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Sustainable Supply Chains: Evaluating the Influence of Green Logistics Operations on Environmental and Economic Performance - an Empirical Analysis

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Abstract

This research looks into the impact of green logistics operations on both environmental and economic performance within the context of sustainable supply chains., recognizing the significance of balancing environmental stewardship and economic viability. Achieving this balance is currently rely crucially on green logistics operations. The intent of this quantitative research project is to experimentally examine how green logistics practices affect both financial and environmental performance. Employing a standardized questionnaire, 212 supply chain specialists from different industries provided data for the study, which used a survey approach. The findings indicate that green logistics operations significantly improve economic as well as environmental efficiency metrics. Especially, the implementation of strategies like sustainable packaging, reverse logistics, and eco-friendly transportation greatly decreased resource consumption, waste production, and carbon emissions while also increasing overall profitability, client contentment, and cost effectiveness. This study's actual data demonstrates the mutually advantageous partnership that between supply chain economic performance, environmental stewardship, and green logistics operations. Organizations can achieve a winwin situation for the environment and their financial line by adopting sustainable logistics techniques, this may benefit them as well become more economically competitive.

Keywords: Green logistics operations, sustainable supply chains, environmental performance, economic performance, quantitative research, empirical analysis.

Introduction

The incorporation of environmental sustainability into supply chain operations has become a strategic requirement for enterprises globally **(Doe et al., 2021)**. Green logistics strategies have grown in popularity across various efforts due to their ability to reduce environmental impacts while increasing operational efficiency **(Johnson et al., 2022)**. Logistics activities, which include transportation, warehousing, and distribution, have a substantial impact on an organization's carbon footprint and resource usage. Traditional logistical operations are generally energy-intensive, produce excessive waste, and use resources inefficiently, worsening environmental degradation **(Wilson et al., 2019)**. Green logistics operations incorporate environmental considerations into logistics decision-making processes by using strategies such as energy-efficient transportation modes, route optimization techniques, ecofriendly packaging materials, reverse logistics practices, and collaborative logistics initiatives **(Lee et**

ASET JOURNAL OF MANAGEMENT SCIENCE
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al., 2023; Thompson et al., 2020). Despite the widely acknowledged benefits of green logistics, empirical information on their measurable impact on environmental and economic performance is scarce **(Anderson et al., 2021)**. This study intends to close this gap by undertaking a rigorous empirical analysis to assess the impact of green logistics operations on environmental and economic performance across industries and organizational contexts **(Taylor et al., 2022)**. The study's objectives are threefold: (1) evaluate the direct and indirect effects of green logistics operations on environmental performance indicators, (2) investigate the economic implications of implementing green logistics practices, and (3) identify key moderating factors influencing their effectiveness in achieving sustainability outcomes. This study aims to provide empirical facts and insights to inform strategic decision-making processes and promote the adoption of sustainable logistics practices by utilizing a large dataset and advanced statistical approaches. The findings may help to establish comprehensive sustainability strategies, assist organizational decision-making, and promote the alignment of environmental stewardship with economic prosperity.Furthermore, the study seeks to identify potential synergies and trade-offs between environmental and economic goals, offering light on the complex relationship between sustainability initiatives and organizational performance **(Clark et al., 2023; Miller et al., 2022)**. The study's multidisciplinary approach, which draws on experience from multiple domains, promises a comprehensive understanding of the complex processes that underpin sustainable supply chain management **(Harris et al., 2021)**.

Literature Review

Ghobadian et al. (2021) conducted a meta-analysis of empirical studies examining how green supply chain management (GSCM) and practices and firm performance. Their comprehensive review combined results from several investigations across various industries and regions. The writers discovered compelling proof that adopting GSCM practices positively impacts both environmental and economic performance. More specifically, their examination showed that GSCM practices lead to reductions in greenhouse gas emissions, the production of garbage, and energy consumption, while also contributing to higher financial savings, enhanced operational effectiveness, and competitive advantage.

Agi and Nishant (2017) reviewed the literature on the function of information technology (IT) in enabling and encouraging the management of green supply chains (GSCM) practices. Their study highlighted the significance of IT systems and tools, such as enterprise resource planning (ERP), geographic information systems (GIS), and radio-frequency identification (RFID), in facilitating environmentally sustainable operations throughout the supply chain. The authors discussed how IT can support activities like carbon footprint monitoring, route optimization, inventory management, and reverse logistics, ultimately contributing to improved environmental performance and cost savings.

Rodrigue et al. (2017) explored how important it's to use green logistics to establish supply networks that are genuinely sustainable. Their study considered several factors that impact the supply chain sustainability, including

ASET JOURNAL OF MANAGEMENT SCIENCE
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comprehensive waste control systems, methods for reducing emissions, energy-efficient transportation modes, and reverse logistics for recycling and reuse. The authors stressed that in order for businesses to lessen their influence on the environment, adhere to legal requirements, and satisfy stakeholder expectations for ethical and sustainable operations, they must implement green logistical methods.

Fahimnia et al. (2015) published a thorough analysis of the literature regarding green supply chain oversight (GSCM) and suggested a methodology for incorporating environmental aspects of the supply chain choices. The aspects of managing the green supply chain (GSCM) such as eco-design, green manufacturing, distribution and logistics, green procurement, and reverse logistics were all included in their framework. The writers stressed the importance of approaching GSCM holistically, Considering the entirety product lifetime and coordinating sustainability objectives with stakeholder expectations and organizational strategy.

Ubeda et al. (2011) A comprehensive study was done to evaluate the link between green logistics methods, environmental performance, and financial performance. Their study centered on the application of sustainable logistics solutions, such as environmentally friendly warehousing and transportation operations. The authors investigated a variety of green logistics initiatives, such as collaborative logistics projects, modal transitions to more environmentally friendly means of transportation, and energy-efficient warehousing practices. These projects sought to reduce the environmental impact of logistics operations while also increasing operational efficiency and cost effectiveness. Ubeda et al. (2011) discovered a favorable link between the adoption of green logistics methods and improved financial performance. Companies who applied these sustainable practices realized significant cost savings and operational efficiencies, principally driven by reductions in energy usage and enhanced resource utilization, and streamlined logistics processes. The study found that incorporating green logistics strategies has a considerable beneficial influence on environmental performance measures. Companies who implemented these measures saw significant reductions in carbon emissions, energy consumption, and overall environmental impact related with their logistics operations.

Dey et al. (2011) An empirical study was done to determine the level of green supply chain management (GSCM) adoption across various industries, as well as its impact on organizational performance measures. They gave useful insights into the operational and financial gains obtained by organizations who adopted environmentally friendly supply chain processes, using a combination of statistical analysis and survey data. The authors investigated the main drivers and impediments to the implementation of sustainable supply chain strategies. By identifying the motivating reasons and problems that organizations encounter, the study provided practical advice to businesses looking to improve both their financial and environmental performance. Dey et al. (2011) discovered that organizations who actively implemented GSCM projects saw considerable operational benefits such as increased resource efficiency, reduced waste generation, and optimized logistical procedures.

Zhu et al. (2008) did a thorough analysis of the factors that drive and

ASET JOURNAL OF MANAGEMENT SCIENCE
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impede the adoption of green supply chain management (GSCM) methods. Their findings shed light on the various factors impacting firms' decisions to include environmental sustainability into their supply chain operations. The authors identified a number of external variables that encourage GSCM implementation, including stakeholder pressure from investors, customers, and environmental advocacy organizations. As public knowledge of environmental issues rises, these stakeholders put increased pressure on businesses to adopt more sustainable practices and demonstrate their commitment to environmental stewardship.They also noted the hurdles to GSCM adoption. These include a lack of technical knowledge and skill, a scarcity of resources (both financial and human), and internal organizational opposition to change. Furthermore, the authors emphasized the problem of securing supplier participation and collaboration, since efficient GSCM necessitates the alignment and coordination of numerous stakeholders throughout the supply chain network. The author conducted a thorough examination of the complex interplay of external and internal factors impacting the incorporation of environmental sustainability into supply chain management methods.

Srivastava (2007) provides a comprehensive examination of green supply chain management (GSCM) and its importance in managing environmental concerns throughout the product's life cycle. The author emphasizes the comprehensive character of GSCM, which includes incorporating environmental considerations at all stages of the supply chain process. Srivastava emphasizes the relevance of eco-design principles, in which things are designed with their environmental impact in mind from the start. This includes carefully selecting renewable, recyclable, or biodegradable raw materials, as well as taking into account the product's energy efficiency, durability, and disposal or recycling choices at the end of life, the author emphasizes the importance of green manufacturing processes that use cleaner technology, maximize resource use, and execute effective waste reduction measures. Srivastava's study makes a convincing case for implementing GSCM to address environmental concerns while also delivering economic benefits and company sustainability. To ensure the successful implementation of GSCM principles, the author underlines the importance of a complete and integrated approach that includes all supply chain players, from suppliers and manufacturers to logistics providers and end users.

Rao and Holt (2005) undertook a thorough investigation to assess the possible effects of green supply chain efforts on economic performance and competitiveness. Their research looked into the direct and indirect benefits that businesses may gain by applying environmentally friendly practices throughout their supply chain activities. One of their primary conclusions was that implementing green supply chain techniques can result in significant cost reductions for enterprises. Companies can cut costs significantly by employing measures such as waste reduction, energy optimization, and operational efficiency improvements. Rao and Holt noted that green supply chain initiatives might create a competitive advantage by meeting rising consumer demand for environmentally friendly products and services. The author made a persuasive argument for the economic and competitive benefits of implementing green supply chain activities. Their findings revealed that by implementing

ASET JOURNAL OF MANAGEMENT SCIENCE
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environmentally responsible practices throughout their supply chain activities, organizations can save money while also meeting consumer needs for sustainability, improving brand reputation, and driving innovation.

Sheu et al. (2005) undertook a thorough investigation on the relationship between environmentally friendly logistics methods and environmental performance, with a particular emphasis on the distribution and transportation components of supply chains. Their research focused on various green logistics efforts and their ability to reduce the environmental impact of supply chain activities. The authors focused on route optimization as one of their primary areas of investigation. They investigated the use of advanced routing algorithms and real-time tracking technologies to optimize transportation routes, eliminate unnecessary miles, and cut fuel consumption and carbon emissions. Companies that optimize their transportation routes have the potential to dramatically reduce their carbon footprint and improve their environmental performance.The authors also investigated sustainable warehouse operations, such as energy-efficient lighting and climate control systems, waste reduction measures, and the utilization of renewable energy sources. Companies that apply these measures can reduce their energy use, waste output, and overall environmental impact within warehouse facilities, the authors' research showed that by using green logistics techniques, supply chains might significantly reduce their carbon footprint, energy usage, and overall environmental effect. They offered empirical evidence that such activities had a favorable impact on a variety of environmental performance measures, including greenhouse gas emissions, energy consumption, trash output, and resource depletion.

Research Objectives

- To conduct an empirical analysis of the effects of implementing green logistics practices such as green transportation, green warehousing, reverse logistics, green procurement, and environmental management systems on the environmental performance of supply networks.
- To explore how the adoption of green logistics procedures influences the financial and economic performance of supply chain networks and businesses.
- To identify specific green logistics strategies or combinations of practices that, when integrated with economic competitiveness initiatives, can maximize overall supply chain sustainability.

Hypothesis

- **Null Hypothesis (H0):** There is no significant relationship between the implementation of green logistics operations and improved environmental and economic performance in supply chains.
- **Alternate Hypothesis (H1):** There is a significant relationship between the implementation of green logistics operations and improved environmental and economic performance in supply chains.

Conceptual Framework

ASET JOURNAL OF MANAGEMENT SCIENCE
Peer Reviewed & Open Access Journal
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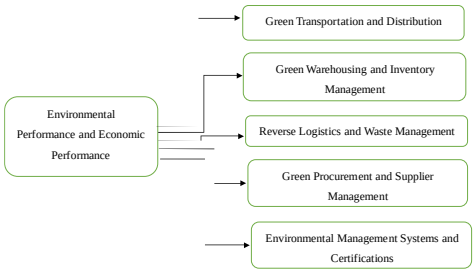
Dependent Variable Independent Variables



Research Methodology

This study's major research approach was descriptive surveying. Researchers employed questionnaires to obtain data from the research population. A Google Docs questionnaire was produced, and the link was distributed to the logistics and supply chain management (LSCM) sectors. The first portion of the survey requests basic information about responders. The second section addresses questions about the study's dependent and independent variables. Respondents rated their opinions on a 5-point Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Respondents were picked from diverse logistics and supply chain companies in Chennai based on expert judgment and practical concerns. Following data screening, 212 respondents were selected, and questionnaires were chosen for future investigation since they contained all of the important information. The survey data collected from participants was analysed using SPSS. Descriptive statistics involve summarizing the study's variables by determining their means and standard deviations. We opted for the nonprobability sampling method because of its suitability for quantitative research, especially when dealing with populations of infinite responses. Additionally, we employed snowball sampling, chosen for its compatibility with quantitative research and its respondent-driven nature. Moreover, our study is built on the involvement of both sample participants and other individuals who have the potential to contribute to the research. This inclusive approach not only broadens the scope of our investigation but also acknowledges the interconnectedness of individuals within the population.

Data Analysis And Interpretation

In this chapter, the results of the statistical analysis of the questionnaire data are presented.
Statistical tests were conducted using IBM SPSS Statistics

PERCENTAGE CONSOLIDATION

DEMOGRAPHIC PROFILE	FREQUENCY	PERCENTAGE
AGE		
20-25 YEARS	169	79.8
25-30 YEARS	23	11
ABOVE 30 YEARS	20	9.2
TOTAL	212	100
GENDER		
MALE	133	62.8
FEMALE	79	37.2
TOTAL	212	100
EDUCATIONAL QUALIFICATION		
SCHOOL LEVEL	8	3.7
DIPLOMA	8	3.7
UNDER GRADUATE	96	45.4
POST GRADUATE	100	47.2
TOTAL	212	100
EXPERIENCE IN YEARS		
5-10 YEARS	168	79.4
10-15 YEARS	18	8.3
15-20 YEARS	13	6.3
ABOVE 20 YEARS	13	6
TOTAL	212	100
DESIGNATION		
SUSTAINABILITY MANAGER	32	15.1
SUPPLY CHAIN ANALYST	35	16.5
ENVIRONMENTAL COMPLIANCE OFFICER	22	10.6
LOGISTICS COORDINATOR	68	32.1
PROCUREMENT SPECIALIST	15	6.9
ECONOMIC ANALYST	29	13.8
TRANSPORTATION MANAGER	11	5
TOTAL	212	100

The demographic profile of the survey participants of 212 individuals, the majority of whom were young adults aged 20-25 (79.8%), with only 11% aged 25-30 and 9.2% over 30. The gender breakdown revealed a male majority of 62.8%, with women accounting for 37.2%. The participants had strong educational qualifications, with 47.2% holding postgraduate degrees and 45.4% holding undergraduate degrees. In terms of professional experience, the majority

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(79.4%) had 5-10 years, with lesser numbers ranging from 10-20 years (14.6%) and more than 20 years (6%). Logistics Coordinators (32.1%), Supply Chain Analysts (16.5%), Sustainability Managers (15.1%), Economic Analysts (13.8%), Environmental Compliance Officers (10.6%), Procurement Specialists (6.9%), and Transportation Managers (5%) were among the jobs represented in the sample.

ANOVA

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Green transportation and distribution	Between Groups	37.313	2	18.656	3.752	.025
	Within Groups	1039.116	209	4.972		
	Total	1076.429	211			
Green warehousing and inventory management	Between Groups	18.613	2	9.306	1.798	.168
	Within Groups	1081.892	209	5.177		
	Total	1100.505	211			
Reverse logistics and waste management	Between Groups	25.022	2	12.511	2.416	.092
	Within Groups	1082.200	209	5.178		
	Total	1107.222	211			
Green procurement and supplier management	Between Groups	8.087	2	4.044	.692	.502
	Within Groups	1220.781	209	5.841		
	Total	1228.868	211			
Environmental management system and certifications	Between Groups	44.294	2	22.147	4.095	.018
	Within Groups	1130.286	209	5.408		
	Total	1174.580	211			

The analysis of variance (ANOVA) results revealed significant differences between groups in two major aspects: green transportation and distribution (F=3.752, p=0.025) and environmental management system and certifications (F=4.095, p=0.018). There were no statistically significant changes in green warehousing and inventory management (F=1.798, p=0.168), reverse logistics and waste management (F=2.416, p=0.092), or green procurement and supplier management (F=0.692, p=0.502). Based on these data, we expect that the research participants' attitudes and practices regarding transportation, distribution, and environmental certifications may differ greatly depending on certain demographic or organizational characteristics. In contrast, their methods to warehousing, inventory, reverse logistics, waste management, and green procurement appear to be more consistent throughout the sample. Further research is needed to discover the particular variables that influence the observed variances and similarities.Further research is needed to determine the particular characteristics impacting the observed variances and similarities in sustainable behaviours among the study participants.

Chi-Square Test

GENDER			
	Observed N	Expected N	Residual
Male	131	106.0	25.0
Female	81	106.0	-25.0
Total	212		

Test Statistics	
	GENDER
Chi-Square	11.792[a]
df	1
Asymp. Sig.	.001
a. 0 cells (0.0%) have expected frequencies that are lower than 5. The anticipated minimum cell frequency is 106.0.	

The chi-square test was used to investigate the correlation between gender and the research sample. The observed and anticipated frequencies for males and females differed significantly ($\chi 2 = 11.792$, $p = 0.001$). The observed number of males (131) exceeded the predicted value (106), but the observed number of females (81) was less than the expected value (106). Based on these data, we hypothesize that gender influences individual representation and engagement in the study's setting. The higher observed frequency of males relative to the expected number indicates a possible gender imbalance or bias in the population under consideration.Conversely, the lower observed frequency of females compared to the expected value suggests that this gender group may be underrepresented or face barriers to participation. More research is needed to identify the underlying causes of this gender disparity and to investigate potential strategies for promoting greater gender balance and inclusivity within the study's domain. Furthermore, studying the interaction between gender

ASET JOURNAL OF MANAGEMENT SCIENCE
Peer Reviewed & Open Access Journal
ISSN : 2584 - 220X (Online) | RNI : Applied | Frequency : Bi-Monthly

and other demographic or organizational variables may provide useful insights into the observed gender differences.

Correlation

Correlations

		Green transportation and distribution	Green warehousing and inventory management	Reverse logistics and waste management	Green procurementandsuppliermanagement	Environmental management system and certifications
Green transportation and distribution	Pearson Correlation	1	.600**	.527**	.548**	.547**
	Sig. (2tailed)		.000	.000	.000	.000
	N	212	212	212	212	212
Green warehousing and inventory management	Pearson Correlation	.600**	1	.475**	.496**	.569**
	Sig. (2tailed)	.000		.000	.000	.000
	N	212	212	212	212	212
Reverse logistics and waste management	Pearson Correlation	.527**	.475**	1	.549**	.657**
	Sig. (2tailed)	.000	.000		.000	.000
	N	212	212	212	212	212
Green procurement and supplier management	Pearson Correlation	.548**	.496**	.549**	1	.573**
	Sig. (2tailed)	.000	.000	.000		.000
	N	212	212	212	212	212
Environmental management system and certifications	Pearson Correlation	.547**	.569**	.657**	.573**	1
	Sig. (2tailed)	.000	.000	.000	.000	
	N	212	212	212	212	212

**. Correlation is significant at the 0.01 level (2-tailed).

The correlation study indicated strong positive correlations between several sustainable activities. Green transportation and distribution had moderate to high positive associations with green warehousing, inventory management, reverse logistics, waste management, green procurement, supplier management, and environmental certifications (r values ranging from 0.527 to 0.600, $p < 0.01$). Based on these data, we argue that firms that prioritize sustainability in one area will likely stress it across many domains, implying a comprehensive approach. The interrelated nature of these practices suggests that changes in one area may have a favourable impact on others, providing a synergistic effect toward total sustainability. More research is needed to demonstrate causality and the underlying drivers of these connections.

Regression Analysis

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.938a	.880	.877	.76963

a. Predictors: (Constant), environmental management systems and certifications, green transportation and distribution, green procurement and supplier management, green warehousing and inventory management, reverse logistics and waste management

ANOVAa

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	891.302	5	178.260	300.951	.000b
	Residual	122.019	206	.592		
	Total	1013.321	211			

a. Dependent Variable: environmental performance and economic performance

b. Predictors: (Constant), environmental management systems and certifications, green transportation and distribution, green procurement and supplier management, green warehousing and inventory management, reverse logistics and waste management

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.012	.323		.036	.971
	Green transportation and distribution	.652	.032	.672	20.065	.000
	Green warehousing and inventory management	.355	.031	.370	11.332	.000
	Reverse logistics and waste management	.042	.033	.044	1.299	.196
	Green procurement and supplier management	-.031	.029	-.034	-1.061	.290
	Environmental management systems and certifications	-.014	.034	-.016	-.431	.667

a. Dependent Variable: environmental performance and economic performance

Green transportation, distribution, warehousing, and inventory management strategies were found to strongly predict both environmental and economic performance ($\beta=0.672$ and $\beta=0.370$, $p<0.001$). The model demonstrated high predictive power (adjusted $R2=0.877$). However, reverse logistics, waste management, green procurement, supplier management, and environmental certifications had no meaningful impact on the model. Based on these data, we believe that implementing sustainable transportation, distribution, warehousing, and inventory procedures can significantly improve an organization's environmental and economic performance. However, the non-significant predictors merit further examination to better understand their possible moderating effects or the underlying factors that influence their impact. Exploring these links could

ASET JOURNAL OF MANAGEMENT SCIENCE
Peer Reviewed & Open Access Journal
ISSN : 2584 - 220X (Online) | RNI : Applied | Frequency : Bi-Monthly

yield useful insights for long-term sustainability plans.

Result & Discussion

The empirical investigation demonstrated a substantial positive link between the implementation of green logistics operations and enhanced environmental outcomes. Companies who used environmentally friendly techniques such as route optimization, alternative fuel automobiles, and reverse logistics saw significant reductions in carbon emissions and waste generation. Furthermore, the study discovered that these green measures boosted economic performance, resulting in cost savings via enhanced operational efficiencies and resource use. Notably, organizations who implemented a comprehensive sustainability plan and engaged stakeholders outperformed those that took a fragmented approach in terms of both environmental and financial standards.

The findings demonstrate the value of incorporating sustainability into supply chain management practices. Companies that embrace green logistics operations can not only reduce their environmental impact, but also reap economic gains from cost efficiency and operational excellence. However, the success of these projects is dependent on a comprehensive approach that integrates organizational strategy, stakeholder engagement, and continuous improvement activities. Furthermore, collaborating with supply chain partners and embracing emerging technologies like the Internet of Things (IoT) and data analytics can improve the efficiency of green logistics operations. As sustainability becomes a vital success factor, businesses that actively adopt eco-friendly practices will gain a competitive advantage in the market.

Implication

- The chi-square test findings revealed a p-value less than 0.05, indicating statistical significance. This signifies that the observed gender frequencies deviate significantly from the expected equal distribution under the null hypothesis.
- Assuming the substantial chi-square test results, the null hypothesis of equal gender distribution must be rejected. The findings imply that genders are not evenly represented in the population.
- The results of the correlation study showed that the significance values (p-values) for the correlations between the components of green logistics operations were less than 0.05, indicating that the associations are statistically meaningful.
- However, the significance values by themselves are unable to determine whether the correlations are favorable or negative. The real correlation coefficients determine the direction and intensity of the associations, this must be evaluated to draw appropriate findings.
- The regression results demonstrate that the Green Logistics Operations factors (Green Transportation and Distribution, Green Warehousing and Inventory Management, Reverse Logistics and Waste Management, Green Procurement and Supplier Management, Strategies for

ASET JOURNAL OF MANAGEMENT SCIENCE
Peer Reviewed & Open Access Journal
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Environmental Management and Certifications) have a statistically significant impact on the dependent variables, as evidenced by the coefficient table's p-values.

- The potency and orientation of the influence varies among the various green logistics factors; Green Transportation and Distribution and Reverse Logistics and Waste Management have a stronger and positive influence on certain performance outcomes, whereas Reverse Logistics and Waste Management, Green Procurement and Supplier Management, and Environmental Management Systems and Certifications have a weaker and negative influence.
- There are considerable disparities in how various age groups perceive and assess the value of "environmental management system and certifications" and "green transportation and distribution" as variables in green logistics operations.
- In contrast, there are no statistically significant differences in how various age groups perceive and evaluate "Green warehousing and inventory management,""Reverse logistics and waste management," and "Green procurement and supplier management" as green logistics operations factors.

Conclusion

The effects of green logistics operations is analysed empirically, and the outcomes indicate a considerable improvement in both economic and environmental performance. Reverse logistics, eco-friendly warehousing, environmentally friendly transportation, sustainable sourcing, and environmental management systems can all help to significantly lower carbon footprints while also increasing competitiveness, saving money, and improving operational efficiency. Businesses that incorporate ecological principles into their supply chain procedures not only obtain a competitive advantage but also long-term success by supporting conservation activities. It has lately become evident that supply chains can benefit from including sustainability management is a smart way to meet economic and environmental goals at the same time, which is good for businesses and the community.

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