Scilight

Operations and Supply Chain Innovation
https://www.sciltp.com/journals/osci

Article

Recognition-Implementation Gap (RIG) Assessment Framework of Environmental Logistics Practices (ELP): A Case among Thai Logistics Service Providers (LSPs)

Tudsuda Imsuwan and T. C. Wong *

Department of Design, Manufacturing and Engineering Management, University of Strathclyde, Glasgow G1 1XJ, UK
* Correspondence: andy.wong@strath.ac.uk

How To Cite: Imsuwan, T.; Wong, T.C. Recognition-Implementation Gap (RIG) Assessment Framework of Environmental Logistics Practices (ELP): A Case among Thai Logistics Service Providers (LSPs). *Operations and Supply Chain Innovation* **2026**, *1*(1), 7. https://doi.org/10.53941/osci.2026.100007

Received: 26 July 2026
Revised: 8 September 2026
Accepted: 16 September 2026
Published: 24 September 2026

Abstract: This study investigates why environmental logistics practices (ELP) that Thai logistics service providers (LSPs) recognize as essential for performance are not uniformly implemented at levels commensurate with their perceived importance and identifies the domain-specific constraints that explain this recognition implementation gap (RIG) in Thailand's resource-constrained logistics sector. Using a sequential exploratory mixed-method design, the study combines semi-structured interviews with logistics professionals and a structured expert questionnaire from a multi-stakeholder panel comprising LSPs, user firms, and academics. Practices across eight logistics domains were assessed for performance recognition and implementation status, with a stakeholder agreement threshold identifying a subset of high-impact practices. Despite near-universal performance recognition (90–100%), implementation among company-affiliated respondents averaged 83% across the high-impact practices, leaving RIGs that are small for practices under direct organizational control but reach 25–38 percentage points for capital-intensive and coordination-dependent practices. Packaging and transportation exhibited the largest domain-level gaps, driven by cost premiums, capital constraints and supply chain coordination failures, whilst customer pressure emerged as the primary adoption driver yet proved insufficient to overcome financial and capability barriers, particularly among Thai SMEs. The study identifies four interlinked constraints: financial capacity, capability and knowledge gaps, inter-organizational coordination challenges, and weak institutional support as the primary moderators of implementation, producing an empirically grounded barrier typology that, whilst derived from the Thai LSPs context, holds wider relevance for sustainability transitions across comparable emerging-market logistics sectors. The RIG assessment framework developed in this Thai case provides a replicable template for comparative research across other emerging-market and developing economies.

Keywords: environmental logistics practices; logistics service providers; recognition-implementation gap; sustainability; emerging-market logistics

1. Introduction

Achieving the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), requires a fundamental transformation of logistics operations worldwide. Accounting for approximately 5–10% of global greenhouse gas emissions and substantial

resource consumption [1,2], the logistics sector faces intensifying pressure to align with global climate commitments. This imperative is particularly acute in emerging economies, where resource constraints, institutional gaps, and limited stakeholder awareness complicate sustainability transitions. Despite growing emphasis on environmental sustainability imperatives, Environmental Logistics Practices (ELP) adoption among Logistics Service Providers (LSPs) remains inconsistent and fragmented, especially in developing Asian contexts. Thailand offers an analytically valuable yet underexamined case within the emerging-market sustainability literature.

Thailand provides a suitable research context for this study due to four context-specific factors.

First, Thailand is one of ASEAN's largest economies and a strategic logistics hub connecting China, mainland Southeast Asia, and maritime Southeast Asia. This regional role, combined with Thailand's position as the third-highest ASEAN member state in the World Bank's Logistics Performance Index [3,4], makes the environmental performance of Thai LSPs relevant to sustainability outcomes beyond the national context.

Second, Thailand's policy agenda places increasing decarbonization pressure on the transport and logistics sector, particularly through the Bio-Circular-Green (BCG) Economy Model [5] and the updated NDC, which targets a 30% unconditional and 40% conditional reduction in greenhouse gas emissions by 2030 [6].

Third, Thailand's logistics sector is largely dominated by small and medium-sized enterprises (SMEs), making it an important context for examining the gap between national sustainability ambitions and firm-level implementation capacity. This is particularly relevant because micro, small and medium-sized enterprises (MSMEs) account for approximately 99.5% of Thai enterprises and around 35% of national GDP [7].

Fourth, Thailand's high-speed rail development and the China–Laos–Thailand logistics corridor are reshaping freight modal choices [8,9], making the country a policy-relevant context for examining environmental logistics practice adoption.

Thailand, therefore, provides a relevant setting for examining how emerging economies balance ambitious sustainability targets with constrained firm-level resources, while offering insights that may inform comparable ASEAN contexts such as Vietnam, Indonesia, and the Philippines.

Thai LSPs are predominantly SMEs, often operating with thin margins, limited access to capital, and weak technical capacity. These constraints have been identified as key barriers to environmental practice adoption among Thai small businesses, particularly SMEs [10]. Although green logistics practices are increasingly adopted by Thai firms, adoption remains uneven and constrained by financial capacity, weak regulatory enforcement and limited supply chain collaboration [10,11], and existing efforts remain fragmented. There is still limited systematic evidence on adoption patterns, performance contributions, and implementation barriers across different logistics functions. This gap limits the ability of Thai LSP managers, industry associations, and policymakers to identify where interventions are likely to have the greatest impact.

Prior research has three main limitations.

First, many studies examine ELP through broad categories, such as "green transportation" or "green warehousing", rather than specific practice-level interventions, limiting guidance for resource allocation [12,13].

Second, evidence remains concentrated in developed economies, while developing Asian contexts are less studied despite distinct implementation constraints. Although studies exist in Vietnam [14] and China [15], domain-specific assessments remain limited.

Third, ELP adoption in resource-constrained settings requires further theoretical validation, as many Stakeholder Theory applications reflect resource-rich contexts [16,17].

Accordingly, this study offers a domain-specific, practice-level assessment of ELP adoption in Thailand and examines why perceived importance (recognition) does not consistently translate into implementation, hence termed as the recognition implementation gap (RIG).

The research addresses three primary questions.

RQ1: To what extent have LSPs in Thailand adopted ELP across logistics functional domains, and which domains show higher versus lower implementation levels?

RQ2: What performance outcomes do practitioners associate with specific practices, and what recognition implementation gaps (RIGs) exist?

RQ3: What factors drive or constrain ELP adoption in resource-constrained contexts?

Drawing on the Triple Bottom Line framework [18] as the organizing lens for sustainability assessment, this mixed-method study combines semi-structured interviews from nine key informants with a structured assessment questionnaire from 30 industry professionals, capturing both qualitative explanations for divergence between recognition and implementation and quantitative domain-level implementation levels. The findings inform

pathways towards SDGs 12 and 13 whilst providing evidence-based guidance to accelerate decarbonization in resource-constrained logistics systems. The findings may also be transferable to other emerging markets facing similar sustainability constraints.

The novelty of this study lies in conceptualizing and operationalizing the recognition–implementation gap (RIG) as a measurable, practice-level construct, applied for the first time to an emerging-market LSP context through a 38-practice, eight-domain assessment framework.

This study makes three contributions to the environmental logistics literature.

First, it develops a domain-specific assessment framework to identify and evaluate 38 ELP across eight logistics domains, rather than relying only on broad constructs such as "green transportation" or "green warehousing" [12].

Second, it provides the first systematic investigation of ELP adoption in Thailand's logistics sector using a sequential exploratory mixed-method design applied to LSPs, strengthening evidence from underrepresented developing-economy contexts beyond existing studies of green logistics practice in Vietnam [19] and of third-party logistics providers in China [15].

Third, it examines whether practices recognized as high-importance are implemented at levels commensurate with their perceived importance (also known as RIGs), and shows that the size of the gap is ordered by the type of structural constraint shaping implementation decisions, including limited financial capacity, capability and knowledge gaps, coordination barriers, and weak institutional support, producing a literature-informed, empirically substantiated barrier typology for resource-constrained settings.

2. Literature Review

2.1. Evolution and Scope of Environmental Logistics Practices (ELP)

ELP are increasingly recognized as operational levers for resource efficiency, emissions reduction, and competitive advantage. Bibliometric and systematic evidence indicate that research on green logistics practices has grown rapidly, yet remains fragmented in its conceptualizations and measurement approaches, reinforcing the need for practice-level, context-specific evidence [20]. The methodological scope of this review, a systematic core covering 2010–2019, supplemented by a 2020–2026 update, is detailed in Section 2.2.

While the "green logistics" concept emerged in the 1990s [21,22], systematic examination of specific practices has intensified only in the past decade, driven by climate commitments and stakeholder pressures [23,24]. ELP directly operationalizes environmental sustainability principles within supply chain operations. Unlike end-of-pipe pollution control approaches that address environmental impacts after they occur, ELP embeds waste prevention, energy efficiency, and resource conservation into operational decision-making processes [2]. Practices such as vehicle routing optimization reduce fuel consumption at source; sustainable packaging design eliminates waste before generation; and energy-efficient warehousing minimizes resource consumption throughout facility operations. This proactive orientation positions ELP as a strategic instrument through which LSPs can simultaneously pursue operational efficiency and environmental performance, a dual objective increasingly demanded by supply chain stakeholders [24,25].

Early research focused on broad conceptualizations without disaggregating practices by functional domain [21,26]. Recent studies examining Vietnam [19] and China [15] point to capability, financial, and institutional constraints that are distinctive to emerging markets. However, these predominantly employ aggregated measurement approaches combining multiple practices into constructs like "green transportation", limiting their utility for identifying specific implementation challenges or performance benefits [12,13].

In Thailand, emerging evidence indicates that green logistics practices are being adopted, with financial capacity, environmental policy and commitment to eco-friendly investment shaping their effectiveness [11], while weak regulation, limited supplier engagement and cost pressures continue to constrain adoption, particularly among SMEs [10]. These scattered initiatives lack a systematic assessment of adoption patterns, performance outcomes, and implementation barriers, a gap this study addresses.

2.2. Domain-Specific Research Gaps

Despite growing literature on ELP benefits [27,28], significant adoption disparities persist, particularly among emerging market SMEs facing financial constraints, technological infrastructure gaps, and inconsistent stakeholder collaboration [10]. Interview-based evidence from LSPs likewise shows that favorable managerial attitudes toward green logistics coexist with restraining external conditions that limit adoption [29], underscoring the need to examine why recognition does not translate into implementation. Critically, existing research provides

insufficient granularity to determine whether barriers affect all logistics domains equally or whether certain functions face domain-specific obstacles.

To map the extent of domain-level evidence and inform the development of the RIG assessment framework, a systematic literature review (SLR) was conducted. The review followed the established SLR protocol of Tranfield et al. [30] and Denyer and Tranfield [31] for source identification, screening, and selection, while the qualitative synthesis of the retained studies was conducted using Mayring's [32] content analysis approach.

Searches were conducted in Scopus, Web of Science, ScienceDirect, and ProQuest, combining the core terms "supply chain sustainability" and "logistics service provider" with the synonyms "freight forwarder", "freight transport", "third-party logistics", and "fourth-party logistics" using Boolean operators (AND/OR). The review included peer-reviewed journal articles published in English between 2010 and 2026, a unified temporal window spanning both the decade of accelerating green logistics scholarship that preceded the study's fieldwork and the pandemic and post-pandemic literature published thereafter. The chronology of the review and the empirical study is as follows: the original SLR covering 2010–2019 was completed first and provided the sole literature basis for the domain taxonomy, the 38-practice set, and the research instrument; empirical data collection then followed; and the review was subsequently updated to 2026 under the same protocol, consistent with established methodological guidance on updating systematic reviews [33,34], with the post-2019 literature used only to contextualize the findings rather than to construct or modify the instrument.

Because the primary data collection was completed before COVID-19 disruptions materially affected Thai logistics operations, the findings are interpreted as a pre-pandemic baseline and are read against the post-2019 scholarship captured within the same review (see the contextualization paragraphs below). Studies were excluded if they were non-peer-reviewed, non-English, or outside the specified time window; conference proceedings, book chapters, and grey literature were also excluded. Screening followed three sequential stages: (i) duplicate removal across the four databases; (ii) title and abstract screening against the inclusion criteria; and (iii) full-text eligibility assessment against the relevance and quality criteria specified below.

The SLR funnel is summarized in Figure 1: 3274 records were identified across the four databases; after removal of 884 duplicates, 2390 records were screened by title and abstract; 177 full-text articles were assessed for eligibility, with citation-chain tracking expanding the comprehensive reviewed pool to 187 sources; and 32 key papers were selected for in-depth synthesis against four quality criteria: (i) clarity of research design; (ii) explicit treatment of ELP; (iii) reported empirical findings; and (iv) relevance to LSP-focused operations. Although 32 studies form the focal synthesis set, all 177 full-text articles contributed to the conceptual mapping, taxonomy development, and identification of recurrent constructs reported in this section.

The synthesis reveals a notable gap: although individual studies examine selected practices, few assess environmental performance and implementation barriers across multiple logistics domains within a single research context. Table 1 summarizes current domain-specific research coverage.

The eight logistics domains were identified from the present synthesis and represent the recurrent functional categories used to organize environmental practices in LSP-focused studies: transportation, warehousing/handling equipment, packaging, inventory management, internal management, customer engagement, supplier engagement, and reverse logistics. This taxonomy captures (i) operational activities under direct LSP control and (ii) managerial/inter-organizational interfaces that shape environmental performance. Using these domains avoids treating sustainability as a single aggregated construct and enables domain-level comparison of adoption barriers and feasibility constraints in resource-constrained contexts. Table 1 summarizes evidence coverage by domain and highlights where practice-level adoption and performance impacts remain under-specified in developing and Southeast Asian settings.

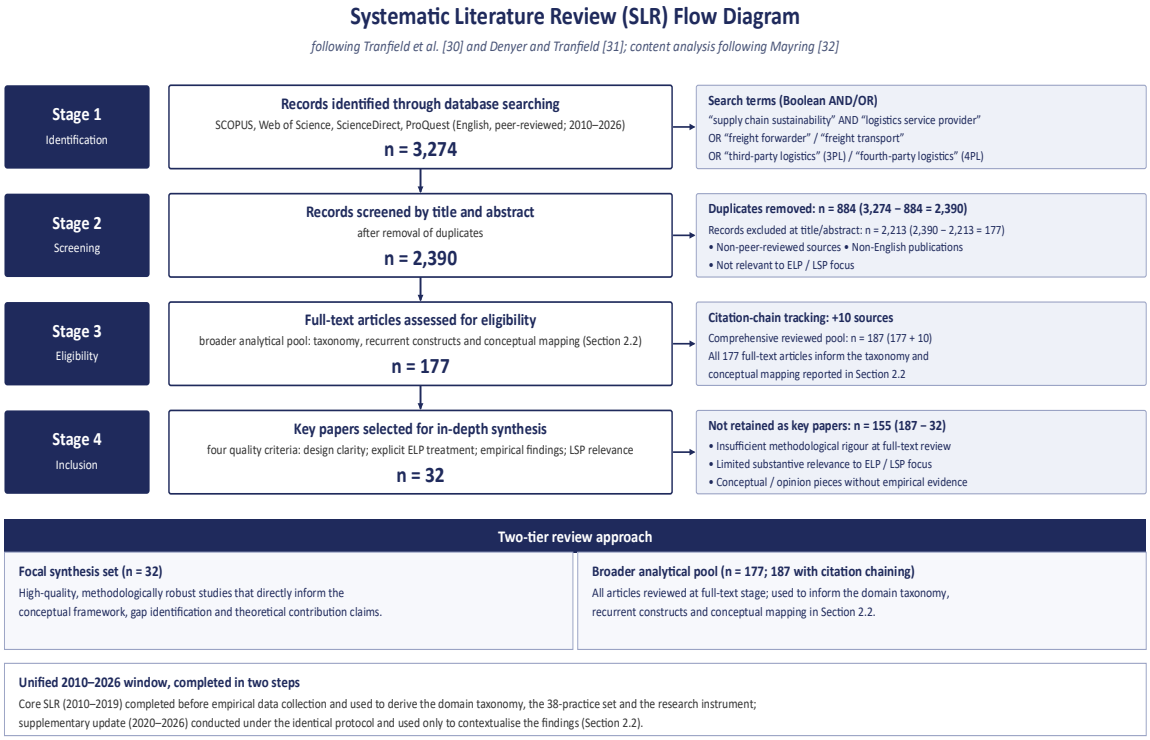

Figure 1. Systematic literature review (SLR) flow following [30,31], with content analysis following [32]: 3274 records identified (2010–2026); 884 duplicates removed; 2390 records screened by title and abstract; 177 full-text articles assessed for eligibility, expanded to a comprehensive reviewed pool of 187 sources through citation-chain tracking; and 32 key papers selected for in-depth synthesis. Source: Authors.

Table 1. Domain-specific research coverage in environmental logistics literature (2010–2019, with 2020–2026 update).

Logistics Domain	Developed Economy Studies	Developing Economy Studies	Key Gap
Transportation	Extensive [2,35]	Limited [19]	Limited practice-level adoption evidence for Southeast Asia; domain often treated as aggregate construct
Warehousing	Moderate [36–38]	Very Limited	Implementation barriers for specific technologies rarely examined in developing-economy LSPs
Packaging	Moderate [39]	Minimal [10]	Lack of systematic comparison across LSP types/firm sizes
Reverse Logistics	Extensive [40]	Limited [11]	Performance contribution and feasibility under resource constraints remain unclear
Inventory Management	Limited [37]	Very Limited	Environmental implications and practice options are under-specified
Internal Management	Moderate [41]	Minimal	Internal practices typically not disaggregated into measurable interventions
Customer Engagement	Moderate [42]	Limited	Environmental performance effects of customer-facing practices rarely measured in emerging markets
Supplier Engagement	Extensive [43]	Limited [44]	Effectiveness of supplier-related practices remains under-evidenced in Southeast Asia

While transportation and supplier engagement are extensively examined in developed economies, domain-specific evidence in developing Asian contexts remains limited. Few studies assess all major logistics functions within a single framework, constraining cross-domain comparison of implementation constraints and performance implications in resource-constrained contexts.

Much of the literature relies on aggregated "green" constructs or focuses on large-scale logistics in developed economies [23,45], offering limited practice-level guidance for LSPs seeking to prioritise scarce resources. Ref. [12] shows that much of this literature treats green initiatives at the level of broad categories rather than individual practices, and comprehensive multi-domain evidence from developing economies remains scarce. Although recent large-

sample studies have begun to examine multiple green practice areas among third-party logistics providers [45], practice-level, domain-comparative evidence from emerging Southeast Asian markets remains scarce. These gaps justify a domain-specific, practice-level investigation in Thailand.

Within the unified 2010–2026 review, the post-2019 literature places the gaps identified above in their current context. Post-SLR developments reinforce rather than invalidate these gaps. The COVID-19 pandemic accelerates digital transformation in supply chains and renews attention to green supply chain management, although the extent to which firms in emerging economies can act on this depends on their supply chain capabilities [46]. ESG reporting mandates have expanded across ASEAN, with the Stock Exchange of Thailand launching its SET ESG Index in 2023 and mandatory climate disclosure frameworks gaining traction regionally [47]. Within Thailand, recent large-sample evidence from the automotive sector likewise indicates that financial ability and government policy are key determinants of green logistics effectiveness [11], although LSP-focused, practice-level evidence remains limited.

Recent bibliometric evidence confirms that practice-level, domain-specific assessment remains scarce: Ref. [20] document continuing fragmentation in how green logistics practices are conceptualized and measured, and Ref. [48] identify digital transformation and net-zero targets as reshaping research priorities without yet producing the disaggregated emerging-market evidence this study provides. Similarly, synthesising over two thousand studies on sustainable green logistics and remanufacturing, Ref. [49] identify adoption drivers and barriers as a distinct research cluster and call for further context-specific evidence, and barrier-focused analyses of green and reverse logistics continue to highlight financial and infrastructure constraints as priority solution areas [50]. These post-2019 trends, particularly the widening gap between ESG aspirations and SME implementation capacity, strengthen the relevance of the present investigation.

Most recently, Ref. [19] demonstrate that internal capabilities and digital transformation, rather than external pressures alone, drive green logistics adoption among Vietnamese SMEs, reinforcing the analytical relevance of an emerging-market, capability-focused lens for the present study.

The persistence of these patterns across the post-2019 portion of the unified review window indicates that the recognition–implementation gap (RIG) identified in the core 2010–2019 SLR is not an artefact of pre-pandemic conditions but a structural feature of emerging-market sustainable logistics.

Post-pandemic evidence indicates that the COVID-19 disruption has not alleviated, financial and capability constraints on environmental practice implementation: Ref. [51] document how supply chain firms refocused on short-term economic decisions at the expense of sustainability commitments during the pandemic, whilst Ref. [46] show that, in emerging economies, translating post-pandemic digital transformation into green supply chain management depends on firms' supply chain capabilities. These post-2019 dynamics underscore the need for the domain-specific, practice-level assessment that this study undertakes.

2.3. Theoretical Framework

While Circular Economy principles [52] provide a normative framing for desired outcomes, an explanatory lens is required to account for why LSPs adopt (or do not adopt) specific ELP. Alternative perspectives are informative but address different mechanisms: institutional approaches emphasize legitimacy-seeking and compliance pressures, whereas capability-oriented perspectives emphasize internal resources and implementation capacity. These mechanisms are often complementary in sustainability management research [17].

This study draws principally on the Triple Bottom Line framework [18] as the organizing lens for sustainability assessment, classifying ELP according to their economic, social, and environmental implications. Stakeholder considerations enter the analysis as a complementary perspective for interpreting adoption drivers: prior research indicates that customers, regulators, and competitors exert differential pressures on firms, including LSPs, to adopt environmental practices [29,42,53], with customer demand frequently identified as the primary driver in supply-chain sustainability research. Evidence on the shipper–LSP interface further shows that green demands are not always matched by willingness to share implementation costs and risks, so that recognized requirements do not automatically translate into purchased or implemented practices [54], whilst organizational and regulatory stakeholder pressures have been shown to shape both green logistics practices and financial outcomes [28]. In emerging markets, however, resource constraints and institutional voids may limit organizational responses even when external demands are recognized [16,17]. Together, these perspectives motivate the study's focus on the RIG and the structural constraints that shape adoption decisions in resource-constrained settings.

Each perspective is operationalized directly in the research instrument: the Triple Bottom Line lens informs the classification of the 38 practices and the sustainability–competitiveness items (Appendix A.3); the stakeholder perspective is operationalized through the adoption-driver items capturing customer, regulatory, and competitive

pressures; and the structural-constraint lens is operationalized through the four barrier categories (financial, capability, coordination, and institutional) used in both the interview template and the questionnaire (Sections 3.3 and 3.4).

Figure 2 integrates these perspectives into the theoretical model underpinning the RIG assessment framework. Within the Triple Bottom Line organizing lens, external stakeholder drivers shape the recognition of ELP importance, while the translation of recognition into implementation is moderated by four structural constraints: financial capacity, capability and knowledge gaps, inter-organizational coordination challenges, and weak institutional support. The RIG is defined at the practice level as the difference between the proportion of the expert panel recognizing a practice as essential to firm performance and the proportion of company-affiliated respondents reporting its adoption, assessed across 38 practices in eight logistics domains.

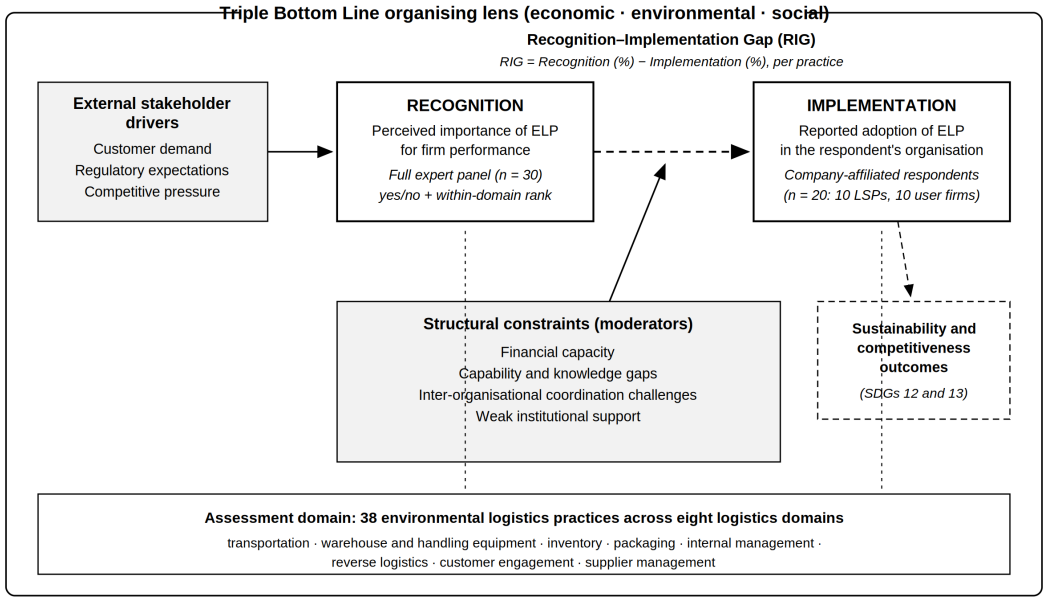

Figure 2. Theoretical model of the Recognition–Implementation Gap (RIG) assessment framework of environmental logistics practices. ELP = Environmental Logistics Practice; LSP = Logistics Service Provider; SDG = Sustainable Development Goal. Source: Authors.

2.4. Research Gaps

The literature reviewed in Sections 2.1–2.3 reveals four gaps that this study addresses.

First, much ELP research relies on aggregated "green" constructs, providing limited practice-level evidence to guide prioritization in resource-constrained settings [12,13].

Second, evidence is uneven across logistics functions, and few studies assess multiple domains within a single framework, limiting cross-domain comparison of implementation constraints and performance implications [12,23].

Third, developing Asian contexts, particularly SMEs remain underrepresented, and existing studies seldom integrate Triple Bottom Line and stakeholder perspectives to interpret why recognized practices are not implemented, constraining the transferability of findings from developed economies [10,15,19].

Fourth, the empirical relationship between practice recognition and implementation in resource-constrained logistics settings remains under-specified, with capability and resource constraints potentially preventing adoption despite high perceived importance [17,46].

Addressing these gaps, this study provides a domain-specific, practice-level assessment of ELP among Thai LSPs and analyses RIG and their drivers through a Triple Bottom Line lens informed by stakeholder considerations and structural constraints.

3. Methodology

This section describes the research design, conceptual framework development, data collection, and data analysis procedures. The study employs a sequential exploratory mixed-method design comprising two phases: Phase 1—semi-structured interviews (qualitative, n = 9), conducted first to explore adoption motivations, contextual factors, and barriers; and Phase 2—a structured expert questionnaire (quantitative, n = 30), informed by Phase 1 insights and used to map practice-level adoption patterns across eight logistics domains [55]. Insights from the qualitative interviews informed the development and refinement of the structured assessment instrument

used in the subsequent quantitative phase. The conceptual framework development step is a preparatory component that specifies the logistics domains and practice definitions used to structure the interview protocol and to design the assessment instrument.

3.1. Research Design

This study employs a sequential exploratory mixed-method design that began with qualitative semi-structured interviews (Phase 1, n = 9), followed by a structured expert assessment questionnaire (Phase 2, n = 30), to examine ELP adoption among LSPs in Thailand. Insights from the qualitative interviews informed the development and refinement of the questionnaire instrument used in the quantitative phase [55]. This approach combines qualitative depth with quantitative breadth, supporting triangulation in emerging-market settings where formal documentation may be limited.

The qualitative phase (Phase 1) was conducted first to explore in depth the motivations, implementation processes, performance outcomes, barriers, and strategic considerations of LSPs regarding environmental practices. Findings from this phase informed the design and prioritization of items in the structured assessment instrument used in the subsequent quantitative phase. The quantitative phase (Phase 2) then assessed adoption rates, performance perceptions, and implementation barriers across 38 environmental practices, providing a practice-level baseline. Consistent with the chronological logic of the sequential exploratory design, the results are reported with the Phase 1 qualitative findings first (Section 4.1), to establish the contextual mechanisms shaping adoption decisions, followed by the Phase 2 quantitative findings (Section 4.2), which provide the practice-level adoption patterns; integrated cross-phase interpretation is then presented in Sections 4.3 and 4.4.

Unit of analysis and treatment of stakeholder categories. The principal unit of analysis in this study is one integrated multi-stakeholder expert panel comprising 30 logistics professionals in Phase 2 and nine interview informants in Phase 1. Although participants are categorized by stakeholder role (LSPs, user firms, and academics), these categories are used interpretively to enable cross-stakeholder triangulation rather than as independent sub-samples for statistical comparison. The three groups jointly inform a single integrated dataset, with stakeholder role serving as an analytical lens through which convergence and divergence of perspectives can be examined. This design choice is consistent with multi-stakeholder qualitative research traditions in which heterogeneous informants strengthen credibility through perspective triangulation rather than enabling between-group inference [56,57]. Accordingly, all reported findings refer to the integrated panel; sub-group means, where presented, are interpretive aids rather than the basis of any inferential claim.

3.2. Conceptual Framework Development

This subsection explains how the domain taxonomy and practice set were developed and operationalized for empirical measurement. It defines the logistics domains used to classify ELP and specifies how practices were identified, screened, and translated into measurable items for the Phase 1 interview guide and the Phase 2 expert assessment questionnaire. The conceptual framework ensures consistent classification and measurement across data sources.

3.2.1. Identification of Logistics Domains

Eight core logistics functional domains were identified through systematic literature review and expert consultation: (1) transportation management, (2) warehouse and handling equipment, (3) inventory management, (4) packaging management, (5) internal management, (6) reverse logistics, (7) customer engagement, and (8) supplier management. This framework synthesizes established logistics taxonomies [22,23] with recent environmental supply chain literature [13,28].

3.2.2. Practice Selection and Operationalization

Thirty-eight environmental practices were identified from the 2010–2019 portion of the SLR described in Section 2.2, which was completed prior to data collection; the subsequent 2020–2026 update of the review did not alter the practice set and is used for contextualization only. Practice selection prioritized specificity over aggregation to generate actionable domain-level guidance. Individual practices (e.g., vehicle routing optimization, eco-driving training, alternative fuel adoption) were assessed separately with clear operational definitions. For instance, "Use of fleet management software" was defined as "Systematic use of digital systems to monitor vehicle location, fuel consumption, maintenance schedules, and driver behavior for operational optimization and environmental performance improvement."

3.3. Data Collection

Data collection followed the sequential exploratory design over five months. The Phase 1 qualitative stage (semi-structured interviews) was conducted first to explore the meanings, motivations, and contextual factors associated with ELP adoption among logistics professionals—including why certain practices were prioritized, why implementation lagged despite high perceived importance, and how resource and coordination constraints shaped decision-making. Insights from these interviews provided contextual grounding for the structured expert assessment that followed, informing the interpretation of respondents' assessments and of the barrier categories. The Phase 2 quantitative stage (expert assessment questionnaire) followed, providing a practice-level baseline of adoption status, perceived performance contribution, and barriers across 38 practices, enabling identification of patterns by stakeholder group and logistics domain.

3.3.1. Phase 1: Interview Design and Sampling

Nine in-depth, semi-structured interviews, each lasting approximately 60–90 min, were conducted with LSPs (n = 5), user firms (n = 2), and academics (n = 2) to examine the drivers, barriers, and contextual factors shaping ELP adoption. The interview protocol was developed following established methodological frameworks for qualitative research [58] and comprised three sections: (1) general information about the company; (2) perceptions on the importance of the eight ELP areas, including reasons for those opinions, ratings of the most important practices, the strength of perceived relationships, and any additional practices considered relevant to the logistics industry; and (3) views on the relationship between sustainability, company competitiveness, and the logistics industry. The subsequent expert assessment employed the structured components of the same instrument as a self-completion questionnaire, with the interview insights providing contextual grounding for interpreting its results. The semi-structured format balanced consistency with flexibility to pursue emergent themes. The research instrument, which served both phases, is provided in condensed form in Appendix A.

The interview sample was deliberately weighted toward LSPs (n = 5) rather than balanced across groups, in line with the study's unit of analysis and its purposive sampling logic. As the research investigates ELP adoption among LSPs, this group constitutes the primary information-rich source: LSP managers hold the operational, financial, and strategic knowledge required to explain adoption decisions, recognition–implementation gaps (RIGs), and resource constraints from the inside. User firms (n = 2) and academic experts (n = 2) were included as triangulation sources, providing complementary demand-side and observer perspectives respectively, rather than as statistical samples of their own populations [56,57]. This composition reflects the principle of information power [59]: when the study aim is narrow, sample specificity high, and analysis cross-case, sample size requirements decrease. In this study, saturation was reached at different points for different stakeholder roles: LSPs required more interviews to capture the full range of operational and strategic considerations than the comparatively focused demand-side or observational perspectives of users and academics, consistent with the observation that the point of saturation depends on the homogeneity of the informant group [60]. Any imbalance in qualitative depth is offset by the Phase 2 expert assessment questionnaire, which uses a balanced three-group panel (10 LSPs/10 user firms/10 academics), ensuring that breadth of cross-perspective comparison is achieved at the quantitative stage [55].

Interview Sample Characteristics

Table 2 shows that the purposively selected sample captured organizational size variation (large corporations to SMEs), ownership diversity (Thai, joint venture, multinational), service scope differences, industry sectors, and geographic coverage.

Table 2. Interview sample characteristics (n = 9).

Code	Group	Role	Organization Type	Experience/Size
LI1	LSP	Region Manager	Large Thai-owned national provider	>100 years, 200+ employees
LI2	LSP	Board Director	Medium Thai company	>14 years, 150+ employees
LI3	LSP	Managing Director	Small Thai agricultural logistics	>40 years, 20–30 employees
LI4	LSP	Operations Manager	Large Thai-Japanese JV	>50 years, 200+ employees
LI5	LSP	Operations Manager	Large Thai-German multinational	25 years, 200+ employees
CI1	User Firm	Logistics Manager	Large multinational food/bev (Thai-American)	>20 years in Thailand (>150 years globally)
CI2	User Firm	Operations Manager	Medium Thai water production	>35 years, 100+ employees
AI1	Academic	Senior Lecturer	Public university	>10 years logistics/sustainability, UK PhD
AI2	Academic	Department Head	Public university	>20 years logistics/SCM, Thai PhD

Note: A = Academics/researchers; L = LSPs; C = Logistics User; "I" denotes the data collection method (Interview); the first number denotes the respondent's order. Codes are read in this order before consulting Table 2.

Interview Procedures

Interviews were conducted over five months in Thai. With consent, interviews were audio-recorded, professionally transcribed, and translated into English by the bilingual primary researcher. The expert assessment questionnaire and participant consent forms underwent a formal back-translation procedure following two-translator model [61]: instruments originally developed in English were translated into Thai by the researcher, then independently back-translated from Thai to English by two qualified bilingual translators with relevant disciplinary expertise. The back-translated versions were compared with the original English instruments to identify discrepancies and ensure semantic equivalence and cultural appropriateness for the Thai logistics context.

Data collection spanned five months, coinciding with the early emergence of COVID-19 in Thailand. The bulk of fieldwork was substantially completed before significant pandemic disruptions to Thai logistics operations, whilst a small number of interviews occurred during early pandemic restrictions. Participants were asked to report on established practices and adoption patterns rather than pandemic-specific responses, and interview analysis indicated no systematic differences between pre- and post-onset responses. Nevertheless, the findings should be interpreted as reflecting pre-pandemic adoption baselines, providing a stable empirical reference point against which the post-2019 literature within the unified review is compared. Subsequent research examining how pandemic disruptions may have accelerated or inhibited ELP adoption trajectories would complement the present findings.

3.3.2. Phase 2: Expert Assessment Questionnaire Design and Sampling

The structured components of the same three-part instrument used in Phase 1 (Appendix A) were administered to a purposively selected expert panel as a self-completion questionnaire, assessing: (1) organizational demographics; (2) adoption drivers, disincentives, and perceived financial benefits; (3) a practice-specific assessment of the 38 practices—whether each practice is essential to increasing firm performance (yes/no), a within-domain ranking of each practice's involvement in increasing company performance, and current adoption status (yes/no); and (4) sustainability and competitiveness perspectives. Consistent with the role-adapted academic version of the instrument (Appendix A), the current-adoption items were administered only to company-affiliated respondents (LSPs and user firms; n = 20), as academic participants are not positioned to report first-hand on organizational practice use; all other assessment items were completed by the full panel (n = 30), as shown in Table 3. The instrument underwent expert review (five academics), pilot testing (five professionals), and refinement based on feedback.

Sampling Strategy and Sample Characteristics

Thirty valid responses were obtained through purposive sampling of logistics professionals meeting criteria: (1) current employment in logistics service provider, user firm, or academic institution; (2) minimum three years professional experience; (3) direct knowledge of environmental sustainability initiatives; and (4) informed consent.

Rationale for the three stakeholder categories. The three stakeholder categories were not designed to support between-group statistical inference, given the small size of each sub-group (n = 10 per category). Rather, they were structured to enable cross-stakeholder triangulation: LSPs supply first-hand operational and strategic insight into adoption decisions; user firms provide the demand-side perspective on environmental expectations imposed on LSPs; and academics offer an external, theoretically informed observer view. Convergence across these vantage points strengthens analytical credibility, whilst divergence highlights areas requiring contextual interpretation [56,62]. Quantitative analysis, therefore, treats the 30 responses as a single integrated expert panel and reports descriptive statistics at the panel level. Where sub-group patterns are mentioned, they are presented for interpretive contextualization only and are not treated as independent samples for inferential testing.

Table 3. Expert panel composition by stakeholder group (n = 30).

Stakeholder Group	n	Sub-Groups/Characteristics	Key Characteristics
Logistics Service Providers (LSPs)	10	Large multinationals (3); medium Thai enterprises (3); small local operators (4)	Diverse ownership; services include freight transportation, warehousing, 3PL, customs brokerage
Logistics User Firms	10	Firms procuring logistics services across multiple industries; range from small domestic manufacturers to large multinationals	Industries: food/beverage, electronics, chemicals, medical equipment, retail
Academics/Researchers	10	Faculty and doctoral researchers from Thai universities specializing in logistics, SCM, and sustainability	All hold PhDs; specialization in logistics, SCM and sustainability; active industry engagement.

Note: Total sample n = 30 across three stakeholder groups. LSP = logistics service provider; 3PL = third-party logistics; SCM = supply chain management.

Recruitment commenced with the identification of a senior logistics expert as the initial point of contact, introduced through the president of a Thai logistics industry association. This expert assisted in compiling a list of potential participants at the executive management level. Snowball sampling was then used to recruit thirty participants, a panel size consistent with expert-based sustainability research in emerging Asian markets [10,15].

Sample Size Justification

The sample sizes (n = 9 semi-structured interviews; n = 30 expert assessments) were guided by established qualitative research principles, where data saturation determines adequacy rather than predetermined statistical thresholds [63]. Ref. [63] notes that 5 to 50 participants can achieve theoretical saturation depending on research scope and complexity. Comparable expert-based studies in emerging Asian markets report similar or smaller panels: Ref. [15] drew on five senior executives of multinational third-party logistics providers in China, and Ref. [10] used a five-expert panel to structure barriers to green supply chain initiatives in Thailand. The balanced three-group expert composition (10 LSPs, 10 user firms, 10 academics) constitutes a structured multi-stakeholder panel enabling systematic cross-perspective comparison, whilst the qualitative interviews (n = 9) provide contextual depth [55].

The figure of n = 30 represents the size of the integrated expert panel for descriptive analysis, not three separate samples of n = 10 used for between-group statistical comparison. The study therefore, does not claim statistical generalizability or perform inferential testing across sub-groups; instead, it offers practice-level descriptive evidence enriched by explanatory triangulation, with the inferential limitations of small sub-groups openly acknowledged in Section 5 (Limitations).

Questionnaire Design and Linkage to Research Questions

The structured assessment instrument was designed to operationalize the three research questions in a transparent, item-level manner, with each section of the questionnaire mapped explicitly to one or more research questions. Section A (organizational demographics) provided the contextual variables used to interpret heterogeneity in adoption patterns. Section B (practice-specific assessment) addressed RQ1 by capturing self-reported adoption status across the 38 practices, and addressed RQ2 by recording whether each practice was perceived as essential to increasing firm performance, together with its within-domain rank, thereby enabling identification of recognition–implementation gaps. Section C (adoption drivers and motivations) addressed RQ3 by eliciting respondents' views on stakeholder pressure, customer demands, regulatory expectations, and cost considerations. Section D (barrier assessment and sustainability perspectives) further addressed RQ3 by capturing reported financial, capability, coordination, and institutional constraints. The interview protocol mirrored this architecture, ensuring that qualitative data could be triangulated with quantitative items at the level of individual research questions. Table 4 summarizes this mapping.

Table 4. Mapping of questionnaire instrument and interview protocol items to the three research questions.

Research Question	Focus of the Question	Questionnaire Section/Item Type	Interview Prompt
RQ1: Adoption levels	Extent of LSP adoption of ELP across the eight functional logistics domains, and identification of higher- versus lower-implementation domains.	Section B (Practice-specific assessment): self-reported adoption status (yes/no) for each of 38 practices.	Section 2: which ELP areas does your firm currently practice, and at what level?
RQ2: Performance perceptions and recognition–implementation gaps	Performance outcomes that practitioners associate with specific practices, and the gap between perceived performance importance and actual implementation.	Section B: essential-to-performance assessment (yes/no) and within-domain ranking for each of 38 practices, paired with current adoption status to compute the recognition–implementation gap.	Section 2: which practices are most important and why; perceived strength of links to firm performance.
RQ3: Drivers and constraints	Stakeholder drivers and structural constraints (financial, capability, coordination, institutional) that shape ELP adoption in resource-constrained contexts.	Section C (Adoption drivers): customer, regulatory, cost, and competitive pressures. Section D (Barriers and sustainability perspectives): financial, capability, coordination, and institutional barriers.	Section 3: relationship between sustainability, competitiveness, and constraints faced when implementing ELP.

Note: This mapping demonstrates that each research question is supported by both quantitative and qualitative evidence streams, supporting analytical convergence and reducing single-method bias.

3.4. Data Analysis

Data analysis followed the sequential exploratory logic. The qualitative interview data were analyzed first to identify themes relating to motivations, barriers, and contextual factors influencing ELP adoption. These thematic insights informed the design and analytic priorities of the subsequent expert assessment questionnaire, which then enabled identification of domain-level and practice-level patterns (e.g., high-importance but low-adoption practices, and domains with the largest recognition–implementation gaps). The two datasets were then integrated through triangulation to assess convergence, complementarity, and expansion [55], with the qualitative themes used to explain the adoption patterns observed in the quantitative data.

3.4.1. Phase 1: Qualitative Data Analysis

Interview data were analyzed using systematic comparative analysis to explain and contextualize the Phase 2 expert assessment questionnaire. A priori coding categories reflected the assessment instrument structure (practice, domain, perceived importance, adoption status, and reported barriers), with inductive codes added for emergent themes. LSP findings were compared with user firm and academic perspectives to identify convergent and divergent viewpoints. Interview findings were triangulated with expert assessment questionnaire results, where respondents assessed whether each of 38 practices was essential for performance enhancement.

Step-by-step coding procedure. The qualitative analysis followed a transparent six-step coding procedure that combined template analysis with inductive thematic analysis [64,65].

Step 1 (familiarization): all interview transcripts were read in full to develop holistic familiarity with the dataset and to record initial analytic memos.

Step 2 (a priori code list): an initial codebook was constructed from the assessment instrument, encompassing the 38 environmental practices, the eight logistics domains, perceived importance, adoption status, and the four pre-defined barrier categories (financial, capability, coordination, and institutional). These categories were drawn from the literature as a sensitizing template rather than treated as exhaustive; they were subsequently refined, differentiated, and substantiated through the inductive coding in Step 4, which also produced emergent codes that were not part of the four pre-defined categories for example, inter-organizational trust deficits, symbolic versus substantive adoption, and Bangkok–regional infrastructure disparities. The barrier typology reported in Section 5 is therefore literature-informed and empirically substantiated, rather than purely inductive.

Step 3 (line-by-line coding): each transcript was coded sentence by sentence, with quotations assigned to one or more a priori codes and source-stakeholder labels (LSP, user firm, or academic) attached to enable later interpretive comparison.

Step 4 (inductive coding): emergent themes that did not fit the a priori scheme—such as inter-organizational trust deficits, symbolic versus substantive adoption, and Bangkok–regional infrastructure disparities—were captured as new inductive codes and incorporated into the codebook.

Step 5 (cross-stakeholder comparison): coded segments were grouped by stakeholder role to identify convergence and divergence among LSP, user firm, and academic perspectives; this comparison was conducted interpretively to enrich understanding rather than as a basis for statistical contrast.

Step 6 (theme consolidation): codes were aggregated into the five higher-order themes reported in Section 4.1, namely stakeholder-driven motivations, financial constraints, knowledge gaps, coordination challenges, and the institutional environment. To enhance trustworthiness, an audit trail of coding decisions was maintained, illustrative quotations were retained for each theme to support transparency, and emerging interpretations were cross-checked against the Phase 2 quantitative patterns to support meta-inference [55].

3.4.2. Phase 2: Quantitative Data Analysis

Expert assessment questionnaire data were analyzed using descriptive statistics to identify: (1) adoption rates; (2) performance recognition rates (the percentage of respondents assessing each practice as essential to firm performance) and mean within-domain ranks; (3) recognition–implementation gaps (RIGs); and (4) domain-level aggregations. Measurement basis of the RIG: for each of the 38 practices, recognition and implementation were elicited as binary (yes/no) items at the respondent level; the recognition and implementation rates reported in this study are the aggregated proportions of affirmative responses to these items, expressed as percentages ranging from 0 to 100%. For each practice, the recognition rate is the percentage of the full expert panel (n = 30) assessing the practice as essential to increasing firm performance, and the implementation rate is the percentage of company-affiliated respondents (n = 20; 10 LSPs and 10 user firms) reporting that their organization currently adopts the practice. The recognition–implementation gap for each practice is computed descriptively as the recognition rate minus the implementation rate. Because both components are proportions of yes/no responses on the same practice

set and response format, the RIG which can in principle range from −100 to +100 percentage points is interpreted as a descriptive discrepancy indicator between panel-level recognition and firm-reported adoption, not as a psychometrically scaled construct, and the two denominators are stated explicitly in this section, in the title and note of Table 5, and in the introduction to Section 4.2, so that all reported comparisons of the two rates can be traced to their respective response bases. Implementation rates are reported as the count of adopting organizations over the 20 company-affiliated respondents (x/20); with this response base each respondent corresponds to 5 percentage points, so implementation rates take values in multiples of 5, and differences of less than 10 percentage points between practices or domains are not considered significant. Drawing on established consensus measurement principles—where Ref. [66] identify 75% as the median consensus threshold across Delphi studies, and Ref. [67] show that expert consensus consolidates once group agreement exceeds 75%—this study applied a stricter ≥90% agreement threshold, substantially higher than the 51–80% range typical of comparable consensus research [68–70], to identify high-impact ELP deemed essential for enhancing firm performance. The ≥90% criterion was applied as two nested conditions. First, any individual practice with a recognition rate below 90% was excluded regardless of its domain; this removed seven practices in otherwise-retained domains (TM-6, TM-9, TM-10, TM-11, WH-5, INT-5 and INT-6). Second, a domain whose mean recognition rate across all its practices fell below 90% was excluded in its entirety, so that isolated practices without broad domain-level support were not carried forward; this removed inventory management (82%), supplier management (81%), and reverse logistics (89%) including two of its practices (RL-1, 97%; RL-4, 93%) that individually exceeded the threshold. Applying both conditions yields 20 high-impact ELP across five domains: transportation (7), warehouse and handling equipment (4), packaging (4), internal management (4), and customer cooperation (1). Given the exploratory nature and modest sample (n = 30), analysis focused on descriptive patterns explained through qualitative triangulation rather than inferential testing.

Table 5. Performance ratings and adoption rates of environmental logistics practices (performance ratings: n = 30; implementation rates: n = 20, reported as adopting organizations/20), with mean within-domain ranks and standard deviations.

Logistics Domain/Practice	Mean Rank	SD	Performance Rating (%)	Implementation Rate (%) (x/20)	RIG (pp)	Classification
1. Transportation Management						
TM-1: Use of fleet management software	2.33	2.4097	85 (17/20)	12	✓	
TM-2: Vehicle routing optimization	2.50	1.38100	90 (18/20)	10	✓	
TM-3: Time-slot scheduling for loading/unloading	4.20	3.5293	90 (18/20)	3	✓	
TM-4: Design of vehicle renewal plan	4.60	3.4693	85 (17/20)	8	✓	
TM-5: Effective shipment consolidation and full vehicle loading	5.37	4.2597	90 (18/20)	7	✓	
TM-6: Shared shipments with non-competing companies	6.27	3.5687	45 (9/20)	42	✗	
TM-7: Promoting eco-driving	6.27	3.9397	85 (17/20)	12	✓	
TM-8: Alternative energy and vehicle technology	6.43	3.69100	75 (15/20)	25	✓	
TM-9: Modal shift (road to rail/water)	7.13	3.6087	60 (12/20)	27	✗	
TM-10: Tracking load units using RFID	7.17	3.7183	50 (10/20)	33	✗	
TM-11: Shared shipments with competing companies	9.03	4.3683	30 (6/20)	53	✗	
Domain Average			92	71	21	✓
2. Warehouse and Handling Equipment						
WH-1: Warehouse staff trained in energy efficiency	2.37	1.40100	90 (18/20)	10	✓	
WH-2: Energy-efficient material handling equipment	2.47	1.41100	95 (19/20)	5	✓	
WH-3: Warehouse Management System (WMS) implementation	2.50	1.57100	80 (16/20)	20	✓	
WH-4: Efficient land use planning	3.07	1.82100	95 (19/20)	5	✓	
WH-5: Eco-friendly building design	3.60	1.4887	55 (11/20)	32	✗	
Domain Average			97	83	14	✓
3. Inventory Management						
IM-1: Sale of used and scrap materials	1.73	0.7987	75 (15/20)	12	✗	
IM-2: Sale of excess inventories/materials	2.03	0.8180	65 (13/20)	15	✗	
IM-3: Sale of excess capital equipment	2.47	0.8280	55 (11/20)	25	✗	
Domain Average			82	65	17	✗
4. Packaging Management						
PK-1: Sustainable packaging material selection	1.97	1.0393	75 (15/20)	18	✓	
PK-2: Eco-friendly packaging design	2.40	1.1093	55 (11/20)	38	✓	
PK-3: Packaging life cycle assessment	2.60	1.0793	65 (13/20)	28	✓	
PK-4: Reducing packaging volume/weight	2.77	1.1090	70 (14/20)	20	✓	
Domain Average			92	66	26	✓
5. Internal Management						
INT-1: Staff trained in energy efficiency	2.63	1.6197	100 (20/20)	-3	✓	
INT-2: Environmental policy development	2.93	1.7497	85 (17/20)	12	✓	
INT-3: Use of green IT systems	3.17	1.6690	75 (15/20)	15	✓	

Table 5. *Cont.*

INT-4: Internal cross-functional collaboration	3.17	1.46100	90 (18/20)	10	✓
INT-5: Environmental Management Systems	3.20	1.8387	75 (15/20)	12	✗
INT-6: Senior management commitment to sustainability	3.47	1.8387	80 (16/20)	7	✗
Domain Average		93	84	9	✓
6. Reverse Logistics					
RL-1: Reduction of consumption whenever possible	1.90	0.9997	95 (19/20)	2	✗
RL-2: Materials recycled whenever possible	2.20	1.0983	70 (14/20)	13	✗
RL-3: Optimized waste transport and disposal	2.53	1.2283	80 (16/20)	3	✗
RL-4: Materials reused whenever possible	2.53	1.0793	80 (16/20)	13	✗
Domain Average		89	81	8	✗
7. Customer Management					
CM-1: Cooperation with customers on environmental objectives	n/a	n/a 90	85 (17/20)	5	✓
Domain Average		90	85	5	✓
8. Supplier Management					
SM-1: Purchase of environmentally friendly material	2.00	1.0880	75 (15/20)	5	✗
SM-2: Cooperation with suppliers on environmental objectives	2.10	1.1683	70 (14/20)	13	✗
SM-3: Supplier selection criteria	2.47	1.0480	75 (15/20)	5	✗
SM-4: Environmental audits for suppliers' internal management	2.80	1.0080	70 (14/20)	10	✗
Domain Average		81	73	8	✗

Note: Performance Rating = percentage of respondents assessing the practice as essential to increasing firm performance; Performance Rating: n = 30 (full expert panel); Implementation Rate = adopting organizations as a percentage of the 20 company-affiliated respondents (10 LSPs and 10 user firms), shown with the underlying count (x/20); adoption items were not administered to academic participants, who are not affiliated with an operating company and therefore cannot report first-hand on organizational practice use (see Section 3.3.2), so the valid response base for these items is 20 in every case. RIG = Performance Rating minus Implementation Rate, in percentage points; a negative value indicates adoption exceeding recognition. Domain-average percentages are pooled across the practices listed (total yes-responses ÷ total responses); domain-average RIG is the mean of practice-level RIGs. ✓ = high-impact ELP (practice recognition ≥ 90% and domain mean recognition ≥ 90%); ✗ = criterion not met at practice or domain level. Mean rank and SD = mean and standard deviation of respondents' within-domain ranking of each practice's involvement in increasing company performance (1 = greatest involvement; lower means indicate greater perceived involvement); n/a = ranking not applicable to the single-practice customer domain.

3.4.3. Mixed-Method Integration and Triangulation

Quantitative and qualitative findings were integrated through three strategies [55]:

- Convergence assessment: high-performance recognition but lower adoption of capital-intensive practices converged with interview findings on financial barriers, strengthening confidence in both datasets.
- Complementarity analysis: low adoption of collaborative practices despite moderate-high recognition was explained through stakeholder perspectives identifying trust deficits, coordination complexity, and power asymmetries not captured quantitatively.
- Expansion investigation: revealed implementation considerations beyond quantitative measurement, including symbolic versus substantive adoption and strategic sequencing based on resources.

Integration is presented in Section 4.3 through side-by-side comparison of quantitative metrics and qualitative insights.

Throughout this integration, the three stakeholder categories function as triangulation lenses rather than as independent statistical samples. Convergence among LSP, user firm, and academic accounts is interpreted as evidence of a shared phenomenon, whilst divergence is treated as a prompt for deeper contextual interpretation. The integrated meta-inferences reported in Section 4.3 therefore arise from the combined evidence of one multi-stakeholder expert panel, not from inferential comparisons between sub-groups.

3.4.4. Validity and Reliability Considerations

Multiple strategies enhanced validity: (1) Construct validity through literature-grounded definitions and 90% stakeholder agreement threshold; (2) Internal validity through triangulation across data sources, respondent types, and organizational profiles; (3) External validity through thick description enabling transferability assessment—while statistical generalization is limited, analytical generalization to theory remains robust; (4) Reliability through systematic documentation, standardized instruments, and triangulation; (5) Reflexivity through managing the researcher's dual positionality as Thai logistics professional with Western academic training.

4. Results

This section presents findings from the mixed-method investigation of ELP adoption in Thailand's logistics sector. Consistent with the chronological logic of the sequential exploratory design (Section 3.1), the Phase 1 interview findings are presented first (Section 4.1) to establish the explanatory mechanisms and contextual constraints shaping adoption decisions, followed by the Phase 2 expert assessment questionnaire findings (Section 4.2), which provide the practice-level adoption baseline; integrated interpretation is then provided (Sections 4.3 and 4.4). This structure follows established mixed-method reporting conventions [55].

4.1. Phase 1: Interview Findings (Qualitative)

Nine semi-structured interviews with LSPs (n = 5), logistics user firms (n = 2), and academic experts (n = 2) provided contextual explanations for ELP adoption decisions across the 38 assessed practices, with particular attention to the 20 high-impact ELP (as defined in Section 3.4.2 and reported in detail in Section 4.2). Comparative analysis across stakeholder groups identified five drivers and constraints shaping adoption: (1) stakeholder-driven motivations, (2) financial and resource constraints, (3) knowledge and capability gaps, (4) inter-organizational coordination challenges, and (5) institutional and policy limitations. Illustrative interview evidence is presented below.

4.1.1. Stakeholder-Driven Motivations

Customer pressure emerged as the primary driver for ELP adoption. As one LSP manager noted: "Our major clients now require ISO 14001 certification. Without it, we lose contracts" (LSP-2). Cost reduction through fuel efficiency and waste minimization also motivates adoption, though participants emphasized that environmental benefits remain secondary to economic imperatives in resource-constrained contexts. User firms confirmed this pressure dynamic from the demand side. As one logistics manager explained: "We include environmental criteria in our LSP selection because our own customers, major retailers, now audit our supply chain sustainability. The pressure cascades downstream" (CI1). Regulatory pressure was cited less frequently than customer demands, with participants describing government enforcement as "inconsistent and easily circumvented" (AI2).

4.1.2. Financial Constraints

High upfront investment costs constitute the most significant adoption barrier. An LSP manager explained: "Converting to electric vehicles costs significantly more than diesel trucks. The payback period is too long for SMEs operating on thin margins" (LSP-1). SMEs face particularly severe constraints, lacking access to green financing mechanisms available to larger corporations. As one SME representative stated: "We want to adopt solar panels, but banks won't finance environmental upgrades without government guarantees" (LSP-3). Even larger firms with greater financial capacity face competing investment priorities. One operations manager noted: "Environmental investments compete with fleet expansion, warehouse automation, and IT systems. When budgets are limited, revenue-generating investments take precedence over cost-saving environmental initiatives with uncertain payback" (LI4). This opportunity cost dynamic affects organizations across size categories, though SMEs experience more acute constraints due to limited access to capital markets.

4.1.3. Knowledge Gaps

Technical expertise deficits constrain implementation. One manager noted: "We lack in-house capability to conduct lifecycle assessments or calculate carbon footprints. External consultants are prohibitively expensive" (LSP-4). Training needs extend beyond technical skills to include change management and stakeholder engagement capabilities. Academic participants highlighted systemic knowledge transfer failures. As one senior lecturer observed: "Universities produce research on sustainable logistics, but dissemination to industry—especially SMEs—remains weak. There is no effective bridge between academic knowledge and practitioner application" (AI1). This disconnect perpetuates capability gaps despite growing awareness of environmental imperatives among logistics professionals.

4.1.4. Coordination Challenges

Inter-organizational coordination difficulties impede collaborative practices. Supply chain fragmentation limits supplier engagement: "Many of our suppliers are small informal operations. They lack resources and motivation to meet our environmental requirements" (User-1). Customer cooperation remains inconsistent: "Some customers refuse packaging changes that increase costs, even marginally. Price sensitivity trumps sustainability"

(LSP-2). Collaborative practices such as shared shipments face additional trust barriers. One manager explained: "We explored shipment sharing with a non-competing company, but concerns about service reliability, data confidentiality, and liability allocation prevented agreement. Neither party was willing to compromise operational control" (LI2). These coordination failures reflect broader trust deficits in Thailand's fragmented logistics sector, where informal relationships often substitute for contractual governance mechanisms.

4.1.5. Institutional Environment

Weak institutional support constrains adoption. Whilst government incentive programs exist, accessibility remains limited: "Current tax incentives for green vehicles are insufficient. We need substantially higher subsidies to make business sense" (LSP-3). Infrastructure gaps, particularly charging stations for electric vehicles and recycling facilities for packaging materials, further limit implementation. However, participants acknowledged gradual improvements in regulatory enforcement and stakeholder awareness. Geographic disparities compound institutional weaknesses. Participants noted that supporting infrastructure concentrates in Bangkok, leaving regional operators without viable alternatives. "In Bangkok, we can find EV charging stations and recycling partners. In the provinces, nothing exists—we cannot implement practices that require infrastructure we don't have access to" (LI1). This urban–rural divide creates systematic adoption barriers for logistics operations serving Thailand's broader geography.

4.2. Phase 2: Expert Assessment Questionnaire Findings (Quantitative)

Building on the contextual mechanisms established in Phase 1, this section presents the quantitative practice-level adoption patterns observed in the expert assessment questionnaire (n = 30). Table 5 presents adoption rates and performance ratings across eight logistics domains. Key patterns include: (1) high recognition (90–97%) but incomplete implementation (domain average: 66–85%) across the five high-impact domains; (2) packaging and transportation exhibit the largest domain-level gaps (92% vs. 66%, 26 percentage points; 92% vs. 71%, 21 points); (3) collaborative and capital-intensive practices record the lowest implementation—shared shipments with competing (30%) and non-competing companies (45%), RFID load tracking (50%), eco-friendly building design (55%) and eco-friendly packaging design (55%); and (4) practices under direct organizational control approach full implementation—staff training in energy efficiency (100%), energy-efficient handling equipment and efficient land use (95% each)—giving internal management the narrowest domain-level gap among the high-impact domains (9 points). Performance-rating percentages reflect the full 30-respondent expert panel, whereas implementation percentages reflect the 20 company-affiliated respondents (10 LSPs and 10 user firms) to whom the adoption items were administered (Section 3.4.2). Accordingly, the reported gaps are interpreted as discrepancies between panel-level recognition and firm-reported adoption that are indicative of sector-level adoption patterns, rather than as directly measured adoption gaps within a probabilistic sample of LSPs. Alongside these proportions, Table 5 reports the mean within-domain rank and its standard deviation (SD) that respondents assigned to each practice's involvement in increasing company performance (lower mean ranks indicate greater perceived involvement), providing a dispersion measure for the panel's practice-level assessments; figures should be interpreted as descriptive panel-level patterns rather than as inferential estimates derived from between-group comparisons across LSPs, user firms, and academics.

Table 5 presents 38 practices evaluated across eight logistics domains; applying the two nested ≥90% conditions described in Section 3.4.2, 20 practices (52.6%) were classified as high-impact ELP. Across these 20 practices, implementation averaged 83% (range 55–100%) and the RIG averaged 13 percentage points (range −3 to 38). These 20 practices span five core domains: transportation (7), warehouse and handling equipment (4), packaging (4), internal management (4), and customer cooperation (1).

4.3. Integrated Analysis: Domain-Specific Adoption Patterns

Triangulation of quantitative and qualitative findings illuminates domain-specific adoption dynamics and explanatory mechanisms.

Transportation Management exhibits the second-widest domain-level gap (92% vs. 71%). Within the domain, the gap is concentrated in the most capital-intensive practice: alternative energy and vehicle technology is recognized by every respondent yet adopted by 75%, the widest gap (25 percentage points) among the high-impact transportation practices, consistent with the financial constraints articulated by LSP-1 ("We simply cannot finance that investment") and the price premiums participants reported. Lower-capital practices—fleet management software, eco-driving and vehicle-renewal planning (85% each), and routing, time-slot scheduling and shipment consolidation (90% each) are close to full implementation. Collaborative practices record the widest gaps in the

entire assessment: shared shipments with non-competing companies (87% recognition, 45% adoption, 42 points) and with competing companies (83%, 30%, 53 points) encounter distinct barriers—inter-organizational trust deficits and coordination challenges rather than pure financial constraints—with modal shift (60%) and RFID load tracking (50%) also lagging.

Warehouse and Handling Equipment achieves strong implementation (97% recognition, 83% adoption), reflecting clearer return-on-investment profiles. Energy-efficient equipment and efficient land use reach 95% adoption, facilitated by shorter payback periods (two years for LED lighting vs. uncertain returns for vehicles). This pattern is consistent with the prominence of energy-efficiency measures in the green-warehousing literature [38], plausibly reflecting their clearer cost–benefit profiles. Warehouse management systems (80%) show the largest gap among the high-impact warehouse practices (20 percentage points), whereas eco-friendly building design (55% adoption, 32 points) faces prohibitive capital requirements.

Inventory Management demonstrates both recognition and adoption deficits (82%, 65%), suggesting awareness gaps. Participants' limited discussion of inventory practices indicates these remain peripheral to environmental initiatives, corroborating AI2's observation that firms "don't know what they don't know" regarding sophisticated environmental optimization.

Packaging Management presents the most pronounced domain-level recognition–implementation gap (92% vs. 66%, 26 percentage points), attributable to supply chain constraints and cost premiums (sustainable material surcharges reported by User-2). Eco-friendly packaging design (55% adoption, 38 points) shows the widest gap of any high-impact practice, and packaging life cycle assessment (65%, 28 points) faces additional capability barriers, with User-1 acknowledging insufficient technical understanding. Reusable packaging initiatives encounter systematic inter-organizational obstacles, exemplified by suppliers' unwillingness to participate in reverse logistics processes.

Internal Management achieves the strongest implementation among the high-impact domains (93% recognition, 84% adoption; 9-point gap), reflecting greater organizational control. Staff training in energy efficiency is reported by all 20 company-affiliated respondents (100%), owing to modest investment requirements and observable cost savings; its recognition rate of 97% reflects one respondent in the full panel of 30, so the nominal RIG of −3 points arises from the two different response bases, lies within the measurement resolution, and indicates a closed gap rather than adoption exceeding recognition. Formal Environmental Management Systems certification (75%) faces external expertise and cost barriers. Senior management commitment is widely reported (80%); qualitative evidence nonetheless suggests that in some firms this commitment may represent symbolic rather than substantive resource allocation.

Reverse Logistics shows that, although aggregate domain-level recognition reaches 89%, this falls marginally below the 90% threshold for classification as high-impact ELP, even as substantial adoption (81%) occurs. This pattern reflects circular economy principle awareness alongside implementation challenges for those practices that require supply chain partner cooperation. User-2's failed reusable packaging initiative illustrates that reverse logistics transcends single-organization boundaries, whilst infrastructure gaps—particularly outside Bangkok—further constrain implementation.

Customer Management shows close recognition–adoption alignment in the survey (90%, 85%; 5-point gap), yet the interview evidence reveals tensions between stated demand and operational cooperation that the binary adoption item does not capture. Whilst customer pressure drives initial adoption (LSP-3: customers "include environmental criteria in evaluations"), genuine operational cooperation remains limited. Customers demand environmental compliance yet resist service modifications supporting sustainability objectives.

Supplier Management records the lowest recognition in the assessment (81%; adoption 73%, 8-point gap), reflecting power asymmetries. LSP-1's assertion that firms "don't have that kind of power" to audit suppliers helps explain why supplier-facing practices are not regarded as essential to firm performance in the first place: recognition, rather than the gap, is the binding constraint in this domain. Downstream firms face customer sustainability demands without commensurate ability to impose upstream requirements, creating coordination failures that systematically constrain supplier engagement.

4.4. Cross-Domain Synthesis

Three cross-cutting empirical patterns emerge from the integrated analysis of quantitative and qualitative data.

First, customer pressure consistently emerges as the primary adoption driver across all logistics domains, consistent with the centrality of downstream demand in shaping LSP environmental behavior. However, this pressure does not translate uniformly into implementation: practices visible to customers and within firms' resource capacity (e.g., eco-driving training, energy-efficient lighting) achieve substantially higher adoption than

capital-intensive alternatives (e.g., alternative-fuel vehicles, eco-friendly building design), regardless of equivalent recognition levels. Power asymmetries within the supply chain mean LSPs face downstream demands they cannot reciprocate upstream, particularly in supplier and packaging management.

Second, the RIG is consistently moderated by four structural constraints: financial capacity, capability and knowledge gaps, inter-organizational coordination challenges, and weak institutional support operating with different intensity across domains. Transportation and packaging show the largest domain-level gaps owing to capital intensity and supply chain coordination requirements; internal management shows the smallest gaps owing to lower implementation barriers and direct organizational control. The pattern indicates that high recognition levels alone are insufficient to drive adoption: firms implement practices that fall within their available resources, whilst deferring those that exceed financial or capability thresholds.

Third, Thai LSPs' adoption pattern reflects a more cautious, reactive approach compared with developed-economy evidence [23,24], characterized by binding capital constraints, weak regulatory enforcement, leaving customer pressure as the dominant driver, and capability deficits hindering implementation despite motivation. These contextual differences underscore the importance of developing emerging-market-specific evidence rather than transferring frameworks from resource-rich contexts.

Recent emerging-market evidence supports the relevance of these findings beyond Thailand. Ref. [19] report that internal capabilities, specifically green intellectual capital and digital transformation, were decisive for green logistics adoption among Vietnamese manufacturing SMEs, with external pressures alone proving insufficient. The convergence with the present findings suggests that capability and capacity constraints may shape ELP adoption across emerging Southeast Asian economies, reinforcing the need for region-specific empirical evidence rather than transferred frameworks from resource-rich contexts. Similarly, recent evidence from Vietnamese logistics enterprises indicates that economic and regulatory pressures, together with managerial commitment, matter more than customer pressure alone in driving green logistics management practices [71], cautioning against assuming a uniform customer-driven adoption pathway across emerging markets.

5. Discussion

Building on the sequential exploratory logic in which Phase 1 interview evidence informed and contextualized the Phase 2 expert assessment questionnaire, the triangulation of qualitative and quantitative findings indicates that RIGs range from 5 to 26 percentage points at domain level and from −3 to 53 points at practice level. Whilst high-impact practices achieve near-universal performance recognition (90–100%), implementation of the capital-intensive and coordination-dependent subset remains constrained by financial barriers (particularly for capital-intensive practices), knowledge deficits, and coordination challenges. Packaging, transportation and collaborative practices exhibit the largest gaps, reflecting cost premiums, high investment requirements and inter-organizational complexity. Conversely, internal management practices show relatively higher adoption, consistent with lower implementation barriers and direct organizational control. The mixed-method integration revealed notable convergence across data sources. Quantitative adoption deficits for capital-intensive practices (alternative vehicles: 75%; eco-friendly building design: 55%) aligned with qualitative testimony regarding financial barriers and payback period concerns. Similarly, low collaborative practice adoption (shared shipments: 30–45%) converged with interview evidence on trust deficits and coordination complexity. This convergence strengthens confidence in both datasets and suggests that the observed patterns are unlikely to be artefacts of a single method, whilst remaining descriptive of this panel's assessments.

Complementary insights emerged where qualitative data explained quantitative anomalies. The narrow adoption gap for internal management practices (93% recognition, 84% adoption) was illuminated by interview evidence suggesting these practices face fewer external dependencies and shorter implementation timelines, enabling organizations to act within existing resource constraints.

The findings suggest that stakeholder pressure, whilst apparently necessary, is not sufficient to drive adoption in resource-constrained contexts. Customer demands motivate ELP consideration, but cannot overcome financial constraints without institutional support. This pattern indicates that closing the RIG in resource-constrained settings requires complementary capacity-building and institutional support, not stakeholder pressure alone.

Returning to the theoretical framework introduced in Section 2.3, the findings can be read through its three lenses. The Triple Bottom Line lens indicates that practices whose economic and environmental benefits coincide (e.g., energy-efficient equipment, shipment consolidation) achieve the highest adoption, whereas practices whose benefits are primarily environmental or social attract recognition without commensurate implementation. The stakeholder lens explains the origin of recognition, customer demand emerges as the dominant reported pressure—but also its limits, as pressure unaccompanied by cost-sharing does not overcome resource thresholds. The

structural-constraint lens accounts for the residual gap: financial, capability, coordination, and institutional constraints moderate the translation of recognition into implementation, as depicted in Figure 2. This aligns with emerging-economy evidence that green human capital employees' environmental skills and knowledge—underpins firms' ability to convert sustainability intentions into practice [72].

This research makes three empirical and contextual contributions to the sustainable logistics literature.

First, it provides descriptive evidence that customer pressure is perceived as the primary adoption driver among Thai LSPs yet appears insufficient on its own to overcome resource constraints. Whilst customer demand successfully motivates adoption of low-cost, visible practices (eco-driving training, LED lighting), it cannot overcome capital constraints for expensive investments (alternative vehicles, eco-friendly building and packaging design) or coordination challenges for collaborative initiatives (shared shipments, supplier audits). The findings indicate that, in resource-constrained settings, demand-side pressure alone cannot deliver implementation; complementary capacity building and institutional support mechanisms are required.

Second, the research provides a literature-informed, empirically substantiated typology of four interlinked barriers: financial capacity, capability and knowledge gaps, inter-organizational coordination challenges, and weak institutional support that systematically explain the RIG across logistics domains. The pattern of high adoption for visible, low-cost practices alongside avoidance of capital-intensive or coordination-intensive initiatives reflects rational resource allocation under binding constraints rather than greenwashing or symbolic compliance, providing a more nuanced empirical account of ELP adoption in resource-constrained settings.

Third, the study demonstrates that evidence and frameworks developed in Western contexts require substantial calibration when applied to emerging economies. Compared with European logistics firms that exhibit proactive environmental strategies enabled by financial resources and robust regulatory frameworks, Thai firms demonstrate primarily reactive, customer-driven adoption constrained by capital limitations, knowledge gaps, and weak institutional support. These contextual differences underscore the importance of developing emerging market-specific evidence sensitive to resource availability, institutional development, and supply chain power dynamics.

6. Managerial Implications

The empirical findings carry three sets of managerial implications: for LSPs and user firms, for policymakers, and for cross-domain prioritization by managers operating in resource-constrained contexts.

6.1. Implications for LSPs and User Firms

For LSPs and user firms, this research offers evidence-based guidance for prioritizing scarce resources. Firms that have not yet done so should first adopt the high-impact, low-barrier practices with demonstrated return on investment, such as eco-driving training, shipment consolidation, and energy-efficient warehouse equipment practices that most panel firms already report to build internal confidence and generate savings that can fund subsequent investments. For capital-intensive practices, firms should explore collaborative investment models such as industry consortia for shared charging infrastructure or leasing arrangements for alternative vehicles, reducing individual financial burden whilst enabling access to advanced technologies.

6.2. Implications for Policymakers

For policymakers, the findings point to the need for targeted SME support mechanisms differentiated from large enterprise programs. Illustrative policy options consistent with these findings the precise calibration of which lies beyond the scope of this study's evidence include capital subsidies for alternative-fuel vehicles and eco-friendly warehouse construction targeted at SMEs, simplified application processes, and green-equipment leasing programs with government-backed guarantees to reduce financing costs. Critical infrastructure investments in electric vehicle charging along major freight corridors, hydrogen refueling for heavy trucks, and regional recycling centers would address the infrastructure gaps currently constraining the adoption of environmentally preferable alternatives.

6.3. Domain-Specific and SME-Focused Recommendations

The empirical findings support three further managerial recommendations. First, the RIG is not uniform across domains: packaging management exhibits the widest gap (26 percentage points), followed by transportation (21 points) and warehousing (14 points), whereas internal management shows the narrowest gap (9 points). This domain-level heterogeneity implies that managers should not apply a "one-size" sustainability strategy; instead, domain-specific action plans are required that account for differing barrier profiles. Second, the data indicate that SME resource constraints, rather than a lack of awareness, are the more plausible driver of adoption gaps: the 20 high-

impact ELP identified in this study achieved near-universal recognition (90–100%) and averaged 83% implementation, but implementation ranged from 55% to 100%, with the lowest values concentrated in capital-intensive and inter-organizational practices, suggesting that willingness exists whilst financial capacity, technical knowledge and coordination act as binding constraints for that subset. Managers in larger LSPs should therefore consider offering structured capacity-sharing arrangements such as joint training programs or shared logistics technology platforms to SME partners, as improving upstream capability directly reduces supply chain sustainability risk for anchor firms. Third, the 45% adoption rate for shared shipments among non-competing companies, despite 87% recognition of its performance value (a 42-point gap, the widest in the assessment after shared shipments with competitors), identifies inter-organizational trust as a specific and tractable barrier. Industry associations such as the Thai Logistics and Production Society (Bangkok, Thailand) are well-positioned to broker pre-competitive collaboration agreements that reduce the first-mover risk currently preventing this high-impact practice from scaling.

These implications differ in their evidential grounding. The prioritization guidance in Sections 6.1 and 6.3 follows directly from the practice-level adoption, recognition, and barrier data reported in Section 4. The policy options in Section 6.2, by contrast, are broader propositions that extrapolate from the identified barriers; they indicate the direction of potentially useful intervention but require dedicated policy analysis and economic evaluation before specific instruments or thresholds can be recommended.

7. Methodological Contributions

Methodologically, this study demonstrates the value of domain-specific, practice-level assessment for advancing sustainable logistics research. By disaggregating 38 practices across eight domains and triangulating quantitative adoption patterns with qualitative barrier identification, the research provides the granular, actionable insights that studies aggregating practices into broad constructs cannot provide [12]. The mixed-method framework developed here, combining structured performance adoption assessment with comparative analysis of stakeholder perspectives and implementation contexts, offers a replicable template for investigating ELP adoption in other developing economies, enabling cross-country comparative research that can identify regional patterns versus country-specific factors.

8. Limitations and Future Research

This study has four limitations. First, the modest sample sizes (n = 30 expert assessments questionnaire; n = 9 interviews), though consistent with comparable expert-based sustainability studies in emerging Asian markets [10,15], constrain statistical generalizability. Future research should employ larger probabilistic samples, enabling inferential analysis. Second, the cross-sectional design precludes examination of adoption trajectories; longitudinal research tracking organizations over 3–5 years would illuminate dynamic adoption processes. Third, systematic financial performance data linking ELP adoption to ROI were not collected, though cost implications emerged anecdotally. Finally, the Phase 1 interview sample comprises predominantly LSPs (five of nine informants), potentially underrepresenting user firm and regulatory perspectives.

A further limitation concerns the size of the three stakeholder sub-groups (n = 10 LSPs, n = 10 user firms, n = 10 academics in Phase 2; n = 5, n = 2, and n = 2 respectively in Phase 1). These sub-group sizes are deliberately small and are unsuitable for between-group statistical inference; consequently, no inferential tests of differences across stakeholder categories are reported in this paper. As emphasized in Section 3, the three categories are used interpretively for cross-stakeholder triangulation rather than as independent samples for hypothesis testing, and findings should be read accordingly. For the same reason, the RIG estimates reported here combine panel-level recognition (n = 30) with firm-reported adoption (n = 20) and should be interpreted as indicative of adoption patterns in the Thai logistics sector rather than as population estimates for LSPs. Moreover, because implementation rates rest on 20 responses, each respondent represents 5 percentage points; differences of less than 10 points between practices or domains (e.g., between the customer, supplier, reverse-logistics and internal-management domain gaps) are not considered significant. Future research employing larger probabilistic samples would enable inferential comparison of stakeholder perspectives and statistical generalization to wider populations of LSPs, user firms, and academic experts.

These limitations suggest five research priorities: (1) intervention studies employing experimental designs to establish causal evidence for policy effectiveness in resource-constrained contexts; (2) rigorous economic analyses quantifying ELP cost–benefit relationships to reduce investment uncertainty; (3) investigation of coordination mechanisms overcoming collaborative implementation barriers; (4) further empirical investigation of how resource constraints and institutional voids moderate ELP adoption in emerging markets; and (5) longitudinal case

studies examining technology adoption trajectories from simple practices to comprehensive environmental management systems.

9. Conclusions

This study provides the first comprehensive, domain-specific, RIG assessment framework of ELP in an emerging market, evaluating 38 practices across eight logistics domains within Thailand's logistics sector. Using a mixed-method design, we identified 20 high-impact practices that received near-universal performance recognition (90–100%) and averaged 83% implementation (range 55–100%), revealing RIGs that are narrow for practices under direct organizational control but persist at 25–38 percentage points for capital-intensive and coordination-dependent practices across the five core domains. The research addressed its three questions through an integrated analytical approach: RQ1 by mapping practice-level adoption patterns across the eight domains; RQ2 by comparing performance perceptions with empirical implementation data to expose systematic gaps; and RQ3 by identifying the financial, capability, coordination, and institutional constraints that moderate practice adoption in resource-constrained contexts. Collectively, the findings demonstrate how awareness, perceived performance benefits, and contextual limitations interact to shape the adoption of ELP in Thailand.

Empirically, this research shows that, in the study context, high recognition of ELP importance does not uniformly translate into implementation in resource-constrained settings, where four interlinked structural barriers, financial capacity, capability and knowledge gaps, inter-organizational coordination challenges, and weak institutional support systematically moderate the recognition–implementation relationship. These findings challenge frameworks developed in resource-rich contexts that assume adequate financial capacity and institutional support are available. For emerging markets pursuing UN SDGs 12 and 13, the findings suggest that closing adoption gaps is likely to require coordinated multi-stakeholder intervention: differentiated SME support mechanisms, phased regulatory frameworks, industry coordination platforms, and supply chain cost-sharing arrangements. The domain-specific assessment framework offers a replicable template for comparative ASEAN research, supporting evidence-based pathways toward zero-carbon logistics transitions that are calibrated to firm-level resource constraints in emerging markets.

Author Contributions

T.I.: Conceptualization, methodology, investigation, data curation, formal analysis, writing original draft preparation. T.C.W.: Conceptualization, methodology, supervision, validation, writing review, and editing. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Institutional Review Board Statement

The study was conducted in accordance with the ethical procedures of the University of Strathclyde. All participants provided written informed consent prior to participation; confidentiality and anonymity were assured, and no organization or individual is identifiable in the reported data.

Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Data Availability Statement

The interview protocol and expert assessment instrument are summarized in Appendix A, and the full instrument is available from the corresponding author on request. The quantitative summary data supporting the findings are reported in Tables 4 and 5. The underlying interview transcripts and item-level responses are not publicly available owing to participant-confidentiality commitments, but anonymized extracts are available from the corresponding author on reasonable request.

Acknowledgments

The authors thank the participating logistics service providers, logistics user firms, and academic experts for their time and insights.

Conflicts of Interest

Given the role as Associate Editor, T. C. Wong had no involvement in the peer review of this paper and had no access to information regarding its peer-review process. Full responsibility for the editorial process of this paper was delegated to another editor of the journal.

Use of AI and AI-Assisted Technologies

During the preparation of this work, the authors used Claude (Anthropic) to support language editing and reference formatting. After using Claude (Anthropic), the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

Appendix A. Research Instrument: Semi-Structured Interview Guide and Expert Assessment Questionnaire (Condensed)

A single three-part instrument, prepared in three parallel versions (B1 for logistics service providers, B2 for logistics user firms, and B3 for academics/researchers), served both phases of the sequential exploratory design: in Phase 1 it guided the nine in-depth, semi-structured interviews, and in Phase 2 its structured components were administered as a self-completion expert assessment questionnaire to the 30-member multi-stakeholder panel. The versions are identical in structure; the academic version omits organization-specific profile items (Part 1 reduced from 13 to six items) and the current-use checklist in Part 2. Each version opened with a confidentiality statement, informed-consent signature, the research objectives, and definitions of key terms. Phase 1 interviews were conducted in Thai, audio-recorded with participant consent, professionally transcribed, and translated into English; each lasted approximately 60–90 min. The full instrument is available from the authors on request.

Appendix A.1. Part 1—Company and Respondent Profile (13 Items; Six in the Academic Version)

Respondent contact details; business type (logistics service provider, transportation company, public/contract warehousing, other); competitive strategy (cost leadership, differentiation, focus, hybrid); geographic scope of operations; transport modes used; fleet size; asset investment; market sectors served; ranking of the eight logistics functions most involved in developing supply-chain sustainability strategy; other supply-chain parties involved (e.g., suppliers, clients, government authorities, industry associations); the main disincentives to establishing a sustainability strategy; the main drivers of a sustainability strategy; and the perceived financial benefits of such a strategy.

Appendix A.2. Part 2—Environmental Logistics Practices (Three Items; Two in the Academic Version)

(i) For each of the 38 environmental logistics practices across the eight logistics domains, whether the practice is essential to increasing an LSP's firm performance (yes/no), together with a within-domain ranking of the practices (e.g., 1–11 for transportation; 1–5 for warehousing and handling equipment); (ii) which of the 38 practices the respondent's organization currently uses (yes/no; omitted in the academic version); and (iii) any additional environmental logistics practices considered essential to firm performance. In Phase 2, these structured items were self-completed by the expert panel, yielding the essential-to-performance percentages, within-domain ranks, and current-use rates reported in Table 5.

Appendix A.3. Part 3—Sustainability and Competitiveness (Seven Items)

Whether the company has formal sustainability best practices, with a ranking of the environmental, economic, and social dimensions (or, if not, plans to establish them); whether sustainability best practices are associated with the company's competitive strategy; whether the logistics industry requires industry-specific sustainability practices; the perceived importance of sustainability best practices for company competitiveness; the need to link competitive strategy with sustainability best practices; the level of LSPs' awareness of sustainability issues; and closing comments or suggestions.

References

1. IEA. *Energy Technology Perspectives 2020*; International Energy Agency: Paris, France, 2020. https://doi.org/10.1787/d07136f0-en.
2. McKinnon, A.C.; Browne, M.; Piecyk, M.; et al. *Green Logistics: Improving the Environmental Sustainability of Logistics*, 3rd ed.; Kogan Page: London, UK, 2015.
3. ASEAN Secretariat. *ASEAN Key Figures 2024*; ASEAN Secretariat: Jakarta, Indonesia, 2024.

4. World Bank. *Connecting to Compete 2023: Trade Logistics in an Uncertain Global Economy—The Logistics Performance Index and Its Indicators*; World Bank: Washington, DC, USA, 2023. Available online: https://hdl.handle.net/10986/39760 (accessed on 19 September 2026).
5. NXPO (Office of National Higher Education, Science, Research and Innovation Policy Council). *BCG in Action.* Available online: https://www.nxpo.or.th/th/en/bcg-in-action/ (accessed on 19 September 2026).
6. Government of the Kingdom of Thailand. *Thailand's 2nd Updated Nationally Determined Contribution*; Office of Natural Resources and Environmental Policy and Planning (ONEP): Bangkok, Thailand, 2022. Submitted to UNFCCC, 2 November 2022. Available online: https://unfccc.int/sites/default/files/NDC/2022-11/Thailand%202nd%20Updated%20NDC.pdf (accessed on 19 September 2026).
7. OSMEP (Office of Small and Medium Enterprises Promotion). *MSME White Paper 2024*; OSMEP: Bangkok, Thailand, 2024.
8. Lin, Q.; Zhang, K.; Huang, D.; et al. Evaluating the impact of Trans-Asian railway on logistics mode selection between Thailand and China: An AHP-TOPSIS approach. *Alex. Eng. J.* **2024**, *98*, 147–158. https://doi.org/10.1016/j.aej.2024.04.041.
9. World Bank. Transforming Lao PDR from a Land-locked to a Land-linked Economy. Available online: https://www.worldbank.org/en/country/lao/publication/transforming-lao-pdr-from-a-land-locked-to-a-land-linked-economy (accessed on 19 September 2026).
10. Faijaidee, W.; Jomnonkwao, S.; Jongkol, P. Unboxing: Exploring the challenges of green supply chain initiatives in Thailand. *Logistics* **2025**, *9*, 12. https://doi.org/10.3390/logistics9010012.
11. Youngswaing, W.; Jomnonkwao, S.; Cheunkamon, E.; et al. Key factors shaping green logistics in Thailand's auto industry: An application of structural equation modeling. *Logistics* **2024**, *8*, 17. https://doi.org/10.3390/logistics8010017.
12. Centobelli, P.; Cerchione, R.; Esposito, E. Developing the WH 2 framework for environmental sustainability in logistics service providers: A taxonomy of green initiatives. *J. Clean. Prod.* **2017**, *165*, 1063–1077. https://doi.org/10.1016/j.jclepro.2017.07.150.
13. Tseng, M.L.; Islam, M.S.; Karia, N.; et al. A literature review on green supply chain management: Trends and future challenges. *Resour. Conserv. Recycl.* **2019**, *141*, 145–162. https://doi.org/10.1016/j.resconrec.2018.10.009.
14. Vo, H.V.; Nguyen, N.P. Greening the Vietnamese supply chain: The influence of green logistics knowledge and intellectual capital. *Heliyon* **2023**, *9*, e15953. https://doi.org/10.1016/j.heliyon.2023.e15953.
15. Rahman, S.; Ahsan, K.; Yang, L.; et al. An investigation into critical challenges for multinational third-party logistics providers operating in China. *J. Bus. Res.* **2019**, *103*, 607–619. https://doi.org/10.1016/j.jbusres.2017.09.053.
16. Eesley, C.; Lenox, M.J. Firm responses to secondary stakeholder action. *Strateg. Manag. J.* **2006**, *27*, 765–781. https://doi.org/10.1002/smj.536.
17. Hörisch, J.; Freeman, R.E.; Schaltegger, S. Applying Stakeholder Theory in Sustainability Management: Links, similarities, dissimilarities, and a conceptual framework. *Organ. Environ.* **2014**, *27*, 328–346. https://doi.org/10.1177/1086026614535786.
18. Elkington, J. *Cannibals with Forks: The Triple Bottom Line of 21st Century Business*; Capstone: Oxford, UK, 1997.
19. Pham, T.A.; Le-Anh, T.; Duong, M.C. A study of green logistics practice in Vietnam—the roles of intellectual capital and digital transformation. *Asia Pac. J. Mark. Logist.* **2026**, *38*, 1466–1484. https://doi.org/10.1108/apjml-02-2025-0265.
20. Tetteh, F.K.; Owusu Kwateng, K.; Mensah, J. Green logistics practices: A bibliometric and systematic methodological review and future research opportunities. *J. Clean. Prod.* **2024**, *476*, 143735. https://doi.org/10.1016/j.jclepro.2024.143735.
21. Murphy, P.R.; Poist, R.F.; Braunschweig, C.D. Green logistics: Comparative views of environmental progressives, moderates, and conservatives. *J. Bus. Logist.* **1996**, *17*, 191–211.
22. Murphy, P.R.; Poist, R.F. Green logistics strategies: An analysis of usage patterns. *Transp. J.* **2000**, *40*, 5–16.
23. Evangelista, P.; Santoro, L.; Thomas, A. Environmental sustainability in third-party logistics service providers: A systematic literature review from 2000–2016. *Sustainability* **2018**, *10*, 1627. https://doi.org/10.3390/su10051627.
24. Bask, A.; Rajahonka, M.; Laari, S.; et al. Environmental sustainability in shipper–LSP relationships. *J. Clean. Prod.* **2018**, *172*, 2986–2998. https://doi.org/10.1016/j.jclepro.2017.11.112.
25. Evangelista, P.; Colicchia, C.; Creazza, A. Is environmental sustainability a strategic priority for logistics service providers? *J. Environ. Manag.* **2017**, *198*, 353–362. https://doi.org/10.1016/j.jenvman.2017.04.096.
26. Wu, H.J.; Dunn, S.C. Environmentally responsible logistics systems. *Int. J. Phys. Distrib. Logist. Manag.* **1995**, *25*, 20–38. https://doi.org/10.1108/09600039510083925.
27. Afum, E.; Osei-Ahenkan, V.Y.; Agyabeng-Mensah, Y.; et al. Green manufacturing practices and sustainable performance among Ghanaian manufacturing SMEs: The explanatory link of green supply chain integration. *Manag. Environ. Qual. Int. J.* **2020**, *31*, 1457–1475. https://doi.org/10.1108/meq-01-2020-0019.
28. Baah, C.; Jin, Z.; Tang, L. Organizational and regulatory stakeholder pressures friends or foes to green logistics practices and financial performance: Investigating corporate reputation as a missing link. *J. Clean. Prod.* **2020**, *247*, 119125. https://doi.org/10.1016/j.jclepro.2019.119125.
29. Leung, T.C.H.; Guan, J.; Lau, Y.Y. Exploring environmental sustainability and green management practices: Evidence from logistics service providers. *Sustain. Account. Manag. Policy J.* **2023**, *14*, 461–489. https://doi.org/10.1108/sampj-03-2022-0133.

30. Tranfield, D.; Denyer, D.; Smart, P. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. *Br. J. Manag.* **2003**, *14*, 207–222. https://doi.org/10.1111/1467-8551.00375.
31. Denyer, D.; Tranfield, D. Producing a systematic review. In *The SAGE Handbook of Organizational Research Methods*; Buchanan, D.A., Bryman, A., Eds.; SAGE: London, UK, 2009; pp. 671–689.
32. Mayring, P. *Qualitative Content Analysis: Theoretical Foundation, Basic Procedures and Software Solution*; SSOAR (open access): Klagenfurt, Austria, 2014.
33. Moher, D.; Tsertsvadze, A.; Tricco, A.; et al. When and how to update systematic reviews. *Cochrane Database Syst. Rev.* **2008**, *2010*, MR000023. https://doi.org/10.1002/14651858.mr000023.pub3.
34. Moher, D.; Tsertsvadze, A. Systematic reviews: When is an update an update? *Lancet* **2006**, *367*, 881–883. https://doi.org/10.1016/S0140-6736(06)68358-X.
35. Liimatainen, H.; van Vliet, O.; Aplyn, D. The potential of electric trucks—An international commodity-level analysis. *Appl. Energy* **2019**, *236*, 804–814. https://doi.org/10.1016/j.apenergy.2018.12.017.
36. Rai, D.; Sodagar, B.; Fieldson, R.; et al. Assessment of CO_2 emissions reduction in a distribution warehouse. *Energy* **2011**, *36*, 2271–2277. https://doi.org/10.1016/j.energy.2010.05.006.
37. Ries, J.M.; Grosse, E.H.; Fichtinger, J. Environmental impact of warehousing: A scenario analysis for the United States. *Int. J. Prod. Res.* **2017**, *55*, 6485–6499. https://doi.org/10.1080/00207543.2016.1211342.
38. Perotti, S.; Colicchia, C. Greening warehouses through energy efficiency and environmental impact reduction: A conceptual framework based on a systematic literature review. *Int. J. Logist. Manag.* **2023**, *34*, 199–234. https://doi.org/10.1108/ijlm-02-2022-0086.
39. Mahmoudi, M.; Parviziomran, I. Reusable packaging in supply chains: A review of environmental and economic impacts, logistics system designs, and operations management. *Int. J. Prod. Econ.* **2020**, *228*, 107730. https://doi.org/10.1016/j.ijpe.2020.107730.
40. Govindan, K.; Soleimani, H.; Kannan, D. Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. *Eur. J. Oper. Res.* **2015**, *240*, 603–626. https://doi.org/10.1016/j.ejor.2014.07.012.
41. Darnall, N.; Henriques, I.; Sadorsky, P. Do environmental management systems improve business performance in an international setting? *J. Int. Manag.* **2008**, *14*, 364–376. https://doi.org/10.1016/j.intman.2007.09.006.
42. Vachon, S.; Klassen, R.D. Environmental management and manufacturing performance: The role of collaboration in the supply chain. *Int. J. Prod. Econ.* **2008**, *111*, 299–315. https://doi.org/10.1016/j.ijpe.2006.11.030.
43. Green, K.W.; Zelbst, P.J.; Meacham, J.; et al. Green supply chain management practices: Impact on performance. *Supply Chain Manag. Int. J.* **2012**, *17*, 290–305. https://doi.org/10.1108/13598541211227126.
44. Zhu, Q.; Sarkis, J. An inter-sectoral comparison of green supply chain management in China: Drivers and practices. *J. Clean. Prod.* **2006**, *14*, 472–486. https://doi.org/10.1016/j.jclepro.2005.01.003.
45. Laguir, I.; Stekelorum, R.; El Baz, J. Going green? Investigating the relationships between proactive environmental strategy, GSCM practices and performances of third-party logistics providers (TPLs). *Prod. Plan. Control.* **2021**, *32*, 1049–1062. https://doi.org/10.1080/09537287.2020.1784483.
46. Hamdy, A. Supply chain capabilities matter: Digital transformation and green supply chain management in post-pandemic emerging economies: A case from Egypt. *Oper. Manag. Res.* **2024**, *17*, 963–981. https://doi.org/10.1007/s12063-024-00481-5.
47. SET (Stock Exchange of Thailand). SETESG Index Methodology and Constituents. Available online: https://www.set.or.th/en/market/index/setesg/profile (accessed on 19 September 2026).
48. Farfán Chilicaus, G.C.; Licapa-Redolfo, G.S.; Arbulú Ballesteros, M.A.; et al. Digital transformation and sustainability in post-pandemic supply chains: A global bibliometric analysis of technological evolution and research patterns (2020–2024). *Sustainability* **2025**, *17*, 3009. https://doi.org/10.3390/su17073009.
49. Nikseresht, A.; Golmohammadi, D.; Zandieh, M. Sustainable green logistics and remanufacturing: A bibliometric analysis and future research directions. *Int. J. Logist. Manag.* **2024**, *35*, 755–803. https://doi.org/10.1108/ijlm-03-2023-0085.
50. Derse, O. Prioritizing solutions of green reverse logistics barriers with Fuzzy DEMATEL–FUCOM–SWARA methods. *Ecol. Indic.* **2024**, *165*, 112198. https://doi.org/10.1016/j.ecolind.2024.112198.
51. Klymenko, O.; Lillebrygfjeld Halse, L. Sustainability practices during COVID-19: An institutional perspective. *Int. J. Logist. Manag.* **2022**, *33*, 1315–1335. https://doi.org/10.1108/ijlm-05-2021-0306.
52. Geissdoerfer, M.; Savaget, P.; Bocken, N.M.P.; et al. The Circular Economy—A new sustainability paradigm? *J. Clean. Prod.* **2017**, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048.
53. Sarkis, J.; Gonzalez-Torre, P.; Adenso-Diaz, B. Stakeholder pressure and the adoption of environmental practices: The mediating effect of training. *J. Oper. Manag.* **2010**, *28*, 163–176. https://doi.org/10.1016/j.jom.2009.10.001.
54. Jazairy, A. Aligning the purchase of green logistics practices between shippers and logistics service providers. *Transp. Res. Part D Transp. Environ.* **2020**, *82*, 102305. https://doi.org/10.1016/j.trd.2020.102305.
55. Creswell, J.W.; Plano Clark, V.L. *Designing and Conducting Mixed Methods Research*, 3rd ed.; SAGE: Thousand Oaks, CA, USA, 2017.

56. Patton, M.Q. *Qualitative Research & Evaluation Methods: Integrating Theory and Practice*, 4th ed.; SAGE: Thousand Oaks, CA, USA, 2015.
57. Palinkas, L.A.; Horwitz, S.M.; Green, C.A.; et al. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Adm. Policy Ment. Health Ment. Health Serv. Res.* **2015**, *42*, 533–544. https://doi.org/10.1007/s10488-013-0528-y.
58. Kallio, H.; Pietilä, A.M.; Johnson, M.; et al. Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *J. Adv. Nurs.* **2016**, *72*, 2954–2965. https://doi.org/10.1111/jan.13031.
59. Malterud, K.; Siersma, V.D.; Guassora, A.D. Sample Size in Qualitative Interview Studies: Guided by information power. *Qual. Health Res.* **2016**, *26*, 1753–1760. https://doi.org/10.1177/1049732315617444.
60. Guest, G.; Bunce, A.; Johnson, L. How Many Interviews Are Enough? An experiment with data saturation and variability. *Field Methods* **2006**, *18*, 59–82. https://doi.org/10.1177/1525822x05279903.
61. Brislin, R.W. Back-translation for cross-cultural research. *J. Cross-Cult. Psychol.* **1970**, *1*, 185–216. https://doi.org/10.1177/135910457000100301.
62. Denzin, N.K. *The Research Act: A Theoretical Introduction to Sociological Methods*, 2nd ed.; McGraw-Hill: New York, NY, USA, 1978.
63. Dworkin, S.L. Sample size policy for qualitative studies using in-depth interviews. *Arch. Sex. Behav.* **2012**, *41*, 1319–1320. https://doi.org/10.1007/s10508-012-0016-6.
64. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. https://doi.org/10.1191/1478088706qp063oa.
65. King, N. Doing template analysis. In *Qualitative Organizational Research: Core Methods and Current Challenges*; SAGE: London, UK, 2012; pp. 426–450. https://doi.org/10.4135/9781526435620.n24.
66. Diamond, I.R.; Grant, R.C.; Feldman, B.M.; et al. Defining consensus: A systematic review recommends methodologic criteria for reporting of Delphi studies. *J. Clin. Epidemiol.* **2014**, *67*, 401–409. https://doi.org/10.1016/j.jclinepi.2013.12.002.
67. Barrios, M.; Guilera, G.; Nuño, L.; et al. Consensus in the Delphi method: What makes a decision change? *Technol. Forecast. Soc. Change* **2021**, *163*, 120484. https://doi.org/10.1016/j.techfore.2020.120484.
68. McKenna, H.P. The Delphi technique: A worthwhile research approach for nursing? *J. Adv. Nurs.* **1994**, *19*, 1221–1225. https://doi.org/10.1111/j.1365-2648.1994.tb01207.x.
69. Sumsion, T. The Delphi technique: An adaptive research tool. *Br. J. Occup. Ther.* **1998**, *61*, 153–156. https://doi.org/10.1177/030802269806100403.
70. Green, B.; Jones, M.; Hughes, D.; et al. Applying the Delphi technique in a study of GPs' information requirements. *Health Soc. Care Community* **1999**, *7*, 198–205. https://doi.org/10.1046/j.1365-2524.1999.00176.x.
71. Phan, K.T.; Hoang, V.H.; Nguyen, T.D.H. Antecedents and performance consequences of green logistics management practices: Evidence from Vietnamese logistics enterprises. *Front. Future Transp.* **2026**, *7*, 1842188. https://doi.org/10.3389/ffutr.2026.1842188.
72. Cheng, Y.; Masukujjaman, M.; Sobhani, F.A.; et al. Green logistics, green human capital, and circular economy: The mediating role of sustainable production. *Sustainability* **2023**, *15*, 1045. https://doi.org/10.3390/su15021045.