Journal of Economic Education and Entrepreneurship Studies
Vol. 7, No. 6, 2026, pp. 1-17
ISSN: 2722-3744 (Print) 2776-0278 (Online)
https://doi.org/10.62794/je3s.v7i6.640

Toward Eco-Friendly Urban Freight Transport: Regulatory Compliance, Green Logistics Practices, and Sustainable Logistics Performance

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Received: June 18, 2026; **Revised:** October 23, 2026; **Accepted**: Nov 05, 2026

Abstract: Sustainable urban freight transport must reconcile delivery reliability with mounting operational and environmental constraints. This study examined associations among Regulatory Support, Regulatory Compliance, Green Logistics Practices, and Sustainable Logistics Performance, including indirect pathways through compliance and green practices. A quantitative cross-sectional survey involved 300 respondents familiar with urban freight operations, and the data were analyzed using partial least squares structural equation modeling (PLS-SEM). Regulatory Support was positively associated with Regulatory Compliance ($\beta = 0.554$, $p < 0.001$) and Green Logistics Practices ($\beta = 0.347$, $p < 0.001$). Regulatory Compliance was associated with Green Logistics Practices ($\beta = 0.560$, $p < 0.001$) and Sustainable Logistics Performance ($\beta = 0.194$, $p < 0.001$), while Green Logistics Practices was associated with Sustainable Logistics Performance ($\beta = 0.493$, $p < 0.001$). The direct Regulatory Support–performance path was smaller ($\beta = 0.106$, $p = 0.047$). Indirect associations were supported through Regulatory Compliance ($\beta = 0.108$, $p = 0.001$), Green Logistics Practices ($\beta = 0.171$, $p < 0.001$), and the sequential pathway through both constructs ($\beta = 0.153$, $p < 0.001$). By integrating Institutional Theory and the Natural Resource-Based View, this study provides a theory-informed interpretation of regulatory compliance and green logistics practices as distinct statistical pathways linking perceived regulatory support to sustainable logistics performance. These findings support coordinated regulatory and managerial attention, although the cross-sectional and self-reported data do not establish causal or objectively measured environmental improvements.

Keywords: Green Logistics Practices; Regulatory Compliance; Regulatory Support; Sustainable Logistics Performance; Urban Freight Transport

How to Cite: Madyanti, A. N., Rini, M. W., Ananda, N., & Rahmawati, A. (2026). Toward Eco-Friendly Urban Freight Transport: Regulatory Compliance, Green Logistics Practices, and Sustainable Logistics Performance. *Journal of Economic Education and Entrepreneurship Studies, 7*(6), 1-17. https://doi.org/10.62794/je3s.v7i6.640.
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INTRODUCTION

Urban freight transport connects producers, distribution centers, retailers, and consumers, but its operating requirements are increasingly difficult to reconcile with urban sustainability objectives. Greater delivery frequency and changing consumption patterns can increase demand for reliable goods movement while intensifying pressure on road space and transport resources (Pan et al., 2021; Silva et al., 2023). Reviews of urban freight sustainability describe persistent tensions between service quality, energy efficiency, and environmental

impacts (Golinska-Dawson & Sethanan, 2023; Karjalainen & Juhola, 2021). These tensions extend beyond transportation technology because logistics flows interact with urban land use, infrastructure, and the organization of everyday economic activity (Haarstad et al., 2024; Zunder, 2021). A sustainable urban freight strategy must therefore address both the conditions under which operators work and the practices through which they organize distribution.

Urban freight firms face practical constraints that make environmental improvements more complicated than simply reducing vehicle use. Congestion, loading restrictions, fragmented delivery schedules, and partially utilized vehicles can create inefficiencies even when companies meet immediate service requirements (Hauge et al., 2021; Letnik et al., 2022). Space allocation for loading and unloading also involves trade-offs among freight operations, public transport, and other street users (Castrellon & Sanchez-Diaz, 2024). Meanwhile, policies developed for a city's transport system may affect operators with substantially different fleets, distribution activities, and resources (Maxner et al., 2025). These considerations motivate an organizational examination of how regulatory environments relate to the everyday implementation of greener freight operations.

In this study, Regulatory Support refers to respondents' perceptions of regulatory clarity, implementation consistency, monitoring, enforcement, information accessibility, and policy assistance within the urban freight transportation sector. Public authorities can influence freight operations through operational standards and policy coordination, yet their ability to generate meaningful change depends on how firms interpret and respond to these measures (Knoppen et al., 2021; Cowie & Fisken, 2023). Research on last-mile logistics scenarios similarly places regulation alongside cooperation and innovation as a condition shaping possible transition pathways (Plazier et al., 2024). From an institutional perspective, regulatory expectations can encourage organizations to formalize responsibilities, but these expectations do not necessarily translate into improved operational outcomes (Gonzalez et al., 2022; Shahzad et al., 2022). Examining Regulatory Support together with corporate responses is consequently more informative than treating the existence of regulation as evidence of sustainable performance.

Regulatory Compliance provides one such organizational response, capturing the extent to which firms follow operational, vehicle, environmental, load, scheduling, and documentation requirements. Compliance may contribute to orderly distribution and lower exposure to regulatory violations, but formal conformity should not be confused with improvements in resource efficiency (Layaoen et al., 2024). For example, meeting vehicle or document requirements does not itself establish that a firm has reduced empty trips or optimized routes. Studies of corporate environmental responses suggest that institutional pressure interacts with organizational capability and managerial commitment rather than operating as a uniform external force (El-Garaihy et al., 2022; Candrianto et al., 2026). The relationship between compliance and actual green logistics practices is therefore a substantive empirical question, not an automatic consequence of regulation.

Green Logistics Practices refer here to route optimization, better utilization of loading capacity, fewer empty trips, energy-conscious operation, vehicle maintenance, consideration of low-emission vehicles, and digital support for distribution decisions. These actions are conceptually distinct from regulatory compliance because they concern how firms allocate resources and execute freight movement (De Souza et al., 2022; Van Vo & Nguyen, 2023). Previous studies associate environmental logistics practices with aspects of organizational and sustainability performance, although the magnitude and form of those relationships vary across supply chains and business contexts (Afum et al., 2022; Roy & Mohanty, 2024; Zhou et al., 2023).

Research on managerial interpretations also suggests that sustainability may be understood through economic and emissions-related priorities that differ between actors (Heikkinen, 2024). The Natural Resource-Based View provides a basis for examining green practices as operational capabilities linked to performance without assuming that an observed association represents a measured emissions reduction.

The literature provides substantial evidence on urban freight policy, institutional pressure, and green logistics practices, but these streams do not always distinguish the regulatory environment, compliance behavior, operational practice, and reported performance within one model. Urban governance research stresses the influence of actors and local policy relationships (Shrestha et al., 2024; Mansouri et al., 2023), whereas logistics studies tend to emphasize resource management, environmental practices, and firm outcomes (Ahmad et al., 2022; Stekelorum et al., 2021). Firm-level evidence from Vietnam further points to differentiated external drivers of green logistics adoption, suggesting that policy and market conditions should not be treated as interchangeable (Phan et al., 2024). Evaluations of transport performance also show that operational and environmental indicators require separate consideration rather than a single generic measure of success (Yingfei et al., 2022; Wan et al., 2022). The research gap addressed in this study concerns the integrated examination of regulatory support, regulatory compliance, and green logistics practices as interconnected constructs, particularly the distinction between direct, separate indirect, and sequential indirect associations with sustainable logistics performance within a single urban freight transportation model.

This study examined the relationships among Regulatory Support (X), Regulatory Compliance (M1), Green Logistics Practices (M2), and Sustainable Logistics Performance (Y) using a survey of 300 respondents involved in urban freight and distribution activities. It tested six direct paths and three indirect pathways linking regulatory support to sustainable performance, including sequential mediation through compliance and green logistics practices. Institutional Theory was used to interpret the regulatory environment and organizational response, while the Natural Resource-Based View informed interpretation of the relationship between green operational practices and performance. The intended theoretical contribution is an integrated examination of these complementary perspectives rather than a claim that either mechanism is newly discovered. Practically, the results can inform consideration of how regulatory clarity and compliance efforts may be aligned with logistics operations, while the cross-sectional design limits conclusions to statistical associations.

METHOD

Research design and scope

The study adopted a quantitative explanatory cross-sectional survey to examine the associations among Regulatory Support (X), Regulatory Compliance (M1), Green Logistics Practices (M2), and Sustainable Logistics Performance (Y). The model included six direct structural paths, three reported indirect pathways from X to Y, and an additional theoretically specified link from M1 through M2 to Y. The survey design was suitable for analyzing respondents' assessments of organizational and regulatory conditions at one observation point, although it did not provide a temporal basis for causal inference. Partial least squares structural equation modeling (PLS-SEM) was implemented in SmartPLS to assess construct measurement and the proposed structural relationships (Legate et al., 2023).

Participants and sampling

The dataset comprised 300 purposively selected respondents with roles relevant to urban freight transportation, logistics operations, distribution management, regulatory compliance, or environmental management. Eligible participants were expected to have direct knowledge of freight distribution operations, relevant regulations, and at least one year of work experience. Reported occupational categories included logistics managers, operations and transportation managers, supervisors, fleet managers, compliance personnel, sustainability personnel, and company owners or managers. Respondents described organizations undertaking freight transportation, third-party logistics, distribution, retail or e-commerce distribution, or manufacturing-related distribution; the respondent-level data should not be interpreted as an independently identified census of companies. A profile of actual respondents and the organizational characteristics represented in their answers is reported in Table 1.

Survey instrument

Data were collected using a structured questionnaire with responses on a five-point scale, from 1 (strongly disagree) to 5 (strongly agree). Regulatory Support contained eight indicators concerning regulatory clarity, interpretability, consistency, monitoring, enforcement, information access, and green freight policy support (X.1–X.8). Regulatory Compliance contained seven indicators concerning operational rules, vehicle requirements, emissions standards, loads, operating restrictions, documentation, and environmental compliance (M1.1–M1.7). Green Logistics Practices contained eight indicators relating to routes, load utilization, empty trips, fuel or energy, low-emission vehicles, maintenance, digital systems, and environmentally responsible operations (M2.1–M2.8). Sustainable Logistics Performance contained eight indicators covering distribution efficiency, vehicle utilization, cost efficiency, energy and environmental impacts, emissions, reliability, and overall sustainable logistics performance (Y.1–Y.8). The resulting 31 items provided respondent-reported indicators rather than independent records of fuel use, fleet emissions, or operational performance.

Data screening and measurement assessment

The available dataset contained 300 distinct respondent IDs and 41 columns encompassing respondent and organization profiles and the 31 survey indicators. Initial screening found no fully duplicated rows, blank responses in the reported variables, or out-of-range indicator values. The measurement assessment reported outer loadings, Cronbach's alpha, reliability coefficients rho_A and rho_C, average variance extracted (AVE), and heterotrait-monotrait ratios (HTMT). These statistics were interpreted as evidence for the measurement specification employed in the original PLS-SEM analysis; the conceptual choice of reflective specification must remain consistent with the intended meaning of the indicators. Screening and construct assessment evaluated the data available for analysis but did not independently verify the reported operational outcomes against company records.

Structural and mediation analysis

Collinearity was assessed using inner variance inflation factors (VIF), and model explanatory power was summarized using R^2, adjusted R^2, and f^2. Predictive relevance was reported using cross-validated redundancy Q^2 statistics, and indicator-level PLSpredict results compared PLS-SEM forecast errors against a linear-model benchmark. Direct relationships comprised X → M1, X → M2, X → Y, M1 → M2, M1 → Y, and M2 → Y. Reported mediation estimates comprised X → M1 → Y, X → M2 → Y, and X → M1 → M2 → Y; the M1 → M2 → Y connection is discussed as an implied product of the estimated structural paths without adding an unreported

significance test. Statistical support was evaluated using the reported bootstrapped coefficients, standard errors, test statistics, and p-values, with a 5% significance criterion; the reported estimates were retained without reconstructing unavailable bootstrap settings or confidence intervals. The analytical sequence, from survey assessment to interpretation of the structural relationships, is outlined in Figure 1.

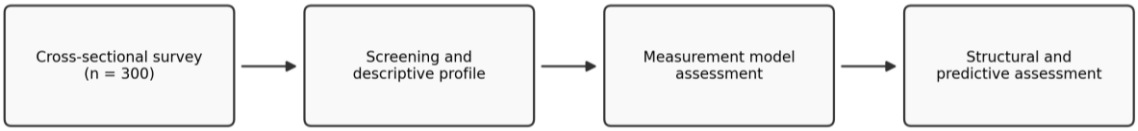


Figure 1. Survey and PLS-SEM analytical workflow

Figure 1 summarizes the sequence used to organize the reported survey analysis. The initial stage concerned the 300 responses and screening of the 31 construct indicators. Measurement assessment covered indicator loadings, reliability, convergent validity, and discriminant validity. Structural assessment then examined direct paths, mediation, explanatory statistics, and predictive statistics. The arrows indicate an analytical workflow and should not be read as a temporal causal process among the four constructs.

RESULTS AND DISCUSSION

Research Results

1) Respondent Characteristics and Data Screening

The respondent profile and screening results provide the basis for interpreting the model estimates. The initial checks identified 300 unique respondents, 41 dataset columns, 31 construct indicators, and no missing values in the reported fields. All indicator responses fell within the five-point response scale. These checks established basic completeness and range validity but did not independently establish respondent-level eligibility or the absence of response bias. Table 1 summarizes the respondents' occupational and organizational characteristics.

Table 1. Respondent Characteristics

Characteristics	Category	Frequency (n)	Percentage (%)
Respondent's position	Logistics Manager	50	16.7
	Compliance Personnel	46	15.3
	Logistics/Distribution Supervisor	46	15.3
	Operations Manager	41	13.7
	Transportation Manager	33	11.0
	Owner/Company Manager	33	11.0
	Sustainability/Environmental Personnel	26	8.7
	Fleet Manager	25	8.3
Years of service	1–3 years	72	24.0
	4–6 years	94	31.3
	7–10 years	76	25.3
	More than 10 years	58	19.3
Type of company	Freight transport company	80	26.7
	Logistics service provider/3PL	70	23.3
	Distributor/wholesaler	60	20.0
	Retail/e-commerce with distribution fleet	54	18.0
	Manufacturing company with own distribution	36	12.0
Length of time the company has been operating	1–5 years	51	17.0
	6–10 years	77	25.7
	11–20 years	101	33.7
	More than 20 years	71	23.7
Company size	Micro/small	89	29.7

Characteristics	Category	Frequency (n)	Percentage (%)
	Intermediate	120	40.0
	Big	91	30.3
Types of logistics activities	Last-mile delivery	69	23.0
	E-commerce distribution	65	21.7
	Mixed distribution	59	19.7
	B2B Shipping	56	18.7
	Distribution between warehouses/stores	51	17.0
Type of vehicle	Mixed fleet	115	38.3
	Medium/heavy trucks	64	21.3
	Light trucks	57	19.0
	Motorcycle/light van	35	11.7
	Low emission/electric vehicles (partially)	29	9.7
Fleet size	1–5 vehicles	59	19.7
	6–20 vehicles	99	33.0
	21–50 vehicles	78	26.0
	More than 50 vehicles	64	21.3
Operational area	One city	89	29.7
	Several cities in one province	81	27.0
	Metropolitan area	66	22.0
	Across provinces	64	21.3
Total respondents		300	100.0

The sample included 300 respondents representing several logistics-related professional roles. Logistics managers formed the largest occupational group (50, 16.7%), while compliance personnel and logistics/distribution supervisors each accounted for 46 respondents (15.3%). Freight transportation companies were the most frequently reported organization type (80, 26.7%), followed by logistics service providers or 3PL firms (70, 23.3%). Medium-sized organizations represented the largest company-size category (120, 40.0%), and mixed fleets were the most common vehicle configuration (115, 38.3%). These distributions characterize the participants' reported context without establishing population-level representativeness.

2) Descriptive Statistics

Table 2 summarizes the descriptive statistics for the four research constructs.

Table 2. Descriptive Statistics of Research Variables

Variables	Variable name	N	Mean	Standard Deviation	Minimum	Maximum
X	Regulatory Support	300	3,465	0.648	1,875	5,000
M1	Regulatory Compliance	300	3,451	0.639	1,714	5,000
M2	Green Logistics Practices	300	3,440	0.626	1,375	5,000
Y	Sustainable Logistics Performance	300	3,437	0.642	1,875	5,000

All four mean construct scores were above the midpoint of the five-point scale. Regulatory Support had the highest reported mean (3.465, SD = 0.648), followed by Regulatory Compliance (3.451, SD = 0.639). Green Logistics Practices had a mean of 3.440 (SD = 0.626), and Sustainable Logistics Performance had a mean of 3.437 (SD = 0.642). The close mean values indicate broadly similar respondent assessments across the four constructs. These scores describe reported perceptions rather than directly measured environmental or financial outcomes.

3) Measurement Model Assessment

The outer loadings of the 31 observed indicators are reported in Table 3.

Table 3. Outer Loading

Variables	Indicator	Outer Loading	Information
Regulatory Support (X)	X.1	0.844	Valid
	X.2	0.873	Valid
	X.3	0.862	Valid
	X.4	0.866	Valid
	X.5	0.841	Valid
	X.6	0.847	Valid
	X.7	0.833	Valid
	X.8	0.830	Valid
Regulatory Compliance (M1)	M1.1	0.863	Valid
	M1.2	0.854	Valid
	M1.3	0.848	Valid
	M1.4	0.850	Valid
	M1.5	0.864	Valid
	M1.6	0.857	Valid
	M1.7	0.858	Valid
Green Logistics Practices (M2)	M2.1	0.840	Valid
	M2.2	0.831	Valid
	M2.3	0.858	Valid
	M2.4	0.848	Valid
	M2.5	0.823	Valid
	M2.6	0.839	Valid
	M2.7	0.849	Valid
	M2.8	0.845	Valid
Sustainable Logistics Performance (Y)	Y.1	0.870	Valid
	Y.2	0.846	Valid
	Y.3	0.833	Valid
	Y.4	0.865	Valid
	Y.5	0.869	Valid
	Y.6	0.874	Valid
	Y.7	0.839	Valid
	Y.8	0.859	Valid

All 31 indicators had outer loadings above 0.70. The smallest loading was 0.823 for M2.5, and the largest was 0.874 for Y.6. Regulatory Support loadings ranged from 0.830 to 0.873, while Regulatory Compliance ranged from 0.848 to 0.864. Green Logistics Practices ranged from 0.823 to 0.858, and Sustainable Logistics Performance ranged from 0.833 to 0.874. The outer loading values provide evidence of satisfactory indicator reliability under the specified reflective measurement model, while the assessment of convergent validity is further supported by the Average Variance Extracted (AVE) results presented in Table 4.

Table 4. Construct Reliability and Validity

Variables	Cronbach's Alpha	Composite Reliability (rho_A)	Composite Reliability (rho_C)	AVE	Information
M1	0.939	0.940	0.951	0.733	Reliable and valid
M2	0.941	0.942	0.951	0.709	Reliable and valid
X	0.945	0.946	0.954	0.722	Reliable and valid
Y	0.948	0.949	0.957	0.734	Reliable and valid

The reported Cronbach's alpha values ranged from 0.939 to 0.948 across the four constructs. The rho_A coefficients ranged from 0.940 to 0.949, and rho_C coefficients ranged from 0.951 to 0.957. Average variance extracted ranged from 0.709 to 0.734, exceeding the conventional convergent-validity threshold of 0.50. Taken together, these statistics show high internal consistency and adequate convergent validity under the reported measurement specification. The high reliability coefficients also make it important to distinguish substantive construct coverage from potentially overlapping survey wording. Discriminant validity was assessed using HTMT values, as summarized in Table 5.

Table 5. Discriminant Validity (HTMT)

Variables	M1	M2	X	Y
Regulatory Compliance (M1)	–	–	–	–
Green Logistics Practices (M2)	0.799	–	–	–
Regulatory Support (X)	0.586	0.695	–	–
Sustainable Logistics Performance (Y)	0.660	0.749	0.566	–

All reported HTMT ratios were below 0.90. The highest ratio was observed between Regulatory Compliance and Green Logistics Practices (0.799). The lowest ratio was between Regulatory Support and Sustainable Logistics Performance (0.566). Green Logistics Practices and Sustainable Logistics Performance had an HTMT value of 0.749. The HTMT estimates below 0.90 are consistent with discriminant validity under the selected evaluation criterion, suggesting adequate empirical differentiation among the four constructs. However, the absence of reported HTMT confidence intervals limits further assessment of discriminant validity, particularly between Regulatory Compliance and Green Logistics Practices.

4) Structural Model Assessment

Figure 2 presents the estimated direct structural paths and the variance explained in the endogenous constructs.

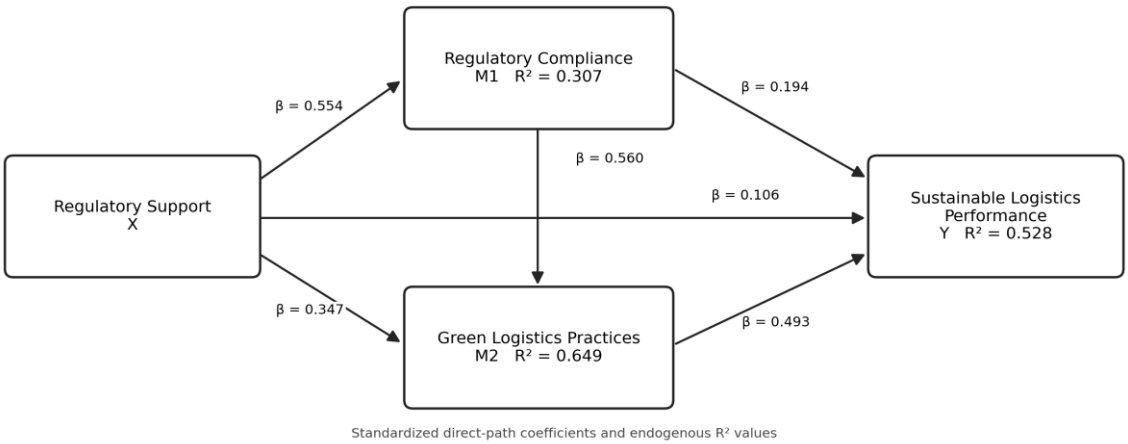


Figure 2. PLS-SEM structural model

Figure 2 displays the estimated structural paths and their associated measured constructs. The model reports $R^2 = 0.307$ for Regulatory Compliance, $R^2 = 0.649$ for Green Logistics Practices, and $R^2 = 0.528$ for Sustainable Logistics Performance. The six direct paths correspond to the relationships evaluated in Table 11. The directional layout represents the proposed analytical model rather than an observed sequence of events. Inferential interpretation therefore relies on

the reported bootstrap tests in conjunction with the cross-sectional design limitations. The inner-model VIF values used to assess predictor collinearity are reported in Table 6.

Table 6. Collinearity statistics (Inner VIF)

Relationship between variables	VIF	Information
M1 → M2	1,443	There is no multicollinearity
M1 → Y	2,336	There is no multicollinearity
M2 → Y	2,849	There is no multicollinearity
X → M1	1,000	There is no multicollinearity
X → M2	1,443	There is no multicollinearity
X → Y	1,786	There is no multicollinearity

The six inner VIF statistics ranged from 1.000 to 2.849. The highest value was associated with Green Logistics Practices as a predictor of Sustainable Logistics Performance. Regulatory Support as the sole predictor of Regulatory Compliance had a VIF of 1.000. All values were below the stated threshold of 5.000. This pattern does not indicate severe collinearity among the modeled predictors. Table 7 reports the explained variance of the three endogenous constructs.

Table 7. Coefficient of Determination (R^2)

Endogenous Variables	R-square (R^2)	Adjusted R-square	Information
Regulatory Compliance (M1)	0.307	0.305	30.7% of the variation is explained by the model
Green Logistics Practices (M2)	0.649	0.647	64.9% of the variation is explained by the model
Sustainable Logistics Performance (Y)	0.528	0.523	52.8% of the variation is explained by the model

Regulatory Compliance had an R^2 of 0.307 and an adjusted R^2 of 0.305. Green Logistics Practices showed the largest explanatory value, with R^2 = 0.649 and adjusted R^2 = 0.647. Sustainable Logistics Performance had R^2 = 0.528 and adjusted R^2 = 0.523. These values indicate that the included predictor sets accounted for different proportions of the observed construct variance. Unexplained variance remains in each endogenous construct, so the model should not be considered a complete account of sustainable logistics outcomes. The contribution of each predictor to the explained variance is summarized by the f^2 estimates in Table 8.

Table 8. Effect Size (f^2)

Predictor Variables	Regulatory Compliance (M1)	Green Logistics Practices (M2)	Sustainable Logistics Performance (Y)
Regulatory Compliance (M1)	–	0.619	0.034
Green Logistics Practices (M2)	–	–	0.180
Regulatory Support (X)	0.443	0.237	0.013

The largest reported f^2 was for Regulatory Compliance as a predictor of Green Logistics Practices (0.619). Regulatory Support had an f^2 of 0.443 for Regulatory Compliance and 0.237 for Green Logistics Practices. Green Logistics Practices had an f^2 of 0.180 for Sustainable Logistics Performance, while Regulatory Compliance had an f^2 of 0.034 for that outcome. The smallest effect size was for the direct Regulatory Support–Sustainable Logistics Performance path (0.013). The pattern indicates that the strongest relative contributions within the tested model were associated with compliance and the adoption of green practices, not the direct support–performance connection. Cross-validated redundancy estimates are presented in Table 9.

Table 9. Predictive Relevance (Q^2)

Variables	SSO	SSE	Q^2	Information
Regulatory Compliance (M1)	2,100,000	1,631,551	0.223	Good predictive relevance
Green Logistics Practices (M2)	2,400,000	1,306,687	0.456	High predictive relevance
Regulatory Support (X)	2,400,000	2,400,000	0,000	Not evaluated as an endogenous construct
Sustainable Logistics Performance (Y)	2,400,000	1,481,078	0.383	Good predictive relevance

The reported cross-validated redundancy Q^2 values were 0.223 for Regulatory Compliance, 0.456 for Green Logistics Practices, and 0.383 for Sustainable Logistics Performance. All three evaluated endogenous constructs had positive Q^2 values. Regulatory Support was an exogenous construct and was therefore not evaluated as a predicted outcome. The highest Q^2 was observed for Green Logistics Practices. These estimates indicate cross-validated redundancy within the specified procedure and should be interpreted separately from the out-of-sample comparisons in Table 10. Table 10 compares indicator-level PLSpredict errors with a linear-model benchmark.

Table 10. PLSpredict

Indicator	Q^2predict	PLS-SEM RMSE	PLS-SEM MAE	LM RMSE	LM MAE
M1.1	0.244	0.596	0.497	0.606	0.503
M1.2	0.206	0.681	0.554	0.693	0.559
M1.3	0.245	0.675	0.548	0.687	0.557
M1.4	0.181	0.673	0.544	0.677	0.546
M1.5	0.247	0.637	0.519	0.648	0.525
M1.6	0.195	0.654	0.545	0.668	0.557
M1.7	0.229	0.700	0.571	0.714	0.582
M2.1	0.313	0.662	0.536	0.674	0.545
M2.2	0.344	0.629	0.515	0.640	0.523
M2.3	0.295	0.600	0.482	0.609	0.486
M2.4	0.251	0.638	0.511	0.646	0.519
M2.5	0.327	0.617	0.494	0.621	0.495
M2.6	0.249	0.617	0.515	0.630	0.526
M2.7	0.281	0.623	0.509	0.628	0.513
M2.8	0.348	0.596	0.479	0.597	0.474
Y.1	0.237	0.644	0.526	0.651	0.533
Y.2	0.177	0.697	0.577	0.706	0.586
Y.3	0.205	0.658	0.539	0.658	0.539
Y.4	0.181	0.691	0.559	0.699	0.561
Y.5	0.197	0.645	0.527	0.658	0.538
Y.6	0.199	0.694	0.570	0.702	0.580
Y.7	0.237	0.628	0.520	0.634	0.523
Y.8	0.220	0.686	0.567	0.687	0.563

Q^2predict was positive for all 23 evaluated endogenous indicators and ranged from 0.177 to 0.348. PLS-SEM had lower RMSE than the linear-model benchmark for 22 indicators and the same reported RMSE for Y.3. Its MAE was lower for 20 indicators, equal for Y.3, and higher for M2.8 and Y.8. This pattern suggests that the fitted model often yielded smaller prediction errors than the benchmark, while performance was not uniformly superior on every metric. The combined comparison should be read alongside the distinction between predictive relevance and predictive performance on held-out cases.

5) Hypothesis Testing

The bootstrapped estimates of the six direct structural relationships are provided in Table 11.

Table 11. Direct Effects

Hypothesis	Relationship between variables	Original Sample (β)	STDEV	T-Statistics	P-Values	Decision
H1	X → M1	0.554	0.037	14,857	< 0.001	Accepted
H2	X → M2	0.347	0.044	7,963	< 0.001	Accepted
H3	X → Y	0.106	0.053	1,987	0.047	Accepted
H4	M1 → M2	0.560	0.039	14,470	< 0.001	Accepted
H5	M1 → Y	0.194	0.055	3,554	< 0.001	Accepted
H6	M2 → Y	0.493	0.063	7,813	< 0.001	Accepted

All six direct relationships were positive and statistically significant at the 5% level, although their explanatory contributions differed considerably. In particular, the relationship between Regulatory Support and Sustainable Logistics Performance was relatively weak (β = 0.106, p = 0.047; f^2 = 0.013), indicating limited incremental explanatory relevance despite meeting the statistical significance criterion. The largest coefficient was for Regulatory Compliance → Green Logistics Practices (β = 0.560), closely followed by Regulatory Support → Regulatory Compliance (β = 0.554). Green Logistics Practices → Sustainable Logistics Performance was the largest of the three direct predictor paths into Y (β = 0.493). Regulatory Support → Sustainable Logistics Performance was the smallest direct coefficient (β = 0.106, p = 0.047), indicating a comparatively weak and borderline-significant association. These results support the specified direct relationships but do not establish that changes in one construct temporally caused changes in another.

6) Mediation Analysis

The three reported specific indirect effects from Regulatory Support to Sustainable Logistics Performance appear in Table 12.

Table 12. Specific Indirect Effects

Hypothesis	Indirect Influence Path	Original Sample (β)	STDEV	T-Statistics	P-Values	Decision
H7	X → M1 → Y	0.108	0.031	3,427	0.001	Supported
H8	X → M2 → Y	0.171	0.032	5,371	0.000	Supported
H9	X → M1 → M2 → Y	0.153	0.023	6,517	0.000	Supported

All three specific indirect effects were positive and statistically significant according to the reported p-values, supporting the hypothesized indirect associations through Regulatory Compliance, Green Logistics Practices, and their sequential combination. Nevertheless, bootstrap confidence intervals were not presented, and the cross-sectional design does not independently establish the temporal ordering of the proposed mediation mechanisms. The indirect association through Regulatory Compliance was β = 0.108 (p = 0.001). The association through Green Logistics Practices was β = 0.171 (p < 0.001), the largest of the three indirect coefficients. The sequential pathway through Regulatory Compliance and Green Logistics Practices was β = 0.153 (p < 0.001). These estimates are consistent with mediation patterns in the specified model, but the survey design cannot independently demonstrate the temporal sequence proposed by the path diagram.

Discussion

Regulatory Support showed a positive association with Regulatory Compliance (β = 0.554), indicating that respondents who perceived a more supportive regulatory environment

also reported stronger organizational conformity with applicable requirements. Institutional Theory offers a plausible explanation because consistent expectations and credible oversight can make compliance a more visible element of organizational routines (Gonzalez et al., 2022; Shahzad et al., 2022). The result is compatible with work on urban freight policy maturity, which emphasizes the relevance of policy conditions to sustainability initiatives (Cowie & Fisken, 2023). It should not, however, be interpreted as demonstrating that an increase in policy support would necessarily produce the same magnitude of compliance improvement across companies. The instrument measured perceived clarity, enforcement, and support, and it did not isolate which regulatory mechanism accounted for the association. For policymakers, the implication is to consider informational clarity and implementation consistency together rather than relying solely on the formal presence of rules (Knoppen et al., 2021).

Regulatory Support was also related to Green Logistics Practices (β = 0.347), suggesting a connection between the perceived policy environment and how respondents assessed everyday freight operations. Research on institutional fields and green supply chain management has similarly emphasized that organizations interpret regulatory signals through their available resources and environmental priorities (Chen et al., 2024; Hebaz et al., 2024). Evidence from logistics firms in Vietnam identifies differentiated regulatory, industry, and customer conditions around green-practice adoption rather than a uniform response to external pressure (Phan et al., 2024). Evidence from previous studies provides a plausible interpretation of the smaller association between Regulatory Support and Green Logistics Practices relative to the association between Regulatory Compliance and Green Logistics Practices. However, because the differences between these coefficients were not formally tested, the proposed explanation should be regarded as theoretically informed rather than empirically established. Regulatory measures may be relevant to organizational decisions, but practical implementation also involves fleet investment, route management, and technical constraints not separately modeled here. Scenario research on sustainable last-mile logistics likewise points to the interdependence of regulation, innovation, and cooperation in shaping feasible change (Plazier et al., 2024).

The Regulatory Compliance–Green Logistics Practices relationship was the largest direct path in the model (β = 0.560), which is consistent with compliance and operational practice being closely connected while remaining distinct constructs. Regulatory compliance concerns obligations such as vehicle standards and operating restrictions, whereas green practices concern choices about routes, loads, vehicle use, and energy efficiency. Earlier studies link institutional pressures and internal organizational abilities with green logistics or environmental outcomes, supporting the relevance of managerial interpretation rather than a purely legalistic view of compliance (Layaoen et al., 2024; Candrianto et al., 2026). Research on managers' sustainability frames also suggests that environmental objectives can remain subordinate to other organizational priorities, even when sustainability is publicly recognized (Heikkinen, 2024). The present findings are compatible with the possibility that compliance routines and operational improvement reinforce each other, but no bidirectional relationship was tested. Distinguishing formal conformity from operationally meaningful practice is consequently essential when interpreting the model and designing practical support measures.

Green Logistics Practices had a substantial positive association with Sustainable Logistics Performance (β = 0.493), and this was the largest direct predictor coefficient for the outcome construct. The Natural Resource-Based View helps interpret this result by treating efficiency-oriented environmental routines as potentially valuable organizational capabilities. Empirical logistics research reports related connections between green practices, operational outcomes,

and sustainability performance, although these studies differ in the activities and performance dimensions assessed (De Souza et al., 2022; Roy & Mohanty, 2024; Stekelorum et al., 2021). Work on green logistics knowledge and circular supply chains likewise suggests that implementation may depend on broader resource and information capabilities (Van Vo & Nguyen, 2023; Zhou et al., 2023). In this dataset, both practices and performance were measured through respondents' perceptions, and the results therefore do not constitute direct measurements of emissions, fuel consumption, or delivery time improvements. The association is nevertheless consistent with the proposition that operational choices are a meaningful link between environmental intentions and reported performance.

The two remaining direct paths into Sustainable Logistics Performance had smaller coefficients, with Regulatory Compliance at $\beta = 0.194$ and Regulatory Support at $\beta = 0.106$. The latter path was significant at $p = 0.047$, while its f^2 was only 0.013, indicating limited incremental explanatory contribution in the specified model. These findings caution against interpreting policy support as a sufficient mechanism for achieving sustainability outcomes. Studies relating logistics performance to environmental performance and green innovation likewise distinguish operational capacity from broad enabling conditions (Wan et al., 2022; Yingfei et al., 2022). The modest direct coefficients may be compatible with a mechanism in which the association between the regulatory environment and performance is expressed more strongly through organizational actions, although alternative unmeasured explanations cannot be excluded. Recent research on green logistics adoption and firm performance also indicates the need to examine how particular operational conditions shape observed relationships (Duzgun, 2026).

The indirect effects provide the clearest integrative contribution of the analysis. Regulatory Support was associated with Sustainable Logistics Performance through Regulatory Compliance ($\beta = 0.108$), through Green Logistics Practices ($\beta = 0.171$), and sequentially through both constructs ($\beta = 0.153$), with all three reported indirect paths statistically supported. Because the direct $X \rightarrow Y$ path remained positive and significant, the results are consistent with statistical partial mediation rather than a complete replacement of the direct association. This pattern brings Institutional Theory and the Natural Resource-Based View together in a single model: the former interprets perceived regulatory expectations and compliance, while the latter interprets operational practices associated with performance. Related studies have linked environmental orientation, institutional pressures, and green logistics to organizational outcomes, but the present model separates the compliance and practice constructs instead of treating all organizational responses as equivalent (Afum et al., 2022; Ahmad et al., 2022; El-Garaihy et al., 2022). Nevertheless, these are products of relationships observed at one time point, not independent evidence that regulatory support preceded compliance or that compliance temporally produced greener operations.

The urban freight setting complicates the translation of organization-level associations into uniform policy recommendations. Urban logistics governance involves different actors, freight demand patterns, space constraints, and competing uses of transport infrastructure (Haarstad et al., 2024; Shrestha et al., 2024). Freight curbside analysis, for example, identifies operational gains but also trade-offs involving access and use of public space (Castrellon & Sanchez-Diaz, 2024). Earlier assessments emphasize that regulatory and operational choices can affect urban freight systems differently according to local planning conditions (Hauge et al., 2021; Maxner et al., 2025). These considerations are relevant to the present sample, which spans several organization and fleet categories but does not establish comparative estimates by city or company type. The results should therefore guide contextual evaluation of compliance and green

operational practices rather than support a claim of one universally optimal regulatory intervention.

For logistics managers, the results suggest value in connecting compliance activities to measurable operational routines such as route design, load utilization, maintenance, and energy monitoring, rather than considering compliance solely an administrative function. Government agencies may likewise consider linking policy guidance and enforcement to implementation support and context-sensitive performance indicators (Mansouri et al., 2023; El Amrani et al., 2024). Such an interpretation is consistent with research connecting green logistics practices to performance while recognizing that the realization of benefits depends on company and sector conditions (Odock et al., 2024; Choudhary & Sangwan, 2022). The conclusions are limited by purposive selection, the lack of objective operational measurements, and the possibility of common-method response patterns in the questionnaire. Differences in technology readiness, urban freight restrictions, and the availability of distribution infrastructure remain plausible contextual factors rather than effects established by this analysis (Letnik et al., 2022; Golinska-Dawson & Sethanan, 2023). Future studies could combine longitudinal observations with fuel, delivery, and emissions records and compare policy environments across organizations or urban settings; such designs would be necessary before making stronger causal or generalizable claims.

CONCLUSIONS

This study investigated associations among Regulatory Support, Regulatory Compliance, Green Logistics Practices, and Sustainable Logistics Performance using cross-sectional responses from 300 participants involved in urban freight and distribution. All six reported direct paths were positive and statistically supported, although their magnitudes differed. The strongest direct relationship in the structural model was between Regulatory Compliance and Green Logistics Practices, while Green Logistics Practices had the largest direct coefficient among predictors of Sustainable Logistics Performance. The small direct Regulatory Support–performance coefficient suggests that regulatory support should not be interpreted as a substitute for organizational and operational action. The three specific indirect effects were statistically consistent with the hypothesized mediation pathways through Regulatory Compliance, Green Logistics Practices, and their sequential combination, suggesting complementary institutional and operational associations without establishing a causal sequence.

The conceptual contribution lies in examining Institutional Theory and the Natural Resource-Based View within the same empirical model. The regulatory environment was associated with compliance as an organizational response, and green operational practices were associated with reported logistics performance. The sequential indirect pathway illustrates how these perspectives can be examined as complementary rather than competing explanations of organizational sustainability. This interpretation remains associational because the study did not observe the proposed stages at separate points in time.

Practical implications include aligning policy communication and enforcement with operational improvements that companies can implement and monitor. For freight operators, these improvements may concern route planning, load utilization, empty-trip reduction, fleet maintenance, and energy management. For authorities, the findings encourage attention to the interaction between regulatory expectations and firms' capacity to put environmentally oriented procedures into practice. These recommendations are directional rather than evidence that a particular intervention would reduce emissions in the organizations surveyed.

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