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The Effect of Implementing Green Logistics and Reducing Carbon Emissions on The Operational Efficiency Of Logistics Companies

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Abstract: Increased emissions of greenhouse gases such as carbon dioxide have made global warming and climate change a major problem worldwide. According to World Air Quality Report data, the Special Capital Region (DKI) Jakarta ranks seventh as the largest contributor to emissions in 2023. This study aims to determine the implementation of the effect of implementing green logistics and reducing carbon emissions on the operational efficiency of logistics companies as an effort to support the Indonesian Government committed to the International Sustainable Development Goals (SDGs) to reduce greenhouse gas emissions in Indonesia, especially in the DKI Jakarta area. The research method to be used is a quantitative method with a survey approach and data collected through questionnaires distributed to 35 logistics companies in DKI Jakarta. SEM-PLS (Structural Equation Modeling Partial Least Squares) analysis technique is used for data processing. The results showed that the application of green logistics on the operational efficiency of logistics companies has a positive effect, the implementation of green logistics on reducing carbon emissions has a positive effect, reducing carbon emissions on the operational efficiency of logistics companies has a positive effect, and the application of green logistics on the operational efficiency of logistics companies through reducing carbon emissions has a positive effect, and the application of green logistics on the operational efficiency of logistics companies through carbon emission reduction has a positive effect.

Keyword: Efficiency, Greenhouse Gas Emissions, Sustainable Development, Green Logistics.

INTRODUCTION

Climate change and global warming are becoming increasingly urgent global issues that demand serious attention from around the world. This is in accordance with research (Phelia, et al., 2021) in (Rahmadania, 2022) that until now global warming is still a hot topic of discussion in the world without exception in Indonesia (Pinontoan, Odi. R et al., 2022). One of the main causes is carbon emissions, which is the release of carbon compounds into the atmosphere. Carbon emissions are greenhouse gas (GHG) emissions, which are a major contributor to climate change and global Warming (ecolife, 2022). GHG emissions are harmful gases that are dispersed in the earth's atmosphere and have the ability to capture the sun's heat, trapping it in the earth's atmosphere, which leads to a rise in the temperature of the earth. GHG emissions come from carbon dioxide, nitrogen dioxide, methane and Freon. The buildup of greenhouse gases in the atmosphere causes global warming of the Earth's temperature which results in climate change, ozone layer depletion and acid rain (Syihabuddin & Ruhaeni, 2022). Various activities that can cause a global warming process, including industrial activities, electricity production activities, forest fires and motor vehicle exhaust gases, namely GHG emissions. This increase in global temperature is causing sea levels to rise, the intensity of extreme weather phenomena to increase, and changes in the amount and pattern of precipitation. Other consequences of global warming are the loss of glaciers, affected agricultural yields and the extinction of various types of animals (Nastiti & Hardiningsih, 2022).

Health and Safety Executive, (2020) states that when the concentration of carbon dioxide on earth increases, it can cause health problems such as headaches, dizziness, confusion and loss of consciousness. based on disaster information data recorded within 10 (ten) years, It shows that out of 1,800 disasters that occurred from 2005 to 2015, more than 78% (11,648) were caused by climate change, resulting from increased atmospheric greenhouse gas emissions (Patrianti et al., 2020). The 2022 data is the highest level ever recorded and has increased by 1.4% or compared to the 2021 level. This upward trend suggests a continued post-COVID recovery. In fact, global (GHG) emissions in 2022 increased by 6.2% compared to 2020 and by 2.3% compared to 2019 (M. Cirippa., D.Guilzzardi., 2023).

Nationally Determined Contribution (NDC) is an ongoing commitment made by countries parties to the Paris Agreement to reduce GHG emissions and increase resilience to the impacts of climate change. The NDC development process starts from the Intended Nationally Determined Contributions (INDC) agreed at COP19 in Warsaw and detailed at COP20 in Lima. The INDC synthesis report shows that INDC implementation will slow global emissions growth and help reduce the aggregate level of global emissions compared to the no INDC scenario, although it is still higher than emissions in 1990, 2000 and 2010. In INDCs, some countries mention the terms conditional and unconditional, where conditional indicates GHG emission reduction efforts that can increase with international support. Therefore, NDCs are an important step in achieving the global goal of keeping global temperature rise below 2°C and not exceeding 1.5°C (Imelda & Soejachmoen, 2023). Based on the data of emission production that continues to increase every year through article 4.19 of the Paris agreement, Indonesia committed to reduce emissions by submitting an Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC). Indonesia's Nationally Determined Contribution outlines the country's transition to a low-carbon future and formulates a long-term low GHG emissions development strategy until 2050. Indonesia's Long Term Strategy (LTS) will play a role in aligning climate goals and targets with national, sub-national and international goals, including the Sustainable Development Goals (SDGs) (Sugawara & Nikaido, 2014).

Sustainable development is development that meets the needs of the present without compromising the ability of future generations. A key principle of sustainable development is to maintain the quality of life for all people now and in the future. Sustainable development has the principles of economic welfare, social justice and environmental preservation (Widdjajanti et al., 2014). The Sustainable Development Goals, commonly known as SDGs or Global Goals, are a set of goals set by the United Nations (UN) to achieve a better and more sustainable life for all people. There are 17 interconnected and mutually supportive SDGs to address the global challenges we face with a 2030 global goal declared by both developed and developing countries at the UN General Assembly in September 2015. Based on the 17 Goals, Goals 7 on Ensure access to affordable, reliable, sustainable and modern energy for all, Goals 9 on Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation, Goals 13 on Take urgent action to combat climate change and its impacts and Goals 17 on Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development. Some of these Goals address taking immediate action to combat climate change and its impacts through green development.

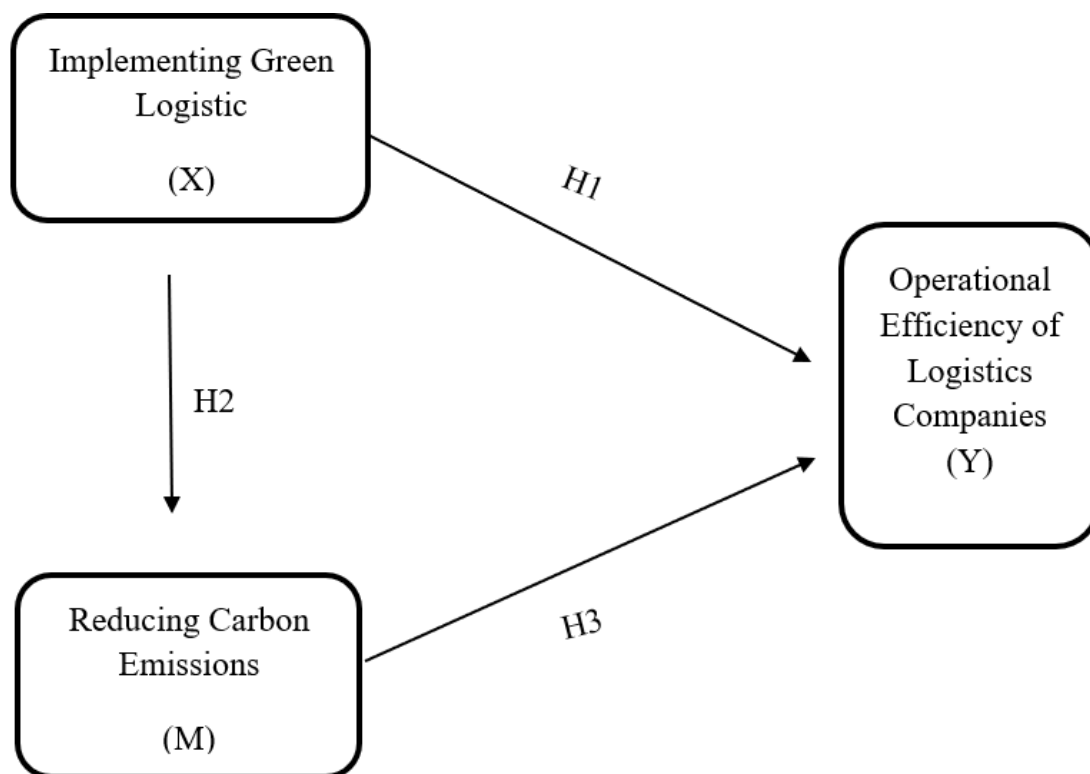
According to Martin et al., (2023) Indonesia is one of the largest contributors to GHG emissions in 2022 compared to 2021. This is motivated by the fact that the most populous region in Indonesia, the Special Capital Region (DKI) Jakarta, is a contributor to the total greenhouse gas emissions in Jakarta in 2022 reaching 60,399 Gg (thousand tons) CO_{2e} according to (Dinas Lingkungan Hidup Provinsi DKI Jakarta, 2023). DKI Jakarta is a dense megapolitan city surrounded by Bogor, Depok, Tangerang and Bekasi (Bodetabek), which requires transportation facilities to support economic activities and community mobilization both in DKI Jakarta and its surrounding areas. Based on data (*Badan Pusat Statistik Indonesia*, 2023) the total number of vehicles in Jakarta in 2022 amounted to 148 million units with a classification of 17 million passenger cars, 243 thousand buses, 5 million freight cars and 125 million motorcycles. The amount of data from the transportation sector, so that the resulting greenhouse gas emissions are the largest contributor to greenhouse gas emissions with a portion of 53% (Dinas Lingkungan Hidup Provinsi DKI Jakarta, 2023)

One form of implementing green development is by using the concept of environmentally friendly logistics or commonly referred to as Green Logistics. The need for green logistics arises from several environmental challenges faced by the industry such as the negative impact of traditional logistics practices. The benefits of transitioning to sustainable logistics are numerous, and by implementing green practices, the logistics sector can contribute to a more sustainable and resilient future (Potter & Robert, 2024). Green logistics is a concept in logistics that prioritizes environmentally friendly and does not damage the environment, starting from the processing of goods until the goods arrive and can be used by consumers. Green logistics guarantees strong profits without compromising customer satisfaction and the well-being of the earth. Green logistics processes are carried out to reduce and minimize the impact of environmental damage, such as pollution or waste generated from the logistics sector. Sustainability in logistics refers to implementing practices and strategies that minimize the environmental impact of transportation, warehousing, and supply chain operations. This logistics sustainability aims to reduce carbon emissions, conserve resources, and promote efficient energy use. Reduction of non-renewable energy consumption, air emissions, greenhouse gas emissions, and waste is one of the efforts to reduce environmental pollution in logistics activities.

Global warming is an increasingly pressing global issue and the main cause is carbon emissions, which contribute greatly to climate change. The implementation of green logistics is one of the concepts to realize the SDGs and Indonesia's commitment to reduce greenhouse gas emissions. By implementing green practices in logistics, not only does it have a positive

impact on the environment but also logistics companies can contribute to sustainable development while improving the Company's operational efficiency. Based on the background and data above, we will conduct research with the title "The Effect of Green Logistics Implementation and Carbon Emissions Reduction on the Operational Efficiency of Logistics Companies".

Framework analysis and Hypotheses



Source: Based an authors
Figure 1 Framework Analysis

- H1: The implementation of Green Logistics has an effect on the Operational Efficiency of Logistics Companies.
- H2: The implementation of Green Logistic has an effect on Carbon Emission Reduction
- H3: The Effect of Carbon Emissions Reduction on Operational Efficiency of Logistics Companies.
- H4: The Effect of Green Logistics Implementation on the Operational Efficiency of Logistics Companies Through Reducing Carbon Emissions.

METHOD

This study uses quantitative research methods and the population consists of logistics companies in Jakarta. The sampling method in this study uses probability sampling. The technique used is purposive sampling, which is a method chosen based on certain criteria or considerations. The sample criteria in this study are respondents must be companies engaged in logistics. sample of 35 respondents was drawn using a Likert scale to collect responses on a point scale ranging from 1 (strongly disagree) to 5 (strongly agree). Data analysis using SEM-PLS (Structural Equation Modeling Partial Least Squares) analysis technique using SmartPLS software.

Object of Research

In this study, it consists of 3 variables with the independent variables being the Implementation of Green Logistics (X1) and Carbon Emissions Reduction (X2) and the dependent variable being the Operational Efficiency of Logistics Companies (Y).

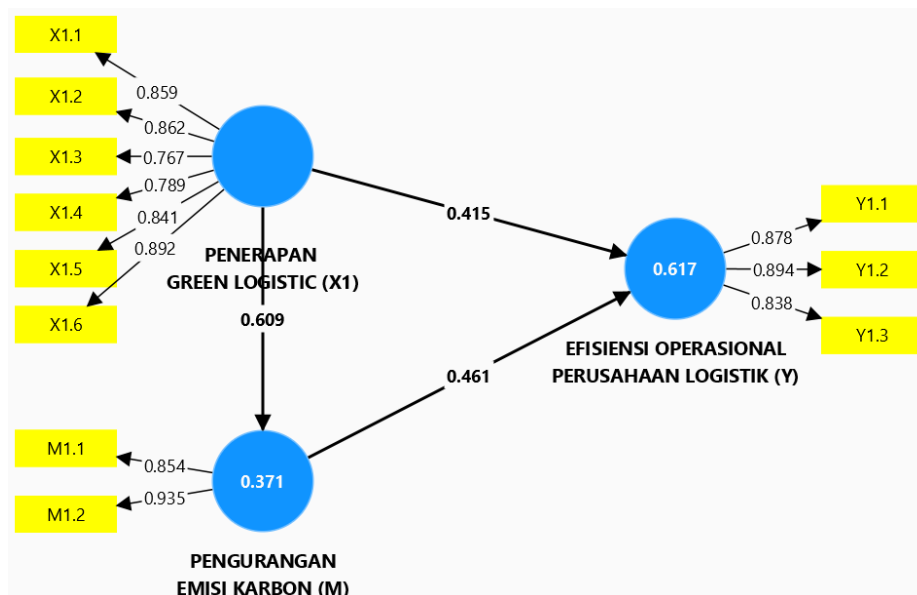
Table 1. Questionnaire indicators

Variable	Indicator	Source
Green Logistic	X1.1	Green Packaging
	X1.2	Green Storage
	X1.3	Green Transportation
	X1.4	Green Technology
	X1.5	Green Purchasing
	X1.6	Reverse Logistic
Carbon Emissions	M1.1	Carbon Emission Disclosure
	M1.2	Energy Efficiency
Operational Efficiency	Y1.1	Low Carbon
	Y1.2	Resource Efficiency
	Y1.3	Socially Inclusive

Source: Based an authors

RESULTS AND DISCUSSION

Calculations supported by SmartPLS give the following results:



Source: Based on SmartPLS4 Calculating
Figure 2 PLS Algorithm

Evaluasi Model Pengukuran (Outer Model)

1. Indicator Reliability

a) Outer Loading

Assessing the outer model involves examining the outer loading of the indicators. A high outer loading indicates a lot of similarity in the construct. The minimum value of outer loading is 0.7 (Hair & Alamer, 2022).

Table 2. Outer Loading

Variable	Implementation Of Green Logistic (X1)	Carbon Emissions Reduction (M)	Operational Efficiency of Logistic Companies (Y)
X1	0.859		
X2	0.862		
X3	0.767		
X4	0.789		
X5	0.841		
X6	0.892		
M1		0.854	
M2		0.935	
Y1			0.878
Y2			0.894
Y3			0.838

Source: Based on SmartPLS4 Calculating

Based on the results of convergent validity testing in the table, it can be seen that all indicators have an outer loading value ≥ 0.70 . Therefore, all indicators in this study can be declared to have met the criteria.

b) Cronbach’s Alpha dan Composite Reliability (Internal Consistency Reliability)

The next test that needs to be done on the outer model is the internal consistency reliability test. This test is carried out through the Cronbach alpha and composite reliability values. The Cronbach alpha value describes the correlation of indicators on a construct, while composite reliability looks at the difference in outer loading of indicator variables. Hair & Alamer, (2022) states that the accepted Cronbach alpha and composite reliability values must be more than 0.6.

Table 3. Cronbach’s Alpha and Composite Reliability

Variable	Cronbach’s Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Implementation Of Green Logistic (X1)	0.84	0.843	0.903	0.757
Carbon Emissions Reduction (M)	0.913	0.914	0.933	0.699
Operational Efficiency of Logistic Companies (Y)	0.761	0.842	0.89	0.802

Source: Based on SmartPLS4 Calculating

The test results in the table show that all latent variables meet the reliability test criteria. This is based on the Cronbach alpha and composite reliability values of all latent variables having a value > 0.6 . Therefore, all latent variables are declared reliable after meeting all measurement criteria.

c) Validitas Konvergen (AVE)

Convergent validity testing can be done by evaluating the Average Variance Extracted (AVE). According to Hair et al. (2022) when the AVE value is greater than 0.5, the construct is able to explain more than 50% of the indicator variance.

Based on the test results, the latent variable Operational Efficiency of Logistics Companies (Y) has a Cronbach's alpha value of 0.84 and a composite reliability of 0.903, with an AVE value of 0.757. This shows that the construct is able to explain 75.7% of the variance of its indicators, which indicates good convergent validity. Furthermore, the Green Logistics Implementation variable (X1) shows a Cronbach's alpha value of 0.913 and a composite reliability of 0.933. With an AVE value of 0.699, this construct is able to explain 69.9% of the variance of its indicators, which indicates that the convergent validity of this construct is quite good. Meanwhile, the Carbon Emissions Reduction variable (M) has a Cronbach's alpha value of 0.761 and a composite reliability of 0.89, as well as an AVE value

of 0.802, which indicates that this construct can explain 80.2% of the variance of its indicators, signifying excellent convergent validity. Overall, all latent variables in this analysis have adequate reliability and convergent validity values, with Cronbach's alpha and composite reliability values above 0.6 and AVE values above 0.5.

d) Discriminant Validity

Evaluation to assess how different a construct is from other constructs to capture different phenomena can be done with discriminant validity test. Generally, researchers use several tests used in discriminant validity, such as Fornell-Larcker criterion, cross loading, and heterotrait monotrait rasion (HTMT) (Hair & Alamer, 2022).

The first criterion to consider for discriminant validity is the Fornell-Larcker criterion. To meet the criteria for this test, the square root of the AVE must be greater than the highest correlation with other constructs, as shown in the Table.

Tabel 4. Fornell-Larcker criterion

Variabel	Implementation Of Green Logistic (X1)	Implementation Of Green Logistic (X1)	Implementation Of Green Logistic (X1)
Implementation Of Green Logistic (X1)	0.836		0.695
Carbon Emissions Reduction (M)	0.609	0.896	0.713
Operational Efficiency of Logistic Companies (Y)			0.87

Source: Based on SmartPLS4 Calculating

Based on the table above, the square root values of the AVE for each construct are greater than the correlations with other constructs, which means that these figures meet the Fornell-Larcker criterion.

The next criterion to consider is the cross-loading value. According to this criterion, the outer loading of an indicator on the related construct must be greater than the cross loading on other constructs. The loading factor value can be seen in the table.

Tabel 5. Cross Loading

Variable	Implementation Of Green Logistic (X1)	Carbon Emissions Reduction (M)	Operational Efficiency of Logistic Companies (Y)
X1	0.859	0.515	0.546
X2	0.862	0.44	0.63
X3	0.767	0.596	0.492
X4	0.789	0.503	0.623
X5	0.841	0.48	0.529
X6	0.892	0.518	0.653
M1	0.371	0.854	0.551
M2	0.671	0.935	0.707
Y1	0.721	0.574	0.878
Y2	0.619	0.615	0.894
Y3	0.462	0.681	0.838

Source: Based on SmartPLS4 Calculating

Based on the table, it can be stated that the values of each *outer loading* are higher than the *cross loading* on other constructs.

Another important criterion to consider in discriminant validity is the heterotrait-monotrait ratio (HTMT). HTMT is the mean of all relationships between indicators across constructs. According to (Hair & Alamer, 2022), The maximum value of HTMT correlation is 0.9. An HTMT correlation value greater than 0.9 indicates a lack of *discriminant validity*.

Table 6. Heteroit Monotrait Ratio (HTMT)

Variabel	Implementation Of Green Logistic (X1)	Implementation Of Green Logistic (X1)	Implementation Of Green Logistic (X1)
Implementation Of Green Logistic (X1)			0.786
Carbon Emissions Reduction (M)	0.695		0.879
Operational Efficiency of Logistic Companies (Y)			

Source: Based on SmartPLS4 Calculating

Based on the table, there are no HTMT correlation values greater than 0.9. These values have met the HTMT criteria and have passed *the discriminant validity test*.

At this stage, each construct has met all the necessary criteria for the discriminant validity test, so it can be concluded that each construct is empirically distinct from the others and is capable of capturing phenomena not represented by other constructs in the model. Therefore, each indicator is deemed to meet the criteria *for the discriminant validity test*.

Inner Model Evaluation (Structural Model Assessment)

The next evaluation that is carried out when the measurement model is declared valid and reliable is the Structural Model Assessment or what is commonly called the inner model evaluation. According to Hair & Alamer, (2022), inner model evaluation is carried out with several tests, such as collinearity, significance and relevance of model relationships, Model's Explanatory Power, and Model's Predictive Power.

1. Assess the significance and relevance of the structural model relationships path coefficient and t-value

this stage, the test carried out is by looking at the path coefficient value and the t value. The path coefficient value close to 1 indicates a positive relationship and vice versa, a value close to 0 indicates a weak relationship in the model structure. Furthermore, the t value shows the significance of a relationship between variables at a certain error level. In this study, researchers used a significance error level of 5%, which means that the t value must be greater than 1.65 (Hair et al., 2022).

Table 7. Path Coefficients and T-Values

Variable	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (O/STDEV)	P Values
Implementation Of Green Logistic (X1) → Operational Efficiency of Logistic Companies (Y)	0.415	0.420	0.109	3.803	0.000
Implementation Of Green Logistic (X1) → Carbon Emissions Reduction (M)	0.609	0.619	0.089	6.831	0.000
Carbon Emissions Reduction (M) → Operational Efficiency of Logistic Companies (Y)	0.461	0.463	0.110	4.184	0.000

Source: Based on SmartPLS4 Calculating

The results of the analysis show that Green Logistics Implementation (X1) has a positive and significant influence on the Operational Efficiency of Logistics Companies (Y) with a path coefficient value of 0.415 and a t value of 3.803. In addition, Green Logistics Implementation (X1) also shows a positive and significant influence on Carbon Emissions Reduction (M) with a path coefficient value of 0.609 and a t value of 6,831. Finally, Reduced

Carbon Emissions (M) has a positive and significant influence on the Operational Efficiency of Logistics Companies (Y) with a path coefficient value of 0.461 and a t value of 4.184.

2. Assess the model’s explanatory power

a) R-Square Value

Structural model evaluation includes assessing the explanatory power of the model. The explanatory power of a model relates to its ability to fit the data at hand by measuring the strength of association indicated by the PLS path model. The most commonly used measure to evaluate the explanatory power of a structural model is the coefficient of determination (R²) value, the R-square value or coefficient of determination used to evaluate the strength of the structural model. The higher the r-square value, the better the prediction model of the proposed research model.

Table 8. R Square

Variable	R Square	R Square Adjusted
Carbon Emissions Reduction (M)	0.371	0.352
Operational Efficiency of Logistic Companies (Y)	0.617	0.593

Source: Based on SmartPLS4 Calculating

The table above shows the R-square value for the Operational Efficiency of Logistics Companies (Y) is 0.617. This value indicates that the influence of the independent variables on the Operational Efficiency of Logistics Companies is 61.7% and the remaining 38.3% is influenced by other variables outside the model. Furthermore, the R-square value for Carbon Emissions Reduction (M) is 0.371. This value indicates that the influence of the independent variables on Carbon Emissions Reduction is 37.1% and the remaining 62.9% is influenced by other variables outside the model.

b) Effect Size Value

Furthermore, the test that needs to be done at the Assess the model's explanatory power stage is to see the effect size or f² value. Effect size evaluation is carried out by looking at the f² value to determine the amount of influence of exogenous variables on endogenous variables in a model. The guideline for assessing f² is that values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively (Hair & Alamer, 2022). The following is the magnitude of the f-square value of each construct which can be seen in Table.

Table 9. Effect Size Value (f²)

Variable	Operational Efficiency of Logistic Companies (Y)	Carbon Emissions Reduction (M)
Implementation Of Green Logistic (X1)	0.282	0.592
Carbon Emissions Reduction (M)	0.348	

Source: Based on SmartPLS4 Calculating

The influence of the implementation of Green Logistics (X1) on the operational efficiency of logistics companies (Y) has an effect size of 0.282, which falls into the large category, indicating that the implementation of Green Logistics has a significant impact on the operational efficiency of logistics companies. Furthermore, the influence of the implementation of Green Logistics on carbon emission reduction (M) has an effect size of 0.591, which is also categorized as large, showing that the implementation of Green Logistics has a substantial effect on carbon emission reduction. Lastly, the influence of carbon emission reduction (M) on the operational efficiency of logistics companies (Y) has an effect

size of 0.348, which is categorized as large, indicating that carbon emission reduction has a significant impact on the operational efficiency of logistics companies.

3. Assess the model's predictive power

Predictive relevance (Q²)

For the path model in this study to be useful for managerial decision-making, it needs to produce generalizable findings. Generating generalizable findings requires assessing whether the research results are not only applicable to the data used during the calculation process, but should also be applicable to other data sets. (Hair & Alamer, 2022). Assessment of predictive power can be done by looking at the predictive relevance (Q²) value. The higher the Q-square value produced, the better the research results produced and the better it is at predicting results with different sample data.

Table 10 Predictive Relevance (Q²)

Variable	SSO	SSE	Q ² (1-SSE/SSO)
Implementation Of Green Logistic (X1)	210	210	
Carbon Emissions Reduction (M)	70	51	0.271
Operational Efficiency of Logistic Companies (Y)	105	57	0.454

Source: Based on SmartPLS4 Calculating

Based on the table, the Q² calculation results show that the research model has a Q² value of 0.454 (>0) for the logistics company operational efficiency variable (Y) and 0.271 (>0) for the carbon emission reduction variable (M), which indicates that the model is quite good and has sufficient predictive relevance.

CONCLUSION

This study tests four hypotheses related to the impact of Green Logistics implementation on the operational efficiency of logistics companies and its role in reducing carbon emissions. First, the results show that the implementation of Green Logistics has a positive and significant influence on the operational efficiency of logistics companies. This confirms that the first hypothesis is accepted. Second, it was found that Green Logistics also contributes positively and significantly to the reduction of carbon emissions, so the second hypothesis is accepted. Third, carbon emission reduction was shown to have a positive and significant influence on the operational efficiency of logistics companies, supporting the acceptance of the third hypothesis. Finally, the research shows that the implementation of Green Logistics indirectly improves operational efficiency through its contribution in carbon emission reduction. This leads to the fourth hypothesis being accepted. Thus, the implementation of Green Logistics not only directly improves operational efficiency, but also indirectly contributes through the reduction of carbon emissions.

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