882**	**0.652**
Y1	Average delivery time has improved (faster).	0.741			
Y2	Distribution costs per unit of goods have decreased.	0.836			
Y3	The error or return rate of shipments has declined.	0.848			
Y4	Customers are satisfied with delivery speed and accuracy.	0.801			

Sources: Feri Rikardo, 2025.

Explanation: Va = Variable, Ind = Indicator, FLo = Factor Loading, Cr_α = Cronbach's Alpha, Cops_Re = Composite Reliability, AV-E = Average Variance Extracted (AVE).

Table 3. Validity and Reliability of Research Variables

	EFF	DE	EFH	OS
EFF	0.827			
DE	0.850	0.807		
EFH	0.864	0.842	0.827	
OS	0.947	0.768	0.876	0.853

Sources: Feri Rikardo, 2025.

Inner Structural Model Results

The inner model evaluation was conducted using three main criteria: coefficient of determination (R^2), t-statistics, and p-values. As presented in Table 4, all R^2 values are above 0.50, indicating that the model possesses strong explanatory capacity for the dependent construct. The analysis further shows that Green Logistics Fleet (GLF), Eco-Friendly Hub (EFH), and Operational Sustainability (OS) significantly affect Distribution Efficiency (DE). These findings show that the connections between the variables under study are accurately captured and represented by the structural model.

Table 4. R-Square (Determinant Coefficient)

	R_Sq	R_Sq_A
DE	0.809	0.802

Sources: Feri Rikardo, 2025.

Explanation: DE = (Distribution Efficiency), R. Sq = (R Square), R_Sq_A = (R Square Adjusted)

To determine the significance of relationships between variables at the 5% level, the study employed the criteria of a t-statistic greater than 1.65 and a p-value below 0.05. Based on the outcomes displayed in Table 5 and Figure 2, all proposed hypotheses were confirmed as statistically significant. This finding suggests that the associations among the variables are positive and meaningful, thereby supporting the acceptance of Hypotheses 1, 2, and 3 in the research framework.

Table 5. Conclusion of Hypothesis Testing

Hypothesis	β	O	SDD	T_Sta	P_Va	Hy_TC
Hyp 1: EFF → DE	0.984	0.984	0.211	4.660	0.000	Accepted
Hyp 2: EFH → DE	0.580	0.580	0.176	3.304	0.001	Accepted
Hyp 3: OS → DE	0.672	0.672	0.242	2.776	0.006	Accepted

Sources: Feri Rikardo, 2025.

Explanation: Hypo = Hypothesis, β = Path Coefficient, O = Original Sample, SDD = Standard Deviation, T_Sta = T-Statistic, P_Va = P-Value, Hy_TC = Hypothesis Testing Conclusion.

Figure 2 presents a summary of the structural model derived from the bootstrapping procedure using the Partial Least Squares Structural Equation Modeling (PLS-SEM) method. The diagram illustrates the connections among latent constructs, along with the corresponding original sample values and p-values for each path. The results demonstrate that Green Logistics Fleet (GLF), Eco-Friendly Hub (EFH), and Operational Sustainability (OS) have significant direct impacts on Distribution Efficiency (DE), with path coefficients of 0.984 ($p = 0.000$), 0.580 ($p = 0.001$), and 0.672 ($p = 0.006$), respectively. All identified relationships are confirmed to be statistically significant.

Furthermore, the measurement items associated with each construct display factor loadings exceeding 0.70, indicating strong convergent validity. This confirms that all indicators accurately capture the constructs they are intended to represent. Taken together, the model provides a comprehensive understanding of the strategic role played by green fleets, sustainable hubs, and operational sustainability in enhancing distribution efficiency.

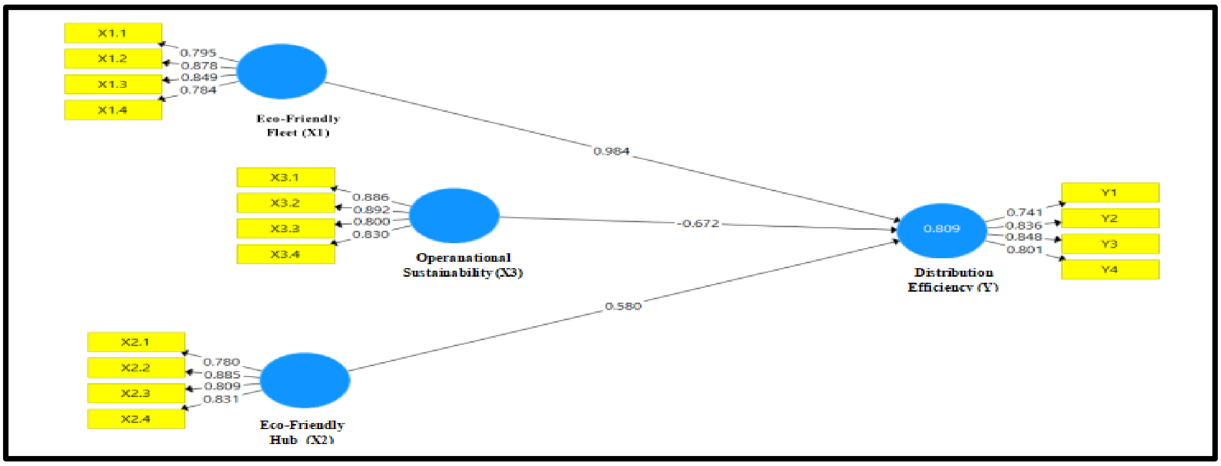

Figure 2: Summary of Model Outcomes: Bootstrapping Results, Path Coefficients, Factor Loadings, and P-Values
Sources: Feri Rikardo, 2025.

Discussion

This section presents the empirical results concerning the effects of Eco-Friendly Fleet (EFF), Eco-Friendly Hub (EFH), and Operational Sustainability (OS) on Distribution Efficiency (DE) within contemporary logistics operations. Utilizing Partial Least Squares Structural Equation Modeling (PLS-SEM) and primary data from PT Pos Indonesia's Medan Main Branch, the analysis interprets how these independent variables strategically contribute to creating a distribution system that is efficient, environmentally responsible, and energy-conscious.

The findings indicate that all three constructs positively and significantly influence distribution efficiency, as evidenced by substantial path coefficients and p-values below the 0.05 threshold. These results support theoretical perspectives on the significance of green logistics transformation and offer actionable guidance for managers and policymakers aiming to develop distribution networks that are more resilient and environmentally sustainable.

Impact of Eco-Friendly Fleet (EFF) on Distribution Efficiency

The path coefficient of 0.984 ($p = 0.000$) indicates that the adoption of environmentally friendly vehicles has a highly significant role in improving distribution efficiency. This aligns with the literature emphasizing that fleet electrification and a shift away from fossil-fuel-powered vehicles help reduce fuel costs, lower carbon emissions, and enhance corporate reputation among stakeholders and customers (Chen et al., 2022).

In the context of Green Logistics and Sustainable Supply Chain Management (SSCM), implementing a green fleet functions not merely as an operational resource but also as a strategic mechanism to enhance overall system efficiency (Purnomo et al., 2024). Advantages such as lower carbon emissions, operational cost reductions, and adherence to environmental regulations further contribute to improved distribution efficiency (Tseng et al., 2018). As a result, logistics companies that consistently adopt eco-friendly vehicles are better positioned to achieve sustainable competitive advantages over the long term.

Impact of Eco-Friendly Hub (EFH) on Distribution Efficiency

The effect of EFH on DE is represented by a path coefficient of 0.580 ($p = 0.001$), indicating a statistically significant relationship. Incorporating renewable energy sources and digital energy management systems in distribution hubs has been demonstrated to enhance loading and unloading efficiency, streamline distribution processes, and reduce waiting times (Lu et al., 2021).

These findings support the Eco-Innovation framework in logistics, which highlights the role of sustainable infrastructure in enabling efficient distribution processes (Purnomo & Syafrianita, 2024). Hubs that adopt automation and lean-green principles tend to be more responsive to demand fluctuations while simultaneously reducing excessive energy consumption (Zhang et al., 2019).

Impact of Operational Sustainability (OS) on Distribution Efficiency

OS demonstrates a direct impact on DE, with a coefficient of 0.672 ($p = 0.006$). This emphasizes that logistics operations grounded in sustainability principles—such as regulatory compliance, energy resilience, and stakeholder engagement—are capable of building distribution systems that are both robust and efficient. This resonates with the concept of Resilient Logistics, where sustainability plays a central role in ensuring continuity of distribution despite uncertainties like energy crises or global supply chain disruptions (Ivanov & Dolgui, 2020).

Organizations with a strong sustainability orientation are also better positioned to adopt digital innovations such as real-time tracking, route optimization, and predictive analytics to boost logistics efficiency. Thus, OS contributes not only to narrow efficiency goals (speed and cost) but also to broader long-term resilience.

Theoretical and Practical Implications

The results of this study contribute to advancing theories in sustainable logistics, such as Green Supply Chain Management (GSCM) and Supply Chain Agility, which conceptualize efficiency as a product of environmental initiatives and adaptive system capabilities. Theoretically, the findings provide empirical support that distribution efficiency is shaped not only by technical and cost considerations but also by organizational commitment to environmental sustainability and the implementation of sustainable operational practices.

From a practical standpoint, the results provide a basis for companies to invest more intensively in green fleets, sustainable logistics infrastructure, and long-term ESG-oriented (Environmental, Social, and Governance) strategies. By considering these three constructs, organizations can design a logistics roadmap that is not only more efficient and adaptive but also environmentally accountable.

5. Conclusions

This study set out to examine the influence of Eco-Friendly Fleet (EFF), Eco-Friendly Hub (EFH), and Operational Sustainability (OS) on Distribution Efficiency (DE) by applying the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. The results of the analysis and hypothesis testing produced several key insights, summarized as follows:

The results indicate that Eco-Friendly Fleet (EFF) exerts a strong and statistically significant influence on distribution efficiency. This suggests that employing logistics vehicles powered by clean energy can markedly improve distribution performance, including reductions in costs, faster delivery times, and lower environmental impact. These findings highlight the importance of shifting toward a more sustainable transportation system within logistics operations.

The study also demonstrates that Eco-Friendly Hub (EFH) significantly contributes to improved distribution efficiency. Logistics infrastructure that incorporates green technologies and energy-efficient systems helps accelerate distribution processes while minimizing operational inefficiencies that often hinder supply chain performance.

Operational Sustainability (OS) is shown to exert a positive influence on DE, underscoring the importance of sustainable operational practices in creating logistics systems that are both resilient and efficient. Strong sustainability orientation enables firms to better adapt and respond to external challenges, ensuring continuity and reliability in distribution activities.

Overall, the study highlights that strengthening environmentally friendly practices and operational sustainability represents a strategic pathway for advancing distribution efficiency. Collectively, the three independent variables provide meaningful contributions to shaping a distribution system that is not only efficient but also aligned with the broader goals of sustainable development.

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