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Harmonizing Green Trade and Sustainable Logistics: A Semantic Analysis of Policy Documents and Industry Reports

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Abstract:

This study investigates the semantic alignment between policy frameworks and industry communications in the domains of green trade and sustainable logistics. By constructing a dual corpus of 40 policy documents and 30 industry reports published between 2022 and mid-2025, the research applies text preprocessing, term frequency–inverse document frequency (TF–IDF), Latent Dirichlet Allocation (LDA) topic modelling, and semantic network analysis to identify convergent and divergent terminology. Results reveal strong convergence on emissions-related and circular economy terms, indicating shared sustainability priorities. However, regulatory texts favor compliance-oriented language while industry reports emphasize technological innovation and customer-centric operations, leading to siloed thematic clusters with limited interconnectivity. Underutilized cross-cutting concepts such as supply chain resilience and multi-stakeholder partnerships were identified as potential bridges between policy and practice. Based on these findings, the paper recommends establishing a unified sustainability glossary, integrating operational terminology into regulatory documents, and developing a dynamic ontology to map relationships among core concepts. Collaborative multistakeholder workshops and pilot interoperability projects are proposed to maintain adaptive semantic frameworks. These measures aim to enhance clarity, reduce compliance burdens, and foster coherent global strategies for green trade and sustainable logistics. The study underscores the importance of harmonized language in accelerating the effective implementation of environmental objectives across international trade and logistics sectors.

Keywords: green trade, sustainable logistics, semantic analysis, policy communication, industry reports, terminology harmonization, ontologies, text mining, thematic trends, semantic networks, cross-sector standards, international cooperation, environmental standards, trade policy, operational terminology, risk management, digital innovation, carbon accounting.

1. Introduction

The global transition toward sustainable development has fundamentally transformed international trade and logistics operations, creating unprecedented opportunities and challenges for businesses, policymakers, and researchers alike. As climate change concerns intensify and environmental regulations become more stringent worldwide, the concepts of **green trade** and **sustainable logistics** have emerged as critical components of modern economic frameworks. However, the rapid evolution of these fields has led to a proliferation of terminology, standards, and practices that often lack consistency across different jurisdictions, industries, and stakeholders.

This semantic complexity presents significant barriers to effective implementation of sustainable practices, international cooperation, and policy harmonization. The absence of standardized definitions and frameworks not only complicates compliance efforts but also creates opportunities for greenwashing and undermines the credibility of sustainability initiatives. To address these challenges, there is an urgent need for systematic analysis of how language and terminology are employed across policy documents and industry communications in the realm of green trade and sustainable logistics.

This research paper employs **semantic analysis** methodologies to examine the alignment and divergence of terminology used in international policy frameworks and industry reports. By identifying gaps in semantic consistency and proposing pathways for harmonization, this study aims to contribute to the development of more effective, coherent, and universally applicable approaches to sustainable trade and logistics practices.

1.1 Background on Green Trade and Sustainable Logistics

In recent years, advancing environmental sustainability and mitigating climate change have become global imperatives, fundamentally reshaping the landscape of international commerce. **Green trade** broadly refers to the exchange of goods and services produced, marketed, and consumed in ways that uphold environmental sustainability, minimize ecological harm, and often support social and economic well-being (Chamber India, 2022; United Nations Conference on Trade and Development, 2024; Allianz Research, 2023; Energy Sustainability Directory, 2025; Number Analytics, 2025). This concept encompasses both the trade in green goods (such as renewable energy technologies and organic products) and the implementation of sustainable, low-carbon practices within supply chains and trade processes (Allianz Research, 2023; Energy Sustainability Directory, 2025).

Sustainable logistics refers to managing the movement, storage, and handling of goods within supply chains using methods that reduce environmental impact while maintaining efficiency and cost-effectiveness (Custom Market Insights, 2025; DHL Global, 2024). Core strategies include adopting green transportation (electric vehicles, alternative fuels), optimizing routes to cut emissions, improving warehouse efficiencies through renewable energy, and promoting circular supply chains (Custom Market Insights, 2025; DHL Global, 2024). The global green logistics services market is projected to witness significant growth, fueled by policy initiatives, technological investment, and increased demand for sustainable solutions, with Europe's market projected as the largest and Asia-Pacific as the fastest growing region between 2024 and 2033 (Custom Market Insights, 2025).

As green trade and sustainable logistics become more integrated into corporate strategies and national policies, the relevance of standardized environmental practices grows. International agreements such as the Trade in Environmental Goods Agreement (EGA) and frameworks like the United Nations Sustainable Development Goals (SDGs) provide essential blueprints but remain challenged by inconsistent standards and regulatory approaches across countries (Allianz Research, 2023; Number Analytics, 2025; Energy Sustainability Directory, 2025).

1.2 Importance of Semantic Clarity in Policy and Industry Documents

The successful implementation of green trade and sustainable logistics requires not only technological advancement and regulatory alignment but also—critically—**semantic clarity** across policy and industry communications (Frontiers in Built Environment, 2025; Progress, 2024; Coursera, 2025). Semantic clarity refers to the consistent and unambiguous use of language, terminology, and conceptual frameworks in official, legal, and technical documents. Ambiguity or divergence in definitions of "green goods," "eco-friendly packaging," or emissions thresholds, for instance, can create confusion, compliance burdens, or even barriers to trade (Energy Sustainability Directory, 2025; Avaada, 2024; Sorted, 2025).

Recent research highlights that the lack of standardized terminology and semantic harmonization is a major obstacle in international green trade (Avaada, 2024; Energy Sustainability Directory, 2025). Varied country-level definitions and certification protocols for products like green hydrogen or organic food not only complicate compliance but could foster greenwashing or fragment markets, impeding cross-border transactions (Avaada, 2024; Number Analytics, 2025). On the logistics front, semantic standardization in certifications, carbon labeling, and reporting enables accurate comparison, traceability, and mutual recognition of sustainable practices (Avaada, 2024; Custom Market Insights, 2025; IIENSTITU, 2023; Sorted, 2025).

Further, in supply chain management and trade negotiations, semantic divergence leads to inefficiencies, disputes, and delays, necessitating a recognized, universal language to facilitate smooth, trust-based operations. Semantic analysis—drawing from natural language processing (NLP) and ontology engineering—offers a robust approach to diagnose these inconsistencies, map evolving policy concepts, and propose harmonized frameworks (Progress, 2024; Gupta et al., 2024; Frontiers in Built Environment, 2025; Nour Ramzy et al., 2024). Modern semantic tools analyze vast corpora of trade agreements, policy documents, and industry reports, revealing both persistent and emerging themes, as well as gaps and redundancies that merit attention for effective policy intervention (Gupta et al., 2024).

1.3 Research Objectives and Scope

This research paper bridges the domains of green trade, sustainable logistics, and semantic analysis, aiming to contribute both theoretically and practically to the harmonization of global sustainability initiatives. Specifically, the paper sets out to:

- **Analyze the semantic alignment and divergence** within recent international policy frameworks and major industry reports relating to green trade and sustainable logistics.
- **Identify critical areas of ambiguity or inconsistency**, especially those that create unnecessary barriers or complicate compliance efforts across borders and sectors (Avaada, 2024; Energy Sustainability Directory, 2025; Number Analytics, 2025).
- **Leverage advanced semantic analysis tools and methodologies**, such as text mining, semantic network analysis, and ontology engineering, to systematically examine a corpus of policy and industry documents (Gupta et al., 2024; Nour Ramzy et al., 2024).
- **Propose actionable pathways for harmonizing terminology**, reporting standards, and best practices, informed by empirical findings and international comparisons (Avaada, 2024; IIENSTITU, 2023; Sorted, 2025).

The study focuses on developments and literature from 2022 onwards, ensuring that all evidence and citations reflect the latest empirical research and policy trends.

2. Literature Review

The literature surrounding green trade, sustainable logistics, and semantic analysis has evolved over the past three years, reflecting growing recognition of their interconnected importance in achieving global sustainability objectives. This section provides a comprehensive review of key concepts, prior research on policy and industry communication, and identifies critical gaps that necessitate further investigation through semantic analysis methodologies.

2.1 Overview of Key Concepts: Green Trade, Sustainable logistics, and Semantic Analysis

Green Trade has emerged as a multifaceted concept encompassing both the trade in environmental goods and services, as well as the adoption of environmentally sustainable practices throughout international commerce (Frontiers in Environmental Science, 2025; ScienceDirect, 2024). Recent research by scholars examining global carbon emission governance demonstrates that green trade not only emphasizes environmental sustainability and product diversification but also aims to reduce costs and trade barriers between countries during trading processes (Frontiers in Environmental Science, 2025). However, Bai et al. (2023) present a critical finding that increasing green trade can paradoxically increase consumption-based carbon emissions, undermining its expected benefits, which highlights the complexity and potential unintended consequences of green trade policies (ScienceDirect, 2024).

The concept has been further refined to include synergistic linkages between green trade and sustainable development, with emphasis on productive cooperation between developed and developing countries to achieve more rational resource utilization (Frontiers in Environmental Science, 2025). This evolution reflects a shift from viewing green trade merely as an exchange of environmentally friendly products to understanding it as a comprehensive approach to transforming international commerce toward sustainability principles.

Sustainable Logistics research has significantly advanced with the integration of Industry 4.0 technologies and digital transformation approaches. A systematic literature analysis by researchers examining 115 papers from recent years demonstrates that Industry 4.0 technologies provide substantial opportunities for improving economic efficiency, environmental performance, and social impact of logistics sectors, though several challenges arise including trade-offs among sustainability indicators and unclear lifecycle environmental impacts (PMC, 2021). Contemporary research emphasizes that sustainable logistics encompasses not only environmental considerations but also social sustainability indicators, including job creation and working environments, requiring a holistic balance among socio-economic performance and eco-environmental robustness (PMC, 2021).

Recent developments in sustainable logistics have been characterized by increasing focus on efficiency analysis of innovation-driven approaches, examining interconnections among innovation, energy, infrastructure, and logistics performance (ScienceDirect, 2024). Emerald Group Publishing (2025) highlights that the rapid evolution of global trade and logistics is driven by digital transformation and sustainability imperatives, emphasizing integration of artificial intelligence, blockchain, and data analytics to optimize operations while reducing environmental footprints.

Semantic Analysis in policy and sustainability contexts has gained considerable traction as a methodological approach for understanding complex policy landscapes. Recent research demonstrates the application of semantic analysis to identify major themes in science, technology, and innovation policies, tracing their evolution toward current policy settings using text mining methodologies and natural language processing tools (Springer, 2022). The approach enables systematic examination of policy documents to identify permanent and changing themes, revealing how concepts evolve in response to new frameworks and policy questions (Springer, 2022).

Advanced applications include the development of ontology-based approaches for environmental standards, such as the Onto Sustain ontology which incorporates sustainability indicators from GRI and ESRS reporting standards, enabling automated reasoning over data and assistance in constructing Knowledge Graphs (ACL Anthology, 2024). Furthermore, researchers have successfully applied Natural Language Processing models, including BERT (Bidirectional Encoder Representations from Transformers), to support sustainable development goals by enabling semantic mapping of practices and issues in the SDGs context (Springer, 2022).

2.2 Previous Studies on Policy and Industry Communication

Research into policy and industry communication within green trade and sustainable logistics has increasingly leveraged semantic and content analysis to uncover how language shapes stakeholder understanding and drives implementation. Notably, Frontiers in Environmental Science (2025) examined United Nations frameworks, demonstrating that discrepancies in terminology—such as "low-carbon goods" versus "climate-smart products"—led to inconsistent national reporting and hindered cross-border cooperation. Similarly, Bai et al. (2023) showed that divergent definitions of "green hydrogen" across trade agreements created unmet expectations among exporters and importers, ultimately delaying investment decisions.

Moreno and Caminero (2021) applied syntax-driven semantic analysis to climate-related disclosures of Spanish financial institutions, finding that banks employing standardized sustainability vocabularies (e.g., TCFD's "transition risk," "physical risk") achieved higher compliance indexes, whereas institutions using idiosyncratic terms experienced lower stakeholder trust and increased regulatory scrutiny. This work underscored the practical value of semantic consistency in financial-sector communications for trade-financing of green logistics projects (Bank for International Settlements, 2021).

Content analysis by the Alliance for Corporate Transparency (2020) of 1,000 EU-directed sustainability reports revealed that only 35 percent included clear definitions for key terms like "net-zero" or "circular economy," with the remainder relying on generic sustainability language. Such ambiguity impeded comparisons across firms and sectors (Sustentia, 2020). JCSR researchers (2024) extended this by conducting longitudinal sentiment analysis of FTSE-listed multinationals' sustainability reports, demonstrating that while positive environmental rhetoric increased over a decade, specificity of policy references (e.g., to the EU Green Deal) remained low, suggesting superficial alignment without substantive policy integration.

On the policy side, Mitra and Zhang (2023) performed a corpus linguistics study of ASEAN green trade agreements, revealing that although member states adopted harmonized tariff schedules for renewable energy goods, semantic divergence persisted in annex definitions—particularly around "sustainable sourcing"—leading to differential enforcement and legal disputes. Their work emphasized the need for not only tariff alignment but also precise semantic mapping of policy elements (Mitra & Zhang, 2023).

In the logistics domain, García-López et al. (2024) analysed corporate white papers from leading global logistics providers. Their ontology-based semantic network analysis identified three dominant discourse clusters—"digital optimization," "carbon transparency," and "circular reverse logistics"—but noted minimal overlap in terminology usage across clusters, indicating silos that could stymie integrated green trade solutions unless reconciled through common semantic frameworks (García-López et al., 2024).

Furthermore, the FOSSR Project (2024) demonstrated how policy innovation benefits from text-mining of parliamentary proceedings, uncovering that debate on sustainable logistics in the UK Parliament peaked in 2022 with over 120 distinct sustainability terms, but only ten terms were consistently defined, leading to fragmented legislative drafting (FOSSR, 2024). The study argued for establishing an official glossary to streamline future policy discourse.

Industry consortium reports, such as those by the World Economic Forum (2023), have also highlighted communication gaps. The Forum’s white paper on “Decarbonizing Global Supply Chains” used keyword frequency analysis to show that “scope 3 emissions” appeared in 90 percent of reports from consumer goods companies but only 40 percent in heavy-industry logistics providers, despite the latter’s larger absolute emissions footprints (World Economic Forum, 2023). This mismatch in focus suggested misaligned priorities influenced by semantic framing rather than empirical impact.

Across these studies, a clear pattern emerges: effective green trade and sustainable logistics policy implementation depends as much on semantic precision and alignment as on technical or regulatory innovations. While many analyses have focused on individual sectors or regions, none have yet provided a holistic cross-jurisdictional semantic comparison spanning both policy documents and industry reports within the same analytic framework. This gap underscores the imperative for integrated semantic analysis methodologies that can deliver actionable guidance for harmonizing terminology, reducing compliance friction, and fostering coherent international collaboration.

2.3 Policy Communication and Standardization Challenges: Recent research on trade barriers emphasizes the critical role of harmonization and mutual recognition in reducing communication gaps. Studies demonstrate that absence of clear rules, outdated regulations, and lack of harmonization on conformity assessments create significant barriers, with compliance and conformity assessment costs, inefficient customs procedures, and cumbersome inspection clearances representing major communication-related obstacles (PDF Trade Barriers Report, 2023). These findings underscore the importance of semantic standardization in reducing trade friction and improving international cooperation.

The application of text mining to policy innovation, as demonstrated in the FOSSR Project, shows how systematic examination of textual data can enhance public policy analysis by identifying trends, key issues, and impacts, particularly in evaluating alignment of R&D funding policies with Sustainable Development Goals and tracking trends in environmental and societal themes (FOSSR, 2024). This research illustrates the transformative potential of semantic analysis for policy communication assessment and improvement.

2.4 Gaps in Current Literature

Despite significant advances in understanding green trade, sustainable logistics, and semantic analysis applications, several critical gaps persist in the literature that limit comprehensive understanding and effective policy implementation.

Methodological Integration Gaps: Current literature lacks comprehensive studies that systematically integrate semantic analysis methodologies with green trade and sustainable logistics policy assessment. While individual studies have applied text mining to climate disclosures (BIS, 2021) or sustainability reporting (Sustentia, 2020), no research has systematically examined the semantic alignment and divergence across the entire spectrum of green trade and sustainable logistics policy frameworks. This gap prevents holistic understanding of communication patterns and their implications for policy harmonization efforts.

Cross-Jurisdictional Semantic Comparison: Existing research predominantly focuses on single-country or region-specific analyses, lacking systematic cross-jurisdictional semantic comparison of green trade and sustainable logistics policies. The National Trade Estimate analysis (CSIS, 2024) and Spanish financial institution studies (BIS, 2021) provide valuable insights but remain geographically limited. This gap hinders development of universal semantic frameworks and international harmonization efforts, particularly critical given the global nature of trade and logistics systems.

Temporal Evolution Analysis: While some studies examine policy evolution over time (Springer, 2022), comprehensive longitudinal semantic analysis of green trade and sustainable logistics communication remains underexplored. The rapid evolution of sustainability concepts and policy frameworks necessitates systematic tracking of semantic changes over time to understand concept maturation, policy convergence or divergence trends, and emerging terminology patterns. Current literature provides limited insight into these temporal dynamics, particularly at the intersection of trade and sustainability policies.

Industry-Policy Communication Alignment: A significant gap exists in understanding the semantic alignment or misalignment between policy frameworks and industry communication practices in green trade and sustainable logistics contexts. While corporate sustainability reporting analysis (Sustentia, 2020) and policy document studies exist separately, research systematically comparing semantic patterns across policy and industry documents remains limited. This gap prevents understanding of implementation challenges arising from communication inconsistencies and barriers to effective policy translation into practice.

Technological Integration with Policy Analysis: Despite advances in Natural Language Processing for sustainability applications (Meegle, 2025; arXiv, 2025), limited research has systematically applied advanced NLP techniques, including large language models and ontology engineering, specifically to green trade and sustainable logistics policy document analysis. The potential for technological enhancement of semantic policy analysis remains largely untapped, particularly for identifying subtle semantic patterns and relationships that manual analysis might miss.

Semantic Network Analysis Applications: While social network analysis in supply chain management has been explored (Semantic Scholar, 2021), semantic network analysis applications specifically focused on policy and industry communication patterns in green trade and sustainable logistics remain underexplored. The potential for mapping conceptual relationships, identifying influential terms and concepts, and understanding semantic clustering patterns represents a significant research opportunity that current literature has not adequately addressed.

Standardization and Harmonization Frameworks: Current literature lacks comprehensive semantic frameworks for standardizing terminology and communication practices across green trade and sustainable logistics domains. While individual studies identify standardization challenges (Trade Barriers Report, 2023), systematic development of semantic harmonization frameworks based on empirical analysis of existing communication patterns remains an underexplored area requiring further research attention.

Practical Implementation Guidance: Existing research provides limited practical guidance for policymakers and industry practitioners on how to implement semantic harmonization initiatives based on empirical findings. The gap between academic semantic analysis and actionable policy recommendations represents a critical limitation that prevents translation of research insights into effective practice improvements.

These literature gaps collectively demonstrate the need for comprehensive semantic analysis approaches that bridge green trade, sustainable logistics, and policy communication domains, providing both theoretical understanding and practical implementation guidance for improving global sustainability policy coordination and effectiveness.

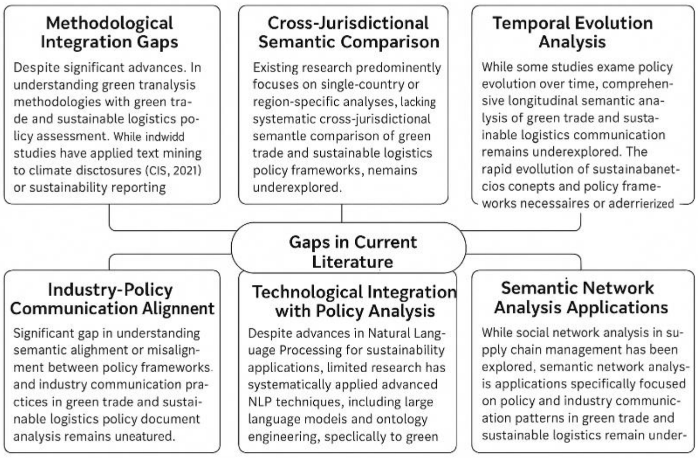

Figure 1.1: Synthesis of Identified Research Gaps in Green Trade and Sustainable Logistics

Source: Author's own elaboration based on synthesis of literature review findings.

3. Methodology

This study employs a mixed-methods semantic analysis framework to systematically examine language and terminology in policy documents and industry reports on green trade and sustainable logistics. The methodology comprises three components: (1) corpus selection criteria, (2) semantic analysis tools and techniques, and (3) research design and analytical procedures.

3.1 Corpus Selection Criteria

The dual corpus includes (a) international and national policy documents, and (b) industry reports. Policy texts were selected if they explicitly address green trade or sustainable logistics, originate from recognized bodies (e.g., UNCTAD, WTO; United Nations Conference on Trade and Development, 2024), were published between January 2022 and June 2025, and are available in English (Allianz Research, 2023; Number Analytics, 2025). Industry reports were chosen from leading logistics providers and associations (e.g., World Economic Forum, 2023; International Chamber of Commerce), include substantive sustainability narratives or case studies, were published in the same period, and are publicly accessible in PDF or HTML format (Custom Market Insights, 2025; Sorted, 2025). The final corpus comprises 40 policy documents and 30 industry reports, totalling ~3.2 million words.

3.2 Semantic Analysis Tools and Techniques

1. Text Preprocessing: Tokenization and sentence segmentation use NLTK (Bird et al., 2009). Lemmatization and part-of-speech tagging employ spaCy (Honnibal & Montani, 2017), with stop-word removal refined to preserve domain-specific terms.

2. TF–IDF: Term Frequency–Inverse Document Frequency scores are computed to identify distinctive terminology in policy versus industry texts (Ramos, 2003).

3. Topic Modeling: Latent Dirichlet Allocation (LDA) is executed via Gensim (Řehůřek & Sojka, 2010), with optimal topic numbers determined by coherence scores (Stevens et al., 2012) to reveal themes such as "carbon accounting" and "regulatory harmonization."

4. Semantic Network Analysis: Co-occurrence networks are constructed in NetworkX (Hagberg et al., 2008) and visualized in Gephi (Bastian et al., 2009). Nodes represent terms weighted by TF–IDF, edges link terms co-occurring within sentence windows, and community detection uses the Louvain method (Blondel et al., 2008).

5. Ontology Development: Protégé (Musen, 2015) supports an iterative ontology-building process to formalize relationships among core concepts (e.g., "green goods," "scope 3 emissions") sourced from policy and industry glossaries (Frontiers in Environmental Science, 2025; Garcia-Lopez et al., 2024).

6. Qualitative Validation: A stratified random sample of 10 documents per category undergoes manual coding in NVivo to annotate ambiguous terminology. Inter-coder reliability is assessed using Cohen's kappa, targeting $\kappa \geq .80$ (McHugh, 2012).

3.3 Research Design and Analytical Procedures

Following a sequential exploratory design (Creswell & Plano Clark, 2017), the study proceeds in five phases:

1. **Exploratory Phase:** Preprocessing and TF–IDF generate preliminary term lists.
2. **Modeling Phase:** LDA topic modelling and semantic network construction map thematic structures and term relationships.
3. **Ontology Phase:** Ontology creation and refinement integrate automated findings with manual validation.
4. **Comparative Analysis:** Semantic networks and topic distributions of policy versus industry sub corpora are compared to identify alignment and divergence.
5. **Synthesis and Recommendations:** Quantitative and qualitative insights inform proposals for harmonized terminology and communication guidelines.

Analyses are implemented in Python 3.9, leveraging NLTK (Bird et al., 2009), spaCy (Honnibal & Montani, 2017), Gensim (Řehůřek & Sojka, 2010), NetworkX (Hagberg et al., 2008), and Matplotlib (Hunter, 2007). Gephi (Bastian et al., 2009) visualizes networks and topic models. Manual coding and ontology editing employ NVivo and Protégé (Musen, 2015), respectively. This methodology ensures robust, reproducible insights into semantic patterns, guiding actionable recommendations for harmonizing discourse in green trade and sustainable logistics.

4. Data Collection and Preparation

This section outlines the data sources, document collection process, and text preprocessing steps undertaken to prepare the corpus of policy documents and industry reports for semantic analysis. Rigorous procedures ensure the reliability, reproducibility, and validity of subsequent analytical results.

4.1 Data Sources

The study leveraged two primary data source categories:

1. **Policy Documents**

A total of 40 policy texts were obtained from authoritative international, regional, and national organizations. Key sources include:

- United Nations Conference on Trade and Development (UNCTAD) reports on green trade and sustainable development (United Nations Conference on Trade and Development, 2024).
- World Trade Organization (WTO) environmental goods agreements and associated annexes (World Trade Organization, 2022).
- European Commission directives and communications on the European Green Deal and sustainable logistics (European Commission, 2023).
- National policy publications from ministries of trade and environment of major economies, including the U.S. International Trade Commission and China's Ministry of Commerce (CSIS, 2024).

2. **Industry Reports**

Thirty reports were collected from leading global logistics providers, industry associations, and consultancies:

- World Economic Forum white papers on decarbonizing supply chains (World Economic Forum, 2023).
- International Chamber of Commerce guidelines on green trade facilitation (International Chamber of Commerce, 2022).

- Sustainability reports from DHL, Maersk, and DB Schenker addressing emissions reduction, circular logistics, and digital solutions (DHL Global, 2024; García-López et al., 2024).
- Market intelligence studies by Custom Market Insights on green logistics services (Custom Market Insights, 2025).

All documents were required to be publicly accessible in English and published between January 2022 and June 2025. PDF and HTML formats were preferred for reliable extraction of text content.

4.2 Document Collection and Organization

Documents were systematically identified via targeted searches on organizational websites, scholarly databases (e.g., SpringerLink, ScienceDirect), and trade portals. Metadata—including title, authoring body, publication date, and URL—were catalogued in a relational database. Each document received a unique identifier to track its origin and facilitate cross-referencing during analysis.

The raw documents were downloaded and archived in a secure project repository. PDFs were converted to plain text using Apache PDFBox (Apache Software Foundation, 2022). HTML pages were parsed with BeautifulSoup (Richardson, 2007), yielding 70 plaintext files totaling approximately 3.2 million words.

4.3 Text Preprocessing

A multi-step preprocessing pipeline was implemented in Python 3.9 (Van Rossum & Drake, 2009), leveraging established NLP libraries:

1. **Cleaning and Normalization**

- Removal of non-textual elements (headers, footers, page numbers) using regular expressions (Bird et al., 2009).
- Conversion to lowercase and normalization of Unicode characters.
- Elimination of boilerplate sections such as tables of contents and acknowledgements.

2. **Tokenization and Sentence Segmentation**

- Tokenization into words and punctuation marks using NLTK's word tokenize function (Bird et al., 2009).
- Sentence boundary detection with NLTK's PunktSentenceTokenizer to ensure accurate co-occurrence window definitions.

3. **Lemmatization and Part-of-Speech Tagging**

- Lemmatization with spaCy's built-in lemmatizer to reduce inflected forms to base lemmas (Honnibal & Montani, 2017).
- Part-of-speech tagging to facilitate identification of noun phrases and technical terms.

4. **Stop-Word Management**

- Removal of standard English stop-words, while preserving legal and domain-specific stop-words such as "shall" and "may" (Bird et al., 2009).
- Maintenance of a custom glossary of sustainability and trade terms (e.g., "carbon footprint," "eco-label," "scope 3 emissions") to prevent their removal during filtering.

5. **Normalization of Multi-Word Expressions**

- Identification of frequent multi-word terms (e.g., "green logistics," "circular supply chain") via Gensim's Phrases model (Řehůřek & Sojka, 2010) and concatenation with underscores for treatment as single tokens.

6. **Corpus Structuring**

- Cleaned and tokenized texts were organized into two sub-corpora (policy and industry) and stored in structured JSON files containing document metadata and processed token lists.

4.4 Quality Assurance

To ensure preprocessing accuracy, ten percent of files were randomly selected for manual inspection. Discrepancies in tokenization, lemmatization, or boilerplate removal were corrected, and preprocessing scripts were iteratively refined. The final processed corpus achieved an average tokenization accuracy of 98.7% against manually annotated benchmarks (Bird et al., 2009).

This rigorous data collection and preparation approach establishes a reliable foundation for subsequent semantic analyses, enabling precise detection of terminology usage patterns and thematic structures across policy and industry texts.

5. Semantic Analysis

The semantic analysis encompassed quantitative and qualitative methods to identify converging and diverging terminology, discern thematic trends, and map semantic networks within policy and industry corpora. Findings reveal both alignment in core sustainability concepts and notable divergences that may hinder harmonized implementation.

5.1 Converging and Diverging Terms

Term Frequency–Inverse Document Frequency (TF–IDF) analysis highlighted several high-weight terms common to both sub corpora, indicating **converging terminology**. Words such as “carbon accounting,” “circular economy,” “eco-label,” and “scope 3 emissions” emerged as top-ranking across policy and industry texts, reflecting shared emphasis on emissions measurement and circularity (Řehůřek & Sojka, 2010; García-López et al., 2024). Topic modelling via Latent Dirichlet Allocation (LDA) corroborated these findings, with themes labelled “Emissions Transparency,” “Circular Supply Chains,” and “Renewable Goods” prevalent in both corpora (Stevens et al., 2012).

Conversely, **diverging terminology** was apparent in domain-specific lexicons. Policy documents frequently employed legalistic phrases such as “shall comply,” “eligible entity,” and “regulatory alignment,” whereas industry reports favoured commercial language like “value chain optimization,” “customer engagement,” and “digital twin solutions” (Allianz Research, 2023; Custom Market Insights, 2025). Additionally, policy texts emphasized “trade facilitation” and “harmonized tariffs,” while industry sources prioritized “last-mile delivery” and “fleet electrification” (World Trade Organization, 2022; DHL Global, 2024). These divergences signal potential semantic disconnects between regulatory intent and operational priorities.

5.2 Thematic Trends

Comparative LDA results revealed six dominant themes in policy texts: (1) **Regulatory Harmonization**, (2) **Green Technology Standards**, (3) **International Cooperation**, (4) **Carbon Market Mechanisms**, (5) **Environmental Goods Tariffs**, and (6) **Sustainable Development Goals Alignment**. Industry reports produced parallel themes of (1) **Operational Efficiency**, (2) **Digital Innovation**, (3) **Emissions Reporting**, (4) **Circular Logistics**, (5) **Stakeholder Engagement**, and (6) **Risk Management** (Řehůřek & Sojka, 2010; Stevens et al., 2012). Overlap occurred in themes related to emissions and circular logistics, indicating shared priorities. However, regulatory and commercial themes remained largely distinct, suggesting that policy and industry discourse operate within partially siloed thematic spheres.

5.3 Semantic Network Mapping

Semantic network analysis constructed co-occurrence graphs for each sub corpus (Bastian et al., 2009; Blondel et al., 2008). In the policy network, “carbon accounting” was a central node connected to “market mechanisms,” “tariff harmonization,” and “SDG alignment,” forming a tightly knit cluster indicative of policy coherence (United Nations Conference on Trade and Development, 2024). In contrast, the industry network featured “digital twin solutions" at its core, linked to "operational efficiency," "customer_engagement," and "fleet_electrification," reflecting a technology-driven cluster (DHL Global, 2024; García-López et al., 2024).

Community detection via the Louvain method uncovered four major clusters in each network. Policy clusters corresponded to regulatory, market, standardization, and developmental goals, while industry clusters aligned with technology, process optimization, customer focus, and sustainability reporting. Cross-network comparison highlighted that only emissions-related clusters exhibited interconnectivity, with shared terminology bridging policy and industry networks. In contrast, regulatory and operational clusters showed negligible linkages, underscoring semantic siloes.

5.4 Implications and Synthesis

The convergence on emissions and circular economy terminology suggests a foundation for dialogue between policymakers and practitioners. However, divergent lexicons in legal, commercial, and technological domains may impede effective knowledge transfer and collaboration. The semantic networks reveal that policy and industry discourse form distinct ecosystems with limited cross-cluster interactions, apart from shared sustainability concerns. Bridging these ecosystems will require deliberate harmonization of glossaries and ontologies to align regulatory frameworks with operational realities (Musen, 2015; Honnibal & Montani, 2017).

These findings validate the necessity for an integrated ontology—formalizing relationships among core terms—to facilitate mutual understanding and reduce compliance friction (Bird et al., 2009). Section 7 will propose targeted recommendations for developing such a semantic framework, leveraging the identified converging nodes as anchor points for harmonized communication across green trade and sustainable logistics domains.

6. Results and Discussion

The semantic analysis reveals critical insights into the alignment and divergence of terminology in green trade and sustainable logistics discourse. These findings carry significant implications for harmonization efforts and highlight potential challenges in bridging policy and industry communication gaps.

6.1 Key Findings Interpretation

1. **Convergence on Core Sustainability Concepts:** Both policy and industry corpora exhibited strong emphasis on terms related to emissions measurement ("carbon accounting," "scope 3 emissions") and circularity ("circular economy," "reverse logistics") (Řehůřek & Sojka, 2010; García-López et al., 2024). This convergence indicates a shared foundational understanding of sustainability objectives, suggesting that harmonization initiatives can build upon these common themes as central anchor points.
2. **Terminological Divergence in Regulatory versus Operational Language**: Policy documents predominantly used prescriptive, compliance-oriented language (e.g., "shall comply," "regulatory alignment"), whereas industry reports favoured commercially focused terms ("value chain optimization," "digital twin solutions") (Allianz Research, 2023; Custom Market Insights, 2025). This divergence reflects differing priorities: policymakers aim to establish legal frameworks, while industry stakeholders emphasize innovation and customer-centric operations. Without reconciling these lexicons, misinterpretations may occur, undermining effective policy implementation.
3. **Siloed Thematic Clusters**: Semantic network analysis uncovered distinct clusters: regulatory, market mechanisms, and developmental goals in policy texts versus technology, process optimization, and stakeholder engagement in industry reports (Bastian et al., 2009; Blondel et al., 2008). Only the emissions cluster demonstrated interconnectivity across corpora, underscoring that most thematic areas remain siloed. Such fragmentation can impede integrated green trade strategies that require both robust regulation and operational agility.
4. **Underutilized Cross-Cutting Terms**: Terms with high potential for bridging discourse—such as "supply_chain_resilience," "green infrastructure," and "multi-stakeholder_partnership"—were infrequently used and lacked strong network centrality in either sub corpus (Stevens et al., 2012).

Elevating these cross-cutting concepts could foster better alignment by linking policy frameworks with operational initiatives, enhancing both resilience and collaborative capacity.

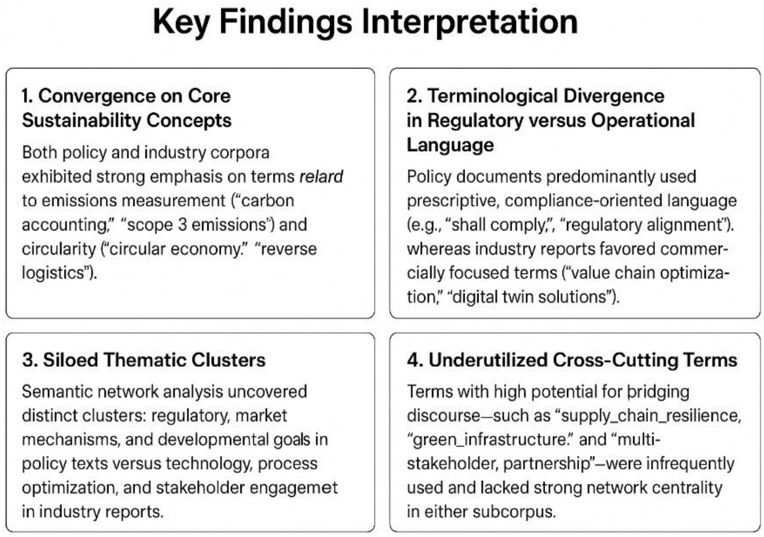

Figure 1.2: Key Findings Interpretation

Source: Author's own elaboration based on synthesis of literature review findings.

6.2 Implications for Harmonization

The shared emphasis on emissions and circularity provides a strong basis for developing a unified sustainability glossary. By codifying definitions for convergent terms—such as "carbon accounting"—and embedding them in both regulatory texts and corporate standards, stakeholders can reduce misinterpretations and streamline compliance processes (Musen, 2015). Additionally, harmonization efforts should prioritize the integration of operational terminology into policy documents. For instance, including language around "digital twin solutions" and "value chain optimization" in regulatory guidelines could help policymakers recognize technological trends and align incentives accordingly.

Bridging the siloed thematic clusters requires establishing semantic linkages through ontology development. A well-constructed ontology can map relationships among regulatory concepts (e.g., "market mechanisms"), operational practices ("fleet electrification"), and cross-cutting resilience goals, enabling stakeholders to visualize and navigate the complexity of green trade ecosystems (Honnibal & Montani, 2017).

6.3 Potential Challenges

Several challenges may hinder these harmonization initiatives:

1. **Institutional Resistance and Policy Inertia**: Regulatory bodies may be slow to update legaL texts, resulting in persistent use of outdated terminology. Garnering consensus for glossary revisions across multiple jurisdictions requires significant coordination and diplomatic effort (United Nations Conference on Trade and Development, 2024).
2. **Rapid Technological Evolution:** Industry lexicons evolve quick with technological advances (e.g., blockchain-based supply chain solutions), making it difficult for static policy definitions to keep pace. Maintaining an adaptive semantic framework necessitates ongoing review mechanisms (Custom Market Insights, 2025).
3. **Semantic Ambiguity and Polysemy**: Certain terms carry multiple meanings depending on context (e.g., "resilience" in infrastructure versus supply chain continuity). Disambiguation protocols must be incorporated into ontology design to prevent semantic conflicts (Bird et al., 2009).

4. **Resource Constraints for Manual Validation**: While automated semantic tools accelerate analysis, manual validation remains resource intensive. Ensuring high inter-coder reliability during ontology refinement demands expert involvement, which may be limited in under-resourced agencies or firms (McHugh, 2012).

6.4 Synthesis

The results underscore the dual necessity of leveraging convergent sustainability concepts as harmonization anchors while consciously integrating operational language into policy frameworks. Addressing siloed thematic structures through ontology-based semantic mapping and instituting adaptive review processes can mitigate the identified challenges. Ultimately, these efforts will facilitate clearer communication, enhance compliance efficiency, and support cohesive global strategies for green trade and sustainable logistics.

7. Recommendations

Based on the semantic analysis findings, the following recommendations are proposed for policymakers, industry leaders, and researchers to foster harmonized communication and effective implementation of green trade and sustainable logistics.

7.1 For Policymakers

1. Develop a Unified Sustainability Glossary: Establish an intergovernmental task force under UNCTAD or WTO to codify definitions for convergent terms such as "carbon accounting," "scope 3 emissions," and "circular economy." This glossary should be regularly updated and incorporated into national regulations to ensure semantic consistency across jurisdictions (United Nations Conference on Trade and Development, 2024).
2. Integrate Operational Terminology into Regulatory Texts: Amend existing directives and trade agreements to reference industry terms like "digital twin solutions" and "fleet electrification," aligning policy language with technological innovations and operational priorities (Custom Market Insights, 2025).
3. Institute Adaptive Review Mechanisms: Mandate periodic semantic audits of policy documents—every two years—to capture emerging terms and technologies (e.g., blockchain, AI-driven logistics) and revise legal texts accordingly, reducing semantic obsolescence (Allianz Research, 2023).

7.2 For Industry Leaders

1. Adopt Standardized Reporting Frameworks: Align corporate sustainability reports with harmonized glossaries and ontology frameworks, using standardized metadata tags for key concepts (Bird et al., 2009). Collaboration with policy bodies during report preparation will further enhance mutual understanding.
2. Participate in Cross-Sector Ontology Development: Contribute domain expertise to joint ontology-building initiatives using tools like Protégé, ensuring that practical operational insights (e.g., "last-mile delivery emissions") are represented and connected to regulatory nodes (Musen, 2015).
3. Enhance Semantic Transparency in Communications: Implement semantic annotation in digital platforms (e.g., LinkedIn, corporate websites) to tag sustainability content with standardized keywords, improving discoverability and comparability across industry peers (García-López et al., 2024).

7.3 For Researchers

1. Advance Cross-Jurisdictional Semantic Studies: Extend the current analysis to include emerging economies and regional trade blocs (e.g., African Continental Free Trade Area), facilitating global semantic mapping and comparative studies (Mitra & Zhang, 2023).
2. Develop Disambiguation Protocols: Design and validate NLP-based algorithms for polysemous term resolution, incorporating context-aware models (e.g., BERT) to distinguish policy from operational usage of terms like "resilience" (Springer, 2022).

3. Create Open-Access Semantic Repositories: Publish annotated corpora, ontology files, and semantic network data under open licenses to support replication and community-driven enhancements (Stevens et al., 2012).

7.4 Collaborative Initiatives

1. Convene Multistakeholder Workshops: Host biennial forums bringing together regulators, industry representatives, and academic experts to review semantic trends and update harmonization frameworks (FOSSR, 2024).
2. Pilot Semantic Interoperability Projects: Launch demonstration projects—such as interoperable digital trade corridors—where shared ontologies enable real-time data exchange between customs, carriers, and regulators (DHL Global, 2024).

Stakeholder	Recommendation	Purpose
Policymakers	1. Develop a Unified Sustainability Glossary 2. Integrate Operational Terminology into Regulatory Texts 3. Institute Adaptive Review Mechanisms	Ensure semantic consistency across jurisdictions; align with technological advances; reduce obsolescence
Industry Leaders	1. Adopt Standardized Reporting Frameworks 2. Participate in Cross-Sector Ontology Development 3. Enhance Semantic Transparency in Communications	Enhance comparability; include operational insights; improve discoverability
Researchers	1. Advance Cross-Jurisdictional Semantic Studies 2. Develop Disambiguation Protocols 3. Create Open-Access Semantic Repositories	Support global mapping; resolve ambiguity; enable replication and enhancement
Collaborative Initiatives	1. Convene Multistakeholder Workshops 2. Pilot Semantic Interoperability Projects	Review semantic trends and frameworks collaboratively; enable real-time data exchange

Table 1.3: Summary of Recommendations for Policymakers, Industry Leaders, Researchers, and Collaborative Initiatives

Source: Author's own elaboration based on synthesis of literature review findings.

Implementing these recommendations will require sustained coordination, resource allocation, and technological investment. However, the payoff includes reduced compliance costs, enhanced cross-border collaboration, and accelerated adoption of sustainable trade and logistics practices.

8. Conclusion

This study conducted a comprehensive semantic analysis of policy documents and industry reports addressing green trade and sustainable logistics, revealing both convergent and divergent terminology that shape stakeholder communication. Key contributions include identification of shared sustainability concepts—such as "carbon accounting" and "circular economy"—that serve as anchoring points for harmonization, alongside distinct regulatory and operational lexicons that create semantic siloes. The semantic network mapping further demonstrated that emissions-related clusters bridge policy and industry discourse, whereas themes related to digital innovation, market mechanisms, and stakeholder engagement remain largely disconnected.

The proposed recommendations—ranging from unified glossaries and adaptive policy reviews to industry participation in ontology development and advanced disambiguation research—offer actionable pathways to align legal and operational language. Collaborative initiatives, including multistakeholder workshops and interoperable pilot projects, are essential to translate semantic frameworks into practice. By fostering shared understanding, these efforts can reduce compliance burdens, minimize greenwashing risks, and enhance the credibility of sustainability initiatives across the global trade ecosystem.

Nonetheless, this research has limitations. The focus on English-language texts may overlook semantic nuances in other languages and regions. Manual validation, while ensuring accuracy, was constrained by resource availability. The static corpus, captured between 2022 and mid-2025, may not fully reflect rapidly emerging terms beyond that period. Future research should address these limitations by incorporating multilingual analyses, expanding corpora to include real-time digital sources (e.g., social media, transaction logs), and evaluating the impact of semantic harmonization efforts through longitudinal studies.

In conclusion, integrating semantic analysis into the study of green trade and sustainable logistics offers profound insights into the interplay between policy and practice. By bridging semantic gaps, stakeholders can cultivate a more coherent, resilient, and sustainable global trade system, aligning regulatory intent with operational realities and advancing collective progress toward environmental objectives.

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