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THE RELATIONSHIP BETWEEN SUSTAINABILITY PRACTICES AND LOGISTICS PERFORMANCE: A META-ANALYSIS STUDY

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Abstract: Sustainability practices have become a fundamental pillars of modern logistics, profoundly influencing operational efficiency, environmental responsibility, and competitive advantage. Increasing regulatory pressures and stakeholder expectations have made the integrating of sustainability into supply chain management a strategic necessity. Traditionally, logistics performance has been assessed based on cost, timeliness, and reliability; however, the degree to which sustainability is incorporated into corporate strategy greatly influences these metrics. Although empirical studies on this relationship have grown, their inconsistent findings underscore the need for a comprehensive and quantitative synthesis. This study adopts a meta-analytic approach to statistically integrate the empirical evidence on the relationship between sustainability practices and logistics performance. Following a systematic search of major academic databases and the application of strict inclusion criteria, five studies presenting quantitative correlation data were included in the analysis. The results indicate a positive and moderately strong relationship (pooled correlation coefficient $r = 0.439$, $p < 0.001$). This finding confirms that sustainability-oriented strategies such as green procurement, eco-friendly packaging, and transportation optimization significantly enhance logistics efficiency, cost-effectiveness, and market competitiveness. Analyses of heterogeneity and publication bias further support the robustness of these results. In conclusion, this study provides compelling quantitative evidence that integrating sustainability into logistics operations serves as a synergistic strategy, simultaneously advancing ecological goals and organizational resilience. It offers a valuable, evidence-based framework for managers and policymakers aiming to develop more efficient, resilient, and environmentally conscious supply chains.

Keywords: Sustainability, Logistics Performance, Strategic Management, Meta-Analysis.
JEL Code: Q56, L98, C30, O13, R42.

SÜRDÜRÜLEBİLİRLİK UYGULAMALARI VE LOJİSTİK PERFORMANS ARASINDAKİ İLİŞKİ: BİR META-ANALİZ İNCELEMESİ

Öz: Sürdürülebilirlik uygulamaları, operasyonel verimlilik, çevresel sorumluluk ve rekabet avantajı üzerinde derin etkiler yaratarak modern lojistiğin temel yapı taşlarından biri hâline gelmiştir. Artan düzenleyici baskılar ve paydaş beklentileri, sürdürülebilirliğin tedarik zinciri yönetimine entegre edilmesini stratejik bir zorunluluk hâline getirmiştir. Maliyet, zamanlılık ve güvenilirlik metrikleriyle ölçülen lojistik performans, kurumsal stratejide sürdürülebilirliğin içselleştirilme derecesinden önemli ölçüde etkilenmektedir. Bu ilişkiye yönelik ampirik çalışmaların sayısı artmakla birlikte, elde edilen bulgular arasındaki tutarsızlıklar kapsamlı ve nicel bir senteze olan ihtiyacı ortaya koymaktadır. Bu çalışma, sürdürülebilirlik uygulamaları ile lojistik performans arasındaki ilişkiye dair ampirik kanıtları istatistiksel olarak birleştirmek için meta-analitik bir yaklaşım benimsemektedir. Başlıca akademik veri tabanlarında gerçekleştirilen sistematik tarama ve sıkı dâhil edilme ölçütlerinin uygulanmasının ardından, nicel korelasyon verileri sunan beş çalışma analize dâhil edilmiştir. Elde edilen sonuçlar, pozitif ve orta düzeyde güçlü bir ilişkiye işaret etmektedir (birleştirilmiş korelasyon katsayısı $r = 0.439$, $p < 0.001$). Bu bulgu, yeşil tedarik, çevre dostu ambalajlama ve taşıma optimizasyonu gibi sürdürülebilirlik odaklı stratejilerin lojistik verimliliği, maliyet etkinliği ve pazar rekabetçiliğini önemli ölçüde artırdığını doğrulamaktadır. Heterojenlik ve yayın yanlılığı analizleri sonuçların güvenilirliğini desteklemiştir. Sonuç olarak, bu çalışma, sürdürülebilirliğin lojistik operasyonlara entegre edilmesinin, ekolojik hedefler ile örgütsel dayanıklılığı aynı anda güçlendiren sinerjik bir strateji olduğuna dair ikna edici nicel kanıtlar sunmakta ve daha verimli, sağlam ve çevreci tedarik zincirleri inşa etmek isteyen yönetici ve politika yapıcılar için değerli bir kanıta dayalı çerçeve sunmaktadır.

Anahtar Kelimeler: Sürdürülebilirlik, Lojistik Performans, Stratejik Yönetim, Meta-Analiz.
JEL Kodu: Q56, L98, C30, O13, R42.

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Introduction

In response to increasing regulatory pressures for sustainable supply chains, logistics systems have evolved from simple operational structures into strategic components that determine supply chain success. In this highly competitive environment, logistics performance is traditionally measured by indicators such as cost efficiency, delivery speed, and customer satisfaction. However, in recent years, additional dimensions such as environmental sustainability, social responsibility, and ethical sourcing have been incorporated into these performance metrics.

In this context, the relationship between sustainability and logistics performance has become a significant area of research both academically and in industry practice. This is particularly relevant in economic unions like the European Union, where regulatory frameworks and market expectations increasingly mandate sustainable logistics practices (Loucanova et al., 2024). The strategic importance of this relationship is further emphasized by research linking it to broader outcomes such as corporate governance and global competitiveness (Erenel Yaşlıca, 2023). Consequently, issues such as climate change, carbon emissions, depletion of natural resources, and social inequality are compelling businesses to restructure their operational strategies and adopt sustainable logistics practices.

Sustainable logistics is a multidimensional approach that encompasses practices such as energy efficiency, emission reduction, waste management, integration of recycling processes, use of renewable energy sources, and reverse logistics. Within this framework, the literature frequently emphasizes that sustainability not only offers environmental benefits but can also positively impact performance indicators such as supply chain efficiency, corporate image, and customer satisfaction. However, empirical research on this topic has produced inconsistent and at times, contradictory, results regarding the strength and direction of these relationship, resulting in a fragmented body of knowledge rather than theoretical clarity (Ellison et al., 2024).

This study aims to systematically synthesize the existing literature through meta-analysis in order to reduce uncertainties and provide more robust, generalizable insights into the relationship between sustainability and logistics performance. By employing meta-analysis, the findings of various studies are statistically integrated, minimizing the limitations inherent in individual studies. Using this approach, the impact of sustainability practices on logistics performance has been quantitatively assessed.

The study aims to contribute both theoretically and methodologically to the field of sustainable logistics management. Its findings are intended to guide academic knowledge production as well as business practices. Accordingly, the study is organized into five sections: introduction, conceptual framework, methodology, findings, and conclusion. The first section discusses, the concepts of sustainability and logistics performance within the theoretical framework. The second section details the data collection and analysis procedures. The third section presents the analysis results, and the fourth and final section draws conclusions based on the findings.

This study is expected to make a significant methodological contribution to the sustainable logistics management literature and to establish a foundation that will guide future empirical research**.**

Logistics Performance Indicators

Logistics Performance Indicators (LPI) are fundamental measurement tools used to assess the effectiveness, competitiveness, and operational efficiency of supply chain processes within a multidimensional framework. The global LPI index, developed by the World Bank (Arvis et

al., 2007; 2010), evaluates countries across six core dimensions of logistics capacity—customs efficiency, quality of infrastructure, ease of international shipments, competence of logistics services, tracking and tracing capabilities, and timeliness. This approach demonstrates that logistics performance is a critical factor not only at the micro-level of firm operations but also in national development strategies and regional competitiveness.

The literature indicates that logistics performance has traditionally been evaluated based on criteria such as cost efficiency, on-time delivery, operational flexibility, service quality, and customer satisfaction (Mentzer & Konrad, 1991). These criteria served as the primary benchmarks for assessing the operational efficiency of supply chains for many years. However, as firms have undergone a sustainability-oriented transformation, the scope of performance measurement has expanded to include environmental and social indicators such as energy efficiency, carbon emission levels, natural resource and corporate social responsibility, which have begun to be integrated into LPI evaluations (Golicic & Smith, 2013). This development indicates that logistics performance no longer reflects solely economic output but has evolved into a multidimensional structure incorporating sustainability criteria.

In the national literature, logistics performance indicators have been analyzed in relation to regional development, spatial planning, and investment analysis. The logistics development index developed by Bayraktutan and Özbilgin (2012) for the case of Kocaeli demonstrates that logistics performance is influenced by factors such as infrastructure density, accessibility to transportation modes, regional clustering tendencies within the logistics sector, and the intensity of economic activity. Their subsequent study (2014), based on a fuzzy logic approach, establishes a systematic framework for determining the logistics center investment potential of provinces and shows that LPI components can be directly integrated into decision-making processes. These findings reveal that the LPI functions not only as a performance measurement tool but also as a strategic instrument for spatial planning.

International studies emphasize that logistics performance is closely associated with economic growth, the acceleration of foreign trade flows, technological capacity, and sustainability. Hausman et al. (2013) demonstrate that high logistics performance significantly increases export volume, while Martí et al. (2017) confirm a positive relationship between LPI and economic development. In recent years, digitalization technologies such as the Internet of Things (IoT), blockchain, big data analytics, green logistics practices and carbon emission management, have become increasingly dominant in LPI research (Winkelhaus & Grosse, 2020; McKinnon, 2015). These studies indicate that modern logistics performance assessment depends not only on physical infrastructure but also on technological and sustainability capabilities.

This study evaluates logistics performance indicators from both traditional and contemporary perspectives, expanding the assessment framework to incorporate transformations highlighted in the literature. In particular, the regional logistics development approach proposed by Bayraktutan and Özbilgin (2012; 2014) and the sustainability dimension emphasized by Golicic and Smith (2013) form the conceptual foundation of this research. As a result, logistics performance indicators are examined in an integrated manner across economic, environmental, social, and technological dimensions leading to the development of a multi-layered evaluation perspective aligned with modern supply chain management.

The Relationship Between Sustainability and Logistics Performance

Many empirical studies indicate that sustainability-oriented logistics practices positively impact operational performance. For example, Green et al. (2012) demonstrated that sustainable supply chain practices enhance efficiency in logistics processes. Sarkis et al. (2010) stated that green logistics strategies reduce transportation costs and improve operational effectiveness.

Various studies in the literature have shown that the relationship between sustainability and logistics performance is not always direct positive. The outcomes of sustainability practices are influenced by factors such as sectoral differences, geographical conditions, and the level of corporate maturity, which consequently pose challenges to the generalizability of the results (Testa and Iraldo, 2010; Eltayeb et al., 2011). These mixed findings highlight the need for a more comprehensive and systematic reassessment of how sustainability impacts logistics performance.

In this context, a meta-analytic approach enables the integration of fragmented empirical findings and yields more robust, generalizable conclusions by statistically synthesizing the results of previous studies. The primary aim of this study is to reinterpret the dispersed and sometimes conflicting evidence in the literature by determining the magnitude, direction, and statistical significance of the impact of sustainability-based practices on logistics performance. Within this framework, the study seeks to address the following research questions:

Is there a significant and systematic relationship between sustainability practices and logistics performance?

If so, is the direction of this relationship positive or negative?

Do the effect sizes obtained across studies exhibit significant variability (i.e., heterogeneity)?

These research questions enable an empirical evaluation of inconsistencies in the existing literature and aim to clarify the actual impact of sustainability-oriented logistics strategies on performance outcomes.

Methodology

Determining the Research Model

In recent years, research exploring the relationship between sustainability practices and logistics performance has increased substantially. However, empirical studies in this field vary considerably in their methodological designs, measurement indicators, and contextual settings. These variations result in inconsistent effect sizes across studies, underscoring the need for a quantitative synthesis method that can statistically integrate dispersed empirical results into a unified structure. Therefore, this study employs a meta-analysis approach to provide a more reliable and generalizable estimate of the relationship between sustainability practices and logistics performance.

This study employs a meta-analysis approach to examine the relationship between sustainability practices and logistics performance, aiming to determine both the direction and magnitude of the effect. Meta-analysis is a statistical technique that enables the synthesis of the findings from independent studies testing similar hypotheses, thereby producing more generalizable and robust results (Hunter and Schmidt, 2004).

The data collection process involved a systematic search of the Web of Science, Scopus, Google Scholar, ProQuest, and ScienceDirect databases in June and July 2025, using the keywords "sustainability", "logistics performance" and "sustainable supply chain".

The inclusion criteria for the meta-analysis were established based on the following factors:

• Studies that examine the relationship between sustainability and logistics performance using quantitative data.

• Studies reporting correlation coefficients (r) and/or effect sizes.

• Publication in peer-reviewed academic journals.

• The sample group must not have been used in more than one study.

A total of 206 studies were identified, and after applying the eligibility criteria, the final sample for the meta-analysis comprised five independent studies (Ellison et al., 2024; Eneş, 2022; Erenel Yaşlıca, 2023; Loucanova et al., 2024; Qazi et al., 2025).

Statistical Approach

In this study, the correlation coefficient (r) served as the primary metric. To enhance comparability and statistical consistency, all correlation coefficients were normalized using Fisher's z-transformation. This transformation is crucial for normalizing the distribution of correlation coefficients, especially with small sample sizes and facilitates a more reliable estimation of pooled results in the meta-analysis.

The analyses were conducted using a Random-Effects Model (RE Model), which has the advantage of accounting for contextual differences between studies (Field & Gillett, 2010). To assess variance among studies, heterogeneity analyses were performed using both Cochran's Q test and the I^2 statistic. Publication bias was evaluated using a funnel plot, Egger's regression test, and Fail-Safe N analysis. All statistical analyses were conducted using the MAJOR module in Jamovi software.

Steps of the Meta-Analysis

Defining the Research Question: The success of a meta-analysis depends on a well-defined, clear, and measurable research question. This question directly influences the selection of literature included in the study.

Systematic Search of Relevant Literature: This involves identifying published studies that are potentially relevant to the topic. Conducting a thorough search of databases is critical at this stage.

Study Inclusion Process: The identified studies are screened based on predefined inclusion criteria. An initialassessment of titles and abstracts is conducted to select relevant research.

Data Extraction: Selected studies are meticulously coded for details such as sample characteristics and type of analysis. This process should be conducted independently by two reviewers, with dual verification to ensure accuracy.

Statistical Combination of Data: The results from each study are combined using either a fixed-effects or random-effects model within a unified statistical framework. The choice of model depends on the degree of heterogeneity among the studies.

Interpretation and Reporting of Results: The overall results obtained from the meta-analysis, including findings related to the level of heterogeneity and publication bias, are evaluated. The implications of these results in both theoretical and practical contexts are subsequently discussed.

In conclusion, the meta-analysis method employed in this study provides a comprehensive and reliable approach to understanding the complex relationship between sustainability practices and logistics performance. The meta-analytic findings not only advance academic knowledge but also hold significant practical value by offering empirical evidence to guide businesses in developing sustainable logistics strategies.

Findings and Discussion

In this meta-analysis, the results of five independent studies examining the relationship between sustainability practices and logistics performance were statistically integrated, and a pooled effect size was calculated. The mean correlation coefficient representing the combined effect of the studies was $r = 0.439$, $p < 0.001$. This estimated effect size indicates a moderate and statistically significant positive relationship, providing strong empirical evidence for the contribution of sustainability approaches to logistics performance. The statistical results of the correlation analysis are presented in Table 1.

Table 1. Correlation test results

	Estimate	se	Z	P	CI Lower Bound	CI Upper Bound
Intercept	0.439	0.0289	15.2	< 0.001	0.382	0.495

The result is statistically significant ($p < 0,001$), with a mean z value of 15.1903 calculated in the analysis. This value clearly demonstrates a deviation from the null hypothesis, suggesting a significant relationship among sustainability practices and logistics performance.

Based on these findings, the 95% confidence interval was found to be between 0,382 and 0,495, reliably confirming that the relationship is positive. In other words, businesses that adopt sustainable logistics practices are more likely to achieve higher levels of success in logistics performance indicators compared to those that do not. This demonstrates that environmental, economic, and social sustainability strategies contribute not only to corporate responsibility but also to operational efficiency.

The level of heterogeneity within the model was calculated using the Restricted Maximum Likelihood (REML) method and expressed as the tau² (τ^2) value (Viechtbauer, 2005). Additionally, to further analyze the presence and extent of heterogeneity, the I^2 statistic was reported alongside Cochran's Q-test (Cochran, 1954). The significance level of these heterogeneity statistics was considered a critical indicator for explaining the variance across samples.

According to the findings from the heterogeneity analysis, no statistically significant difference were observed among the studies. The result $Q(4) = 0.361$, $p = 0.986$ indicates that the between-sample variance can be attributed to random variations. The heterogeneity coefficient were determined as $tau^2 = 0.000$, and $I^2 = 0\%$. These results suggest that the total variance is entirely due to within-sample errors and that the true effect size does not vary significantly across studies.

The low level of heterogeneity does not directly prove that sample diversity was ineffective; rather, the limited sample size in the reviewed studies may have hindered the detection of statistically significant variance. Therefore, although the results do not rule out the influence of contextual differences, they can be interpreted as indicating general consistency across the samples examined.

Table 2. Heterogeneity test results

Tau	Tau²	I²	H²	R²	df	Q	p
0.000	0 (SE= 0.0029)	0%	1,000	--	4,000	0.361	0.986

In this context, a funnel plot was created to visually demonstrate the symmetry of the meta-analysis findings and to detect potential publication bias. A symmetric distribution indicates a low level of systematic bias, whereas a significant asymmetry may suggest that the

results have been influenced by publication bias or methodological biases. This funnel plot is presented in Figure 1 of the study.

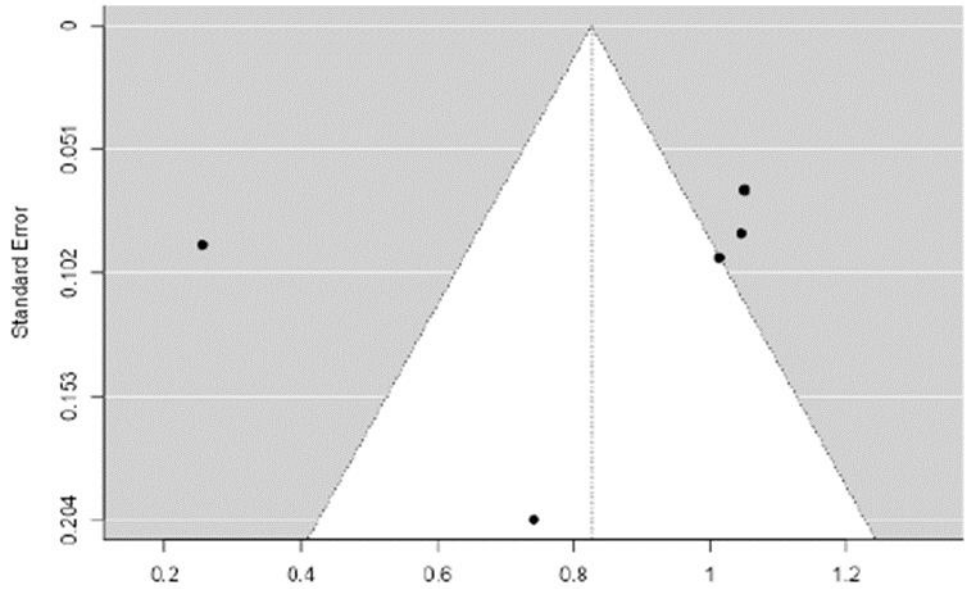


Figure 1. Funnel plot

Figure 1 demonstrates a visually symmetrical funnel plot; however, the data derived from the included studies still exhibit a certain degree of heterogeneity. This result reinforces the reliability of the findings. The transformed correlation coefficients ranged from 0,4001 to 0,4599, and all values were positive. This finding supports the generally positive relationship between sustainable practices and logistics performance.

The possibility of publication bias was thoroughly addressed. Statistical results related to publication bias are presented in Table 3.

Table 3. Publication bias test results

Test Name	value	p
Fail-Safe N	399,000	< 0.001
Begg and Mazumdar Rank Correlation	-0.400	0.483
Egger's Regression	-0.439	0.661
Trim and Fill Number of Studies	2,000	

The Fail-Safe N test, however, yielded a striking result. According to this test, an additional 394 studies would be required for the overall effect to lose statistical significance. This number demonstrates that the effect observed in the current sample is quite robust.

To assess the presence of publication bias and determine whether the results were asymmetrically distributed, the Begg and Mazumdar rank correlation test yielded a p-value of 0.483, while the Egger regression test produced a p-value of 0.661, indicating that the regression slope was not statistically significant. This finding, consistent with the visual inspection of the funnel plot, confirms that there is no statistically significant evidence of publication bias. These tests are widely used, particularly to evaluate whether published studies are biased toward positive or significant results. The regression test specifically examines the relationship between the standard error of each study and the magnitude of its effect.

Another method for assessing publication bias, the Trim-and-Fill procedure, suggests that although publication bias appears minimalh, there may be two missing studies.

Tests conducted to detect publication bias confirm the reliability of the findings. First, the funnel plot, a symmetry-based visualization, and its associated statistical tests show no significant bias in the dataset. The p-values obtained from the regression test, p = 0,6608, and the rank-order correlation test, p = 0.4833, indicate no statistically significant evidence of publication bias. These results demonstrate that the observed results do not systematically deviate from what would be expected due to sampling error, thereby reinforcing the internal validity of the meta-analysis.

Based on these results, it can be concluded that the average effect size and correlation coefficients obtained in this study accurately reflect true trends in the literature and are free from systematic errors. This demonstrates that the relationship between sustainability practices and logistics performance is not only statistically significant but also epistemically valid.

To provide a clearer and more visual representation of the analyses and statistical operations performed, the forest plot illustrating the distribution of the obtained effects is presented in Figure 2.

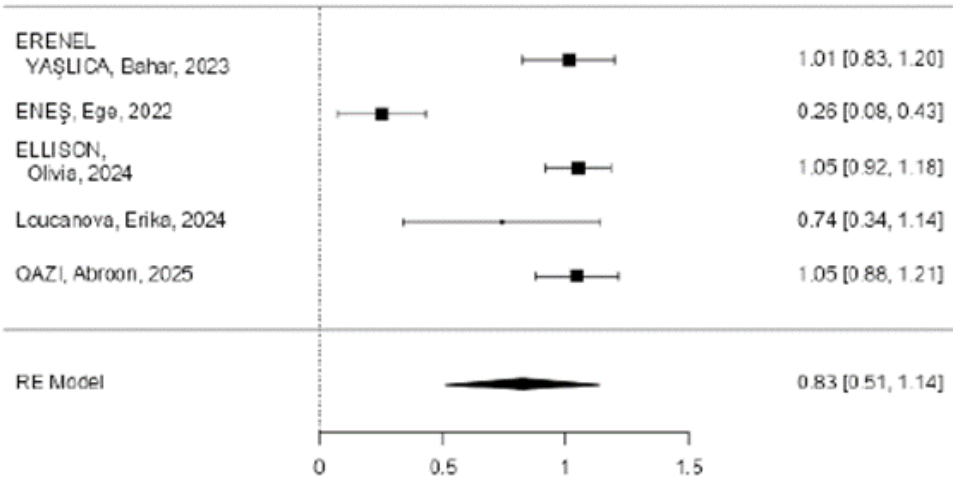


Figure 2. Forrest Graph

The meta-analysis findings revealed a strong and statistically significant relationship between sustainability practices and logistics performance. While this quantitative synthesis provides robust evidence of this relationship, understanding the complex causal pathways and interdependencies between specific sustainability practices and performance outcomes could be further enhanced by employing advanced analytical techniques, such as the Bayesian network approach (Qazi et al., 2025).

Using quantitative synthesis, the study integrates research conducted with various methodologies into a unified analytical framework. This approach consolidates previously fragmented findings into a generalizable model, offering a clearer, more reliable, and more actionable guide for decision-makers regarding the theoretical and practical impacts of sustainable logistics policies on performance.

Conclusion

Logistics is a fundamental operational area that inherently consumes resources but can also create value through effective management. Therefore, the systematic integration of

sustainability principles into logistics activities has become a necessity rather than a choice for businesses today.

This study employs meta-analytic techniques to quantitatively evaluate the relationship between sustainability practices and logistics performance. Empirical studies were identified through a systematic literature search conducted across five academic databases in June and July 2025. These studies were screened based on predefined methodological and conceptual inclusion criteria and subsequently included in the analysis. Statistical analyses were performed using the MAJOR module of Jamovi software, ensuring the robustness and reliability of the synthesized effect sizes. The meta-analysis reveals a moderate, positive, and statistically significant association between sustainability practices and logistics performance ($r = 0.439$, $p < 0.0001$).

This finding aligns with prior empirical evidence in the literature and clearly demonstrates the transformative role of sustainability principles in the operation of logistics systems (Ahi and Searcy, 2013; Govindan et al., 2014; Sarkis et al., 2011). Specifically, sustainable logistics practices (such as green supply chain management, energy-efficient transportation methods, and waste management policies) lead to significant improvements in performance indicators, including process optimization, cost savings, and service quality (Green et al., 2012; Zhu and Sarkis, 2004). In this context, sustainability transcends its traditional role as a compliance-driven obligation and emerges as a critical source of strategic competitive advantage for firms operating in increasingly dynamic and environmentally sensitive markets (Porter and van der Linde, 1995; Seuring and Müller, 2008).

The study has several limitations. First, the small number of studies included in the analysis limits the generalizability of the findings, indicating that results may vary across different contexts. Additionally, variations in the definitions of sustainability and logistics performance reduce conceptual consistency and increase heterogeneity among measurements. While methodological diversity provides richness, it also necessitates careful interpretation.

Future studies should examine the sub-dimensions of sustainability (environmental, economic and social) and logistics performance indicators such as delivery time, cost efficiency separately. Additionally, comparative studies conducted across different sectors and geographical regions could more clearly and comprehensively reveal the effects of sustainability practices on various logistics structures. Additionally, future research could adopt novel methodological approaches, such as Bayesian network analysis, to elucidate the complex causal relationships and multidimensional interactions between specific sustainability initiatives and logistics performance metrics, building on emerging methodological frameworks.

In conclusion, the results of this meta-analysis provide robust evidence that sustainability practices are strategic tools capable of enhancing logistics performance. Therefore, sustainability principles should be an integral part of logistics management and holistically integrated into corporate strategies.

Data Availability Statement: This meta-analysis, this research synthesizes data from previously published empirical studies. All data points used in the statistical analysis were extracted from the five studies cited in the manuscript (Ellison et al., 2024; Eneş, 2022; Erenel Yaşlıca, 2023; Loucanova et al., 2024; Qazi et al., 2025). The full datasets are available in the original publications.

Author Contributions

All stages of this study, including the research design, data collection, analysis, writing, and revision processes, were carried out by Ahmet I.

Ethical Approval

Ethical committee approval was not required for this study.

Conflict of Interest Statement

The author declares that there is no conflict of interest with any individual or institution regarding the preparation of this study.

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