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Development of a Sustainable Logistics Service Level Agreement (SLSLA) Model: a Partial Least Squares Structural Equation Modeling and Measurable Index Approach

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ABSTRACT

The increasingly complex development of the logistics sector requires service level agreements that are oriented not only toward operational efficiency but also toward sustainability. This study develops and empirically validates a Sustainable Logistics Service Level Agreement (SLSLA) model comprising seven dimensions—operational efficiency, reliability, responsiveness, digital transparency, environmental performance, customer satisfaction, and resilience—operationalized into 28 reflective indicators. A quantitative survey was distributed to logistics practitioners and academics selected through purposive sampling; of 50 questionnaires distributed, 40 were valid for analysis (80% response rate) after 3 were omitted owing to absent values or anomalies. The implementation of Partial Least Squares Structural Equation Modeling (PLS-SEM) that utilize SmartPLS aimed to deliver data analysis. The convergent validity of the measurement model was satisfactory (outer loadings 0.867–0.944; AVE 0.798–0.824), high construct reliability (Cronbach's Alpha also Composite Reliability with value above 0.90), sufficient discriminant validity (Fornell-Larcker criterion and HTMT go under 0.90), as well as no collinearity problems (VIF 2.235–3.012). Bootstrapping with 5,000 resamples confirmed that all seven dimensions contributed positively and significantly to the SLSLA construct (t-statistics 10.093–16.150; $p < 0.01$), with relatively balanced path coefficients (0.169–0.177), so that hypotheses H1–H7 were fully supported. The resulting SLSLA Index, weighted by path coefficients, reached 70.93 on a 0–100 scale (high category), led by digital transparency and operational efficiency, while reliability and customer satisfaction contributed relatively less. The validated SLSLA model and index offer logistics service providers a measurable reference for designing and evaluating more sustainable service level agreements.

Keywords : *Sustainable Logistics, Service Level Agreement, PLS-SEM, Measurable Index, Sustainability.*

INTRODUCTION

The growing complexity of distribution networks has driven a significant transformation in modern supply chain systems. Supply chain itself is no longer merely including distribution stage sequences but also an integrated system involving coordination among suppliers, producers, distributors, and end users within a dynamic global network. Logistics management therefore carries the strategic task to monitor the goods, information also financial transactions flows within an integrated manner, ensuring operational efficiency and the fulfilment of customer needs (Islam et al., 2024).

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In recent years, the transformation toward sustainable logistics has become a major concern of the global supply chain industry. Globally, the green logistics market is projected to grow from US$1.7 trillion in 2026 to US$3.0 trillion in 2033, at a CAGR of 8.4%, with the Asia Pacific region recording the highest CAGR at 9.6%—reflecting an accelerated logistics transformation in developing countries, including Indonesia (Deviputra, 2026; Bahr & Sweeney, 2019).

This transformation, however, has created new challenges in logistics service management. The Service Level Agreement (SLA), as the formal instrument for measuring logistics service quality, is still dominated by conventional operational indicators such as delivery punctuality and distribution accuracy, without integrating the sustainability dimension (Ahmed, 2018). Prior studies show that many organizations experience a gap between internal operational performance and actual SLA achievement, caused by suboptimal fleet allocation, weak cross-departmental coordination, and limited data-based monitoring mechanisms (Agustina & Purwanto, 2025).

Historically, research on sustainable logistics evolved from green supply chain management studies. It discusses how economy, social, and environment aspects are integrated to be part of supply chain activities (Srivastava, 2007; Seuring & Müller, 2008), before shifting toward the operational efficiency and environmental implication towards distribution, transportation, and warehousing operational (Dekker et al., 2012; Govindan et al., 2014). More recent research indicates that the success of sustainable logistics implementation is reflected not only in environmental friendliness and distribution optimization, but also in the quality of service delivered to customers, which is in practice measured through the SLA mechanism (Ali et al., 2022). Research on Sustainable Logistics Service Quality (SLSQ) has grown significantly since 2013, yet studies that explicitly integrate sustainability principles into the SLA framework remain very limited (Abdelaziz & Munawaroh, 2025).

The research is compiled to address the gap as explained above through developing a Sustainable Logistics Service Level Agreement (SLSLA) model equipped with a multidimensional composite index measurement instrument. To ensure this research originality, discussion was founded within SLSLA Index development as a quantitative instrument in which to validate the measurement model, Partial Least Squares Structural Equation Modelling was implemented to be reflective-formative higher-order construct. Such examination is able to seek how valid and reliable are the seven sustainability dimensions—operational efficiency, reliability, responsiveness, digital transparency, environmental performance, customer satisfaction, and resilience—as a single unified SLSLA construct (Figure 1).

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Figure 1. Conceptual Framework of the Sustainable Logistics Service Level Agreement (SLSLA)

Following the discussion, it is mapped that research problems include: (1) how can the transformation of sustainable logistics and the seven SLSLA dimensions be conceptualized based on modern supply chain management theory; (2) are the 28 reflective indicators valid and reliable in measuring the seven SLSLA dimensions based on the PLS-SEM outer model evaluation; (3) do the seven SLSLA dimensions combine well as a reflective-formative Higher Order Construct (HOC) based on the PLS-SEM inner model evaluation; and (4) how can the SLSLA Index model be constructed from the scores of the seven validated dimensions as a measurement instrument for sustainable logistics SLA performance.

In line with these research problems, this study aims to conceptualize the seven SLSLA dimensions, examine how far 28 reflective indicators are valid and reliabel through outer model evaluation, test the seven dimensions contribution (path coefficient) significantly in forming the SLSLA construct through inner model evaluation, and develop and validate the SLSLA Index model as a measurable and operational instrument for assessing sustainable logistics SLA performance.

As the SLSLA model is constructed for reflective-formative Higher Order Construct, the seven dimensions acted to be Lower Order Components that formatively form the SLSLA construct, leading to the following hypotheses: H1–H7 state that Operational Efficiency, Reliability, Responsiveness, Digital Transparency, Environmental Performance, Customer Satisfaction, and Resilience, respectively, positively and significantly form the SLSLA construct.

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RESEARCH METHOD

The research implements quantitative methodology to test and validate SLSLA measurement model. The seven dimensions and 28 indicators developed from the theoretical review were empirically examined for its validity and reliability through questionnaire data collected from logistics practitioners and academics as respondents. To analyse data research, writer implied Partial Least Squares Structural Equation Modelling (PLS-SEM) approach through SmartPLS software (Ringle, Wende, & Becker, 2022), that were applicated for validity and reliability instrument (outer model) examination while simultaneously evaluating the relationships between constructs (inner model). PLS-SEM was selected because it suits reflective constructs, performs well with a limited sample size, doesn't need data normality rigidness assumptions, also offers an empirical basis for evaluating instrument feasibility prior to composite index construction.

The population comprised practitioners and academics working in logistics management who understood the application of SLA and the concept of sustainable logistics. Sampling used a purposive technique, selecting respondents that possess minimum three years professional work and research experiences in logistics field. To collect data, closed-ended questionnaire was employed utilizing Likert scale started from 1 into 5 (1 = strongly disagree into 5 = strongly agree), consisting of 28 indicators measuring the seven SLSLA dimensions, each represented by four reflective indicators.

Data analysis was proceeded through descriptive statistics at the indicator and dimension levels that include measurement model (outer model) evaluation that had convergent validity (outer loading also Average Variance Extracted/AVE), construct reliability (Cronbach's Alpha and Composite Reliability), discriminant validity as well (Fornell–Larcker criterion also Heterotrait-Monotrait Ratio/HTMT) (Fornell & Larcker, 1981; Henseler, Ringle, & Sarstedt, 2015; Hair et al., 2021); a collinearity test that use Variance Inflation Factor (VIF); structural model (inner model) evaluation through path coefficient tested via bootstrapping with 5,000 resamples to determine hypothesis premise through t-statistic value surpassed 1.96 or $p < 0.05$; and evaluation of predictive relevance through R^2, and Q^2predict utilizing PLSpredict mechanism (Shmueli et al., 2019). Finally, the SLSLA Index was constructed as a composite index normalized to a 0–100 scale, using the path coefficient of each dimension as its weight, following the formula: SLSLA Index = $\Sigma(w_i \times Di_i)$, where w_i is the normalized weight (path coefficient) and Di_i is the normalized score of dimension.

RESULTS AND DISCUSSION

Respondent Profile

Derived from 50 questionnaires distribution, 43 were returned (86%), and 3 were excluded due to missing values/outliers, resulting in a final valid sample of N = 40 (80% response rate) used in all PLS-SEM analyses (Table 1). Most respondents

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held the position of Logistics Manager (42.5%) or Logistics Supervisor (37.5%), came from 3PL Providers (50.0%), and had 3–5 years of work experience (47.5%) (Table 2).

Table 1. Response Rate and Questionnaire Eligibility

Description	Number	Percentage (%)
Questionnaires distributed	50	100
Questionnaires returned	43	86
Excluded (missing value/outlier)	3	6
Valid for analysis (response rate)	40	80

Table 2. Respondent Demographic Characteristics

Characteristic	Category	Frequency	Percentage (%)
Position	Logistics Manager	17	42.5
	Logistics Supervisor	15	37.5
	Operations Director	4	10.0
	Senior Supply Chain Staff	4	10.0
Company type	3PL Provider	20	50.0
	E-commerce	9	22.5
	Manufacturing	6	15.0
	Distributor/Retail	5	12.5
Work experience	3–5 years	19	47.5
	6–10 years	15	37.5
	More than 10 years	6	15.0
Total		40	100

Measurement Model (Outer Model) Evaluation

The 28 indicators showed outer loadings that have range between 0.867 into 0.944, counted above 0.70 recommended threshold overall. The output of convergent validity also construct reliability are presented on Table 3 below:

Table 3. Convergent Validity and Construct Reliability

Construct	Cronbach's Alpha	CR (rho_a)	CR (rho_c)	AVE
Operational Efficiency	0.926	0.928	0.948	0.819

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Construct	Cronbach's Alpha	CR (rho_a)	CR (rho_c)	AVE
Reliability	0.924	0.925	0.946	0.814
Responsiveness	0.916	0.916	0.941	0.798
Digital Transparency	0.918	0.918	0.942	0.802
Environmental Performance	0.925	0.926	0.947	0.817
Customer Satisfaction	0.928	0.930	0.949	0.824
Resilience	0.924	0.924	0.946	0.814

From table, it is known that all AVE values (0.798 to 0.824) had succeed threshold number 0.50 (Fornell & Larcker, 1981) that confirm the convergent was valid within construct level. This value suggests that data from the measurement towards seven constructs are consistent internally in terms of Cronbach's Alpha (0.916 to 0.928) also Composite Reliability (0.941 to 0.949) which was exceeding threshold minimum 0.70 evidently (Hair et al., 2021). Further, discriminant validity examination passed Fornell-Larcker standards, in which AVE square root for every dimension had greater number than their correlations to another dimensions (highest cross-correlation 0.728, between Environmental Performance and Responsiveness), and by the HTMT ratio, which remained below the 0.90 threshold for all dimensions pairs (highest HTMT 0.790) (Henseler, Ringle, & Sarstedt, 2015). A collinearity test showed inner VIF values of 2.235–3.012 for all seven paths, positioned under conservative threshold minimum number that is 3.3 (Hair et al., 2021), suggesting the SLSLA model is free of multicollinearity issues among predictors.

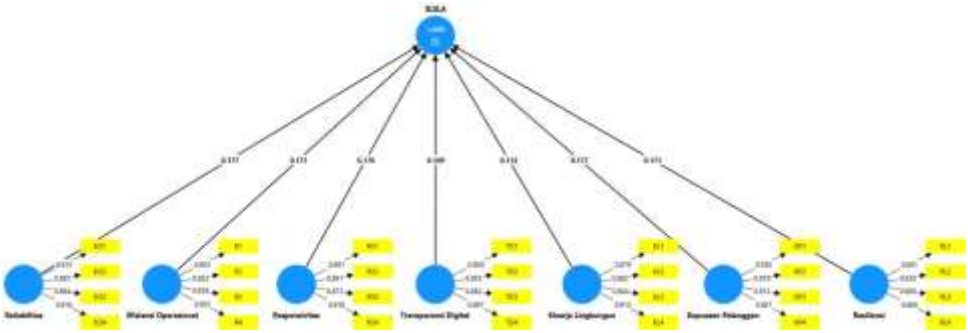


Figure 2. SLSLA Outer and Inner Model (Loadings and Path Coefficients)

Hypothesis Testing (Inner Model)

Path coefficient significancy from each SLSLA dimensions (H1–H7) were examined through bootstrapping technique, utilizing 5,000 resamples as summarized in table below:

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Table 4. Hypothesis Testing Results (Path Coefficients, Bootstrapping)

Hyp.	Path	Coefficient (O)	t-statistic	p-value	Decision
H1	Operational Efficiency → SLSLA	0.173	10.982	0.000	Supported
H2	Reliability → SLSLA	0.177	13.167	0.000	Supported
H3	Responsiveness → SLSLA	0.176	11.828	0.000	Supported
H4	Digital Transparency → SLSLA	0.169	11.515	0.000	Supported
H5	Environmental Performance → SLSLA	0.174	16.150	0.000	Supported
H6	Customer Satisfaction → SLSLA	0.177	10.486	0.000	Supported
H7	Resilience → SLSLA	0.171	10.093	0.000	Supported

From the output, the seven path were demonstrated significance with number $p < 0.01$, t-statistics ranging from 10.093 to 16.150, substantially beyond threshold number critically at 1.96; hence, H1–H7 received fully supported. The path coefficients included within seven dimensions were relatively balanced, ranging from 0.169 (Digital Transparency) to 0.177 (Reliability and Customer Satisfaction), indicating that no single dimension dominates the formation of SLSLA. The R^2 value for SLSLA reached 1.000, a mathematical consequence of repeated-indicators technique was used to estimate the reflective-formative Construct of Higher Order (Becker, Klein, & Wetzels, 2012), rather than evidence of substantive predictive strength; consequently, f^2 values were not interpretable and are not reported. Meanwhile, the relevance was predictively assessed used PLSpredict procedure (Shmueli et al., 2019). All 28 indicators produced positive Q^2predict values (0.448–0.622, mean 0.518), well above both the zero threshold and the 0.35 "large" threshold (Hair et al., 2019), and PLS-SEM RMSE numbers were consistently lower in comparison to Indicator Average (IA) RMSE benchmark across all 28 indicators—confirming that model's robust relevance predictively beyond the sample at the indicator level.

SLSLA Index

Table 5. SLSLA Index Weighted by PLS-SEM Path Coefficient

Dimension	Path Coefficient (wi)	Normalized Weight	Weighted Contribution
Operational Efficiency	0.173	0.1422	10.57

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Dimension	Path Coefficient (wi)	Normalized Weight	Weighted Contribution
Reliability	0.177	0.1454	9.45
Responsiveness	0.176	0.1446	9.94
Digital Transparency	0.169	0.1389	10.63
Environmental Performance	0.174	0.1430	10.23
Customer Satisfaction	0.177	0.1454	9.57
Resilience	0.171	0.1405	10.52
Total	1.217	1.0000	70.91*

*Computed from unrounded weights, the SLSLA Index reached 70.93; the total in Table 5 (70.91) reflects rounding of four-decimal weights.

The PLS-SEM-weighted SLSLA Index was 70.93 on a 0–100 scale, classified as a high category. The highest weighted contributions came from Digital Transparency (10.63) and Operational Efficiency (10.57), while Reliability (9.45) and Customer Satisfaction (9.57) contributed relatively less.

Discussion

Hair et al. (2021) explained the requirement for measurement model to meet all feasibility criteria to do PLS-SEM analysis, providing such valid empirical basis for interpreting the path coefficients in Table 4 as sound evidence for testing H1–H7.

H1 (Operational Efficiency, $\beta = 0.173$, $t = 10.982$) confirms that optimizing fleet allocation and controlling operational costs without sacrificing service quality remain a fundamental element of logistics performance assessment, even after sustainability dimensions are integrated (Agustina & Purwanto, 2025), and aligns with evidence linking customer service level to logistics cost management (Ouyang, 2024).

H2 (Reliability, $\beta = 0.177$, $t = 13.167$) obtained the highest coefficient alongside Customer Satisfaction, consistent with Ahmed (2018), who positioned punctuality, accuracy, and dependability as core SLA indicators, and with Ali, Gruchmann, and Melkonyan (2022), who found that sustainable logistics service quality still rests on the consistent fulfilment of service promises as the foundation of customer trust.

H3 (Responsiveness, $\beta = 0.176$, $t = 11.828$) outcome is aligned with study that highlights adaptive speed importantly within the logistics 4.0 framework (Tiwong et al., 2024) and the ability to respond to operational disruptions as a determinant of service continuity amid supply chain uncertainty (Abbasi et al., 2024).

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H4 (Digital Transparency, β = 0.169, t = 11.515) recorded the lowest, though still significant, coefficient. This supports the argument that processes mining and data-based monitoring systems strengthen SLA measurability (Audia & Er, 2024) and that artificial intelligence supports operational accountability (Shawon et al., 2025); the relatively lower coefficient suggests that tracking-system sophistication and data openness are not yet perceived as strongly as conventional operational dimensions, consistent with Zulfikri's (2024) observation of technology-readiness gaps between logistics companies.

H5 (Environmental Performance, β = 0.174, t = 16.150) recorded the highest t-statistic among the seven paths, reinforcing evidence that energy efficiency, emission reduction, and environmentally friendly transportation practices consistently shape logistics service quality assessment (Yingfei et al., 2022; Hou et al., 2021), and that organizational support for green initiatives has a stable influence on logistics service provider performance (Sureeyatanapas, Poophiukhok, & Pathumnakul, 2018).

H6 (Customer Satisfaction, β = 0.177, t = 10.486), tied with Reliability as the highest coefficient, confirms that the quality of long-term business relationships is the ultimate outcome of sustainable logistics service improvement efforts (Ali et al., 2022), consistent with the emphasis on customer trust in the context of post-pandemic logistics efficiency recovery (Bayraktar et al., 2025).

H7 (Resilience, β = 0.171, t = 10.093), though recording the lowest t-statistic, remained far above the critical value, confirming that the ability to sustain service continuity under uncertain conditions remains an inseparable part of overall SLSLA evaluation—in line with evidence that supply chain resilience positively affects firm competitiveness (Zheng & Wang, 2025), risk-management integration and stakeholder collaboration (Liza et al., 2025), and horizontal collaboration as support for logistics system resilience (Sumarna et al., 2026).

The SLSLA Index of 70.93—led by Digital Transparency and Operational Efficiency, with relatively lower contributions from Reliability and Customer Satisfaction—suggests that digital and operational strengths at the object of this study are not yet fully matched by consistency in fulfilling service promises and depth of customer relationships, echoing the finding that service reliability is often a critical differentiator between superior and average logistics service providers (Gupta, Singh, & Suri, 2018).

CONCLUSION

The seven SLSLA dimensions—operational efficiency, reliability, responsiveness, digital transparency, environmental performance, customer satisfaction, and resilience—were successfully conceptualized based on modern supply chain management theory and operationalized into 28 reflective indicators, tested on 40 valid respondents. The measurement model based on PLS-SEM with a repeated- indicators technique towards reflective-formative Higher Order Construct

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are valid and reliable: convergent validity is met (outer loading 0.867–0.944; AVE 0.798–0.824), construct reliability is high (Cronbach's Alpha and Composite Reliability above 0.90), discriminant validity is met (Fornell-Larcker and HTMT below 0.90), and the model is free of collinearity issues (VIF 2.235–3.012). All seven dimensions are significant formative indicators of the SLSLA construct (t-statistics 10.093–16.150; $p < 0.01$) with relatively balanced path coefficients (0.169–0.177), so that H1–H7 are fully supported; the SLSLA R^2 of 1.000 is a mathematical artifact of the repeated-indicators design, while the model's predictive relevance is more meaningfully demonstrated by uniformly strong, positive indicator-level Q^2predict values (mean 0.518). According to PLS-SEM path-coefficient weights, SLSLA Index output within the object of this study is 70.93 on a 0–100 scale (high category), with the highest weighted contributions from Digital Transparency and Operational Efficiency, and relatively lower contributions from Reliability and Customer Satisfaction.

This study contributes theoretically by introducing the SLSLA construct and the SLSLA Index as new measurement instruments in the sustainable logistics management literature, empirically validated through PLS-SEM. Methodologically, the study contributes through repeated-indicators technique which is testing higher-order construct measurement model, complemented by a transparent evaluation of the R^2/f^2 interpretation limitations of this design and a strengthened evidence base through PLSpredict-based Q^2predict. Practically, it provides an operational guide for designing and evaluating SLAs among sustainability-oriented logistics service providers, complemented by an SLSLA Index benchmark of 70.93 (high category) as a comparative reference for similar companies.

Future research agendas are suggested to include replicating and extending the SLSLA Index that conduct broader and variative cohort samples from Indonesian logistics firms, developing a dashboard-based information system for real-time SLSLA Index implementation integrated with IoT and big data analytics, conducting comparative studies of SLSLA Index application across industry sectors, and utilizing two-phases methodology that are compared into repeated-indicators technique to obtain structural-level R^2 and f^2 values that are substantively interpretable. Logistics companies are recommended to integrate sustainability indicators into SLA design and management and to prioritize improvements in the consistency of service-promise fulfilment and complaint-handling mechanisms, while governments and regulators should consider establishing minimum SLSLA standards to encourage the national logistics industry to transition toward a more sustainable and competitive service system.

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