



ARTIFICIAL INTELLIGENCE IN GREEN LOGISTICS AND ENVIRONMENTAL PERFORMANCE: A BIBLIOMETRIC ANALYSIS OF GLOBAL RESEARCH TRENDS (2016-2026)

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ABSTRACT

The environmental impact of logistics operations has accelerated the adoption of Artificial Intelligence (AI) to enhance operational efficiency and environmental performance. However, research on AI-enabled green logistics remains fragmented, limiting a comprehensive understanding of its intellectual development. This study presents a bibliometric analysis of AI-enabled green logistics research using 1,929 peer-reviewed journal articles indexed in Scopus between 2016 and May 2026. Following data cleaning with OpenRefine, performance analysis and science mapping were conducted using VOSviewer and Scopus analytical tools, including citation, keyword co-occurrence, and co-authorship analyses. The findings indicate rapid publication growth since 2020, with machine learning, intelligent transportation systems, optimisation, emission reduction, and energy efficiency emerging as dominant research themes. The United States, China, and the United Kingdom lead global research collaboration, although the field remains conceptually fragmented with limited theoretical integration. This study provides a comprehensive knowledge map, identifies key research gaps, and proposes future research directions for AI-enabled green logistics and environmental performance.

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1. INTRODUCTION

Green logistics has developed as a strategic response to escalating environmental concerns, tightening regulatory requirements, and increasing societal expectations for improved environmental performance. Logistics activities are among the primary sources of greenhouse gas emissions, energy use, as well as urban pollution, thereby representing critical leverage points for enhancing environmental outcomes across supply chains (Chen et al., 2024; Challouf et al., 2025; Fang et al., 2023; Mrad et al., 2025). In parallel, the logistics sector is undergoing rapid digital transformation, driven by innovations including the Internet of Things (IoT), big data analytics, Artificial Intelligence (AI), as well as robotics. These technologies enable enhanced visibility, automation, and optimisation of logistics operations (Benzidia et al., 2021; Nunes, 2025; Rodrigues et al., 2025; Farshadfar et al., 2024).

The convergence of environmental imperatives and AI-enabled capabilities is fundamentally reshaping how logistics systems are designed, managed, and evaluated. AI-enabled solutions are increasingly applied across various logistics activities, including transportation, warehousing, last-mile delivery, and reverse logistics, all with the objective of strengthening operational efficiency while simultaneously mitigating environmental consequences (Chen et al., 2024; Ferreira & Esperança, 2025; Fang et al., 2023). This transformation highlights the growing significance of embedding sophisticated technological systems within green logistics frameworks to improve environmental performance.

Despite the rapid growth of research in this domain, existing studies remain fragmented across multiple disciplines, including engineering, operations management, and environmental science. There is limited synthesis of how AI specifically contributes to environmental performance in green logistics contexts. Therefore, a comprehensive bibliometric analysis of the research landscape is necessary to consolidate existing knowledge, identify key trends, and highlight emerging research directions. This research responds to that requirement by delivering an extensive bibliometric examination of AI in green logistics for environmental performance.

2. LITERATURE REVIEW

Growing evidence suggests that AI, as well as data-driven technologies, contributes meaningfully to improving environmental outcomes by optimising resource utilisation, reducing waste, and lowering emissions. Empirical studies indicate that AI and big data analytics strengthen green supply chain collaboration as well as environmental process integration, leading to improved environmental performance in industries including manufacturing and healthcare (Benzidia et al., 2021; Rashid et al., 2024). Recent systematic reviews highlight that AI-enabled optimisation in logistics ranks as one of the most effective approaches for lowering emissions associated with transportation activities, while robotics contributes to increased energy efficiency in warehousing operations (Mrad et al., 2025). At a broader level, AI technologies are also recognised as important enablers for achieving environmental objectives through improved energy management as well as reductions in waste generation (Fan et al., 2023).

Other than that, urbanisation and the rapid growth of e-commerce have further intensified pressure on logistics systems, particularly in last-mile delivery and urban freight operations. AI-enabled frameworks integrating autonomous vehicles and IoT

technologies have been proposed to optimise route planning, traffic management, and demand forecasting, thereby reducing congestion and carbon emissions (Mohsen, 2024). Empirical evidence demonstrates that AI-based optimisation combined with electric vehicles can significantly improve delivery efficiency and reduce emissions in urban logistics (Ferreira & Esperança, 2025). Similarly, data-driven decision support systems utilising machine learning and optimisation techniques have been established to enhance capacity utilisation and reduce environmental impacts in densely populated cities (Gutiérrez-Franco et al., 2021). These findings indicate that AI-enabled logistics systems can simultaneously achieve operational efficiency and environmental performance improvements.

Beyond forward logistics, AI is progressively being embedded within reverse logistics systems and circular economy frameworks. Industry 4.0 innovations, notably AI, the IoT, and blockchain technologies, strengthen transparency, process automation, and environmental sustainability across functions such as recycling activities, remanufacturing processes, and the recovery of usable resources (Rodrigues et al., 2025). Machine learning applications support supplier selection, waste reduction, and operational optimisation in circular supply chains, while AI-enabled waste management systems strengthen efficiency while simultaneously mitigating environmental consequences across smart cities (Farshadfar et al., 2024; Fang et al., 2023). These developments highlight the role of AI in enabling circular as well as regenerative logistics systems.

At the operational level, AI technologies are transforming essential logistics activities such as warehousing, transportation, as well as inventory management. Intelligent warehousing systems that integrate machine learning, IoT, and robotics improve efficiency, reduce energy consumption, and minimise material waste (Arvind et al., 2025). Consequently, advanced optimisation algorithms further enhance operational performance by reducing logistics costs and emissions (Li et al., 2023). However, emerging concerns regarding the environmental footprint of AI itself have led to growing interest in “green AI,” which emphasises the development of energy-efficient algorithms and sustainable digital infrastructure (Bolón-Canedo et al., 2024).

From a strategic standpoint, organisational capabilities and alignment with green strategies are critical in translating AI adoption into improved environmental performance. AI capabilities, when integrated with green business strategies and supply chain practices, contribute to sustainable outcomes through mechanisms such as innovation and knowledge integration (Liu et al., 2026). Nevertheless, the literature also identifies a range of obstacles, such as substantial implementation expenses, intricate technological demands, heterogeneous data structures, as well as limited real-world applications. These gaps indicate a continuing requirement for additional investigation into how AI can be optimally leveraged to support environmental performance in logistics systems.

3. RESEARCH QUESTION

The following research questions are formulated to yield insights into the field’s evolution, themes, influence, and collaboration patterns, as well as to examine how these developments translate into organisational and strategic outcomes in practice.

RQ1: How has the volume of scholarly publications on Artificial Intelligence (AI) in green logistics for environmental performance evolved between 2016 and May 2026?

RQ2: Which publications are the most influential in the field of Artificial Intelligence (AI) in green logistics for environmental performance, as measured by citation impact?

RQ3: What are the dominant and emerging research themes in Artificial Intelligence (AI) in green logistics for environmental performance, as identified through keyword co-occurrence analysis?

RQ4: What patterns of international research collaboration can be identified in Artificial Intelligence (AI) in green logistics for environmental performance, based on country-level co-authorship networks?

4. RESEARCH GAP AND CONTRIBUTION

Even though scholarly attention is focused on AI in logistics and environmental performance, the existing literature remains fragmented and predominantly technology-driven, with limited integration across AI technologies, green logistics practices, and environmental performance outcomes. In particular, there is an absence of an overarching integrative review that methodically charts the thematic evolution, intellectual structure, as well as global collaboration patterns of this interdisciplinary field. Furthermore, current studies exhibit a strong bias toward computational optimisation, with insufficient theoretical integration and limited empirical evidence linking AI applications to measurable environmental performance. This highlights the need for a structured, holistic bibliometric analysis to consolidate existing knowledge, identify critical gaps, and guide future research on AI-enabled green logistics and environmental performance.

5. METHODOLOGY

Bibliometric analysis refers to the structured process of retrieving, organising, and quantitatively analysing bibliographic information extracted from scholarly literature (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). In addition to descriptive metrics such as publication venues, chronological patterns, and prominent authorship contributions (Wu & Wu, 2017), it also applies more sophisticated analytical methods, including document co-citation mapping, to reveal the underlying intellectual architecture of a given research domain. Conducting a rigorous bibliometric review necessitates an iterative, transparent methodology that involves carefully defined keyword identification, exhaustive database searches, and systematic data screening followed by detailed analysis. This methodical framework supports the development of a dependable and reproducible dataset, thereby strengthening the overall validity and robustness of the research outcomes (Fahimnia et al., 2015).

Consistent with this rationale, the current investigation concentrates on scholarly outputs of substantial impact, given that such works yield essential perspectives on both the theoretical frameworks and methodological underpinnings of the field. In order to maintain precision and uniformity in the dataset, the Scopus database was selected as the principal repository for bibliographic information (Al-Khoury et al., 2022; Di Stefano et al., 2010; Khiste & Paithankar, 2017). In accordance with widely accepted academic conventions, the dataset was restricted exclusively to peer-reviewed journal articles, whereas non-refereed materials, including books and lecture notes, were deliberately excluded (Gu et al., 2019). Leveraging the comprehensive indexing breadth of Scopus, all pertinent publications published

between 2016 and May 2026 were methodically extracted for further bibliometric examination.

6. DATA SEARCH STRATEGY

The bibliometric dataset was developed through the Scopus database, which was chosen due to its broad indexing of peer-reviewed scholarly literature and its suitability for quantitative mapping and analysis tools. Table 1 presents a structured Boolean search strategy that was implemented within the TITLE-ABS-KEY field to retrieve publications situated at the convergence of three core constructs, namely green logistics, AI, as well as environmental performance. The search string integrated a wide-ranging set of synonymous and conceptually aligned terms (e.g., “machine learning,” “deep learning,” “big data analytics,” “green transportation,” “reverse logistics,” “carbon emissions,” and “energy efficiency”) to maximise retrieval accuracy while maintaining conceptual relevance. To further refine the dataset and ensure disciplinary alignment, subject area filters were applied, limiting results to environmental science, computer science, energy, as well as business, management, and accounting. Additional constraints were imposed to enhance data quality, including English-language publications, the final publication stage, journal articles as the document type, and a publication timeframe spanning 2016 to May 2026. This systematic retrieval process yielded an initial dataset of 1,929 records for subsequent screening and analysis.

Table 1: The search string

Scopus	TITLE-ABS-KEY ((“artificial intelligence” OR “artificial intelligence in logistics” OR “artificial intelligence in green logistics” OR “machine learning” OR “deep learning” OR “AI” OR “neural network*” OR “reinforcement learning” OR “predictive analytics” OR “big data analytics” OR “expert system*” OR “decision support system*” OR “intelligent system*”)) AND ((“green logistics” OR “sustainable logistics” OR “eco-logistics” OR “environmental logistics” OR “low-carbon logistics” OR “green transportation” OR “sustainable transportation” OR “eco-transportation” OR “green freight transport*” OR “green distribution” OR “reverse logistics” OR “green warehousing” OR “sustainable warehousing” OR “eco-warehousing”)) AND ((“environmental performance” OR “environmental impact” OR “environmental efficiency” OR “environmental sustainability” OR “carbon emission*” OR “CO2 emission*” OR “greenhouse gas emission*” OR “GHG emission*” OR “energy efficiency” OR “energy consumption” OR “emission reduction” OR “pollution reduction” OR “carbon footprint” OR “ecological performance”)) AND (LIMIT-TO (SUBJAREA , “COMP”) OR LIMIT-TO (SUBJAREA , “ENVT”) OR LIMIT-TO (SUBJAREA , “ENER”) OR LIMIT-TO (SUBJAREA , “BUSI”)) AND (LIMIT-TO (LANGUAGE , “English”)) AND (LIMIT-TO (PUBSTAGE , “final”)) AND (LIMIT-TO (DOCTYPE , “ar”)) AND (LIMIT-TO (SRCTYPE , “j”)) AND PUBYEAR > 2015 AND PUBYEAR < 2027
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Subsequently, a rigorous screening process was conducted in accordance with predetermined inclusion and exclusion criteria, as outlined in Table 2. Only peer-reviewed journal articles published in English within the selected subject areas were retained to ensure consistency and academic quality. Non-relevant document types, including review papers, conference proceedings, editorials, retracted articles, and non-journal sources like trade publications and books, were deliberately omitted in order to preserve methodological consistency. In addition, the analysis was confined exclusively to fully published studies, with articles in press excluded to avoid

incomplete bibliographic information. The temporal scope was also constrained to works published from 2016 forward, ensuring that the dataset reflects contemporary advancements in AI-enabled green logistics research. This multi-stage filtering approach ensured the development of a robust and reliable dataset, suitable for subsequent bibliometric mapping and analysis.

Table 2: The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Subject	Computer Science, Environmental Science, Energy, Business, Management and Accounting	Others
Document Type	Article	Review, conference paper, retracted, editorial
Source Type	Journal	Conference proceedings, books, book series and trade journals
Publication Stage	Final	Article in press
Timeline	2016-May 2026	Before 2016

7. DATA ANALYSIS

VOSviewer is a broadly utilised and highly accessible instrument for bibliometric analysis, created by Nees Jan van Eck and Ludo Waltman at Leiden University (van Eck & Waltman, 2010; van Eck & Waltman, 2017). The programme is purpose-built for the visual representation and examination of scholarly literature, incorporating sophisticated capabilities for the construction of network visualisations, the grouping of interconnected entities into clusters, and the production of density-based maps. Its adaptability permits the investigation of a wide range of bibliometric associations, encompassing co-authorship structures, co-citation linkages, and keyword co-occurrence patterns, thereby enabling an extensive and nuanced mapping of research domains. With an interactive user interface and regularly maintained updates, VOSviewer supports the efficient processing of large-scale datasets while also offering adaptable tools for calculating bibliometric measures, tailoring visual presentations, and merging information drawn from diverse data sources.

A significant strength of VOSviewer is its ability to convert intricate bibliometric datasets into visual outputs that are both accessible and easy to interpret. The software is particularly effective in network-based analyses, where it supports the identification of thematic clusters, patterns of keyword co-occurrence, as well as focal points of research activity through density-based and overlay visualisations. Its design, which prioritises usability, caters to both inexperienced users and seasoned researchers alike, supporting systematic interpretation of evolving research trends. Continuous methodological enhancements further ensure that VOSviewer remains a leading tool for bibliometric mapping across diverse analytical contexts, including authorship, citation, and thematic networks.

In this study, bibliographic records comprising publication year, article title, author information, citation counts, source journals, as well as keywords were extracted in Plain Text format from the Scopus database, spanning the timeframe from 2016 through May 2026. The resulting dataset was then processed and examined using VOSviewer (version 1.6.20). Through the implementation of VOS mapping and clustering methodologies, the software enabled the generation and interpretation of bibliometric networks. In contrast to traditional Multidimensional Scaling (MDS),

VOSviewer arranges items in a reduced-dimensional space in such a way that inter-node distances correspond to the extent of their relational similarity (van Eck & Waltman, 2010). Although it is conceptually aligned with MDS approaches (Appio et al., 2014), the VOS technique introduces specialised normalisation procedures designed for co-occurrence data, including the association strength measure AS_{ij} , thereby enhancing the accuracy and interpretability of bibliometric mappings (van Eck & Waltman, 2007):

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}, \quad (1)$$

which is described as being “proportional to the ratio between on the one hand the observed number of co-occurrences of i and j and on the other hand the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent” (van Eck & Waltman, 2007).

8. RESULT AND DISCUSSION

8.1 How has the volume of scholarly publications on Artificial Intelligence (AI) in green logistics for environmental performance evolved between 2016 and May 2026?

As presented in Figure 1 and Table 3, the publication trajectory spanning 2016 to 2026 demonstrates a distinct upward progression, suggesting that investigations into AI in green logistics for environmental performance have grown from an initially emerging area into a firmly established field. In general, the early years (2016-2019), publications were low (1.45%-2.80%), reflecting limited attention and mainly exploratory studies. From 2020 onwards, publications increased steadily, rising from 73 (3.78%) to 178 (9.23%) in 2022, driven by digital transformation and increased awareness of environmental challenges, particularly after the COVID-19 pandemic. The most significant growth occurred between 2023 and 2026, with a peak in 2025 (530; 27.48%), indicating a highly active research phase supported by advancements in AI technologies, regulatory pressure, and the need for improved environmental performance. The slight decline in 2026 is likely due to incomplete indexing rather than reduced interest.

This trend can be systematically interpreted through three distinct eras: the emergent phase (2016-2019), the expansion phase (2020-2023), and the acceleration phase (2024-2026). During the emergent phase (2016-2019), the number of publications remained relatively low (1.45%-2.80%), reflecting limited scholarly attention and the early-stage development of AI applications within green logistics. This period was characterised by foundational and exploratory studies, where AI technologies were primarily applied in isolated operational contexts rather than integrated systems. The focus was largely conceptual, aiming to establish the relevance of digital technologies in enhancing logistics performance while also mitigating environmental consequences. This finding aligns with prior studies highlighting the initial stage of green logistics research as conceptually driven with limited empirical validation (Dekker et al., 2012).

A noticeable inflection point emerges in the expansion phase (2020-2023), where publications increase significantly from 73 (3.78%) in 2020 to 129 (6.69%) in 2021

and further to 178 (9.23%) in 2022. This surge reflects a transition from conceptual exploration to empirical and application-oriented research. The acceleration of digital transformation, coupled with heightened awareness of environmental challenges, has driven this growth. In particular, worldwide disruptions like the COVID-19 pandemic exposed structural inefficiencies in logistics systems and reinforced the need for intelligent, resilient, and environmentally friendly solutions. Consequently, this phase is marked by the convergence of AI with green logistics strategies, alongside the expanding adoption of circular economy concepts aimed at improving environmental outcomes. This development is consistent with the increasing scholarly attention highlighting the significance of digital technologies in enabling sustainable logistics systems (Al-Khatib, 2023; Oliveira Neto et al., 2023; Naz et al., 2022; Yavari et al., 2023). The most substantial growth is observed in the acceleration phase (2024-2026), with publications peaking at 530 (27.48%) in 2025 and remaining relatively high in 2026 (13.27%), indicating that the field has entered a mature and highly active research stage. This sharp increase reflects the convergence of several structural and technological drivers. First, rapid advancements in AI, especially within machine learning frameworks and predictive analytics, have markedly improved the ability of logistics and transportation systems to optimise operations while reducing environmental impact (Elarifi & Khalifa, 2026; Arvind et al., 2025; Wagino et al., 2025; Mohsen, 2024). Second, escalating regulatory demands alongside societal pressure to improve environmental performance have compelled organisations to adopt more sustainable and data-driven logistics practices, reinforcing the integration of AI within green logistics strategies (Simsek et al., 2026; Mohsen & Mohsen, 2025). As a result, AI-enabled green logistics is no longer treated as an emerging concept. However, it has evolved into a strategic imperative that directly influences organisational competitiveness and compliance.

From a critical perspective, the recent literature further suggests that AI-enabled approaches are increasingly applied to complex decision-making contexts, such as supply chain resilience, sustainable mobility, and carbon emission prediction, demonstrating their practical relevance and performance implications (Elarifi & Khalifa, 2026; Simsek et al., 2026). Despite this rapid expansion, the field remains conceptually fragmented, as studies adopt diverse methodological approaches and disciplinary perspectives, ranging from engineering-based optimisation models to business-oriented strategic analyses (Wagino et al., 2025). This interdisciplinarity, while enriching the field, may limit theoretical consistency and hinder the development of unified frameworks linking AI, green logistics, and environmental performance. The slight decline observed in 2026 compared to 2025 is likely attributable to incomplete indexing processes rather than an actual downturn in research output. In broader terms, the acceleration phase confirms both the maturity and strategic importance of AI-enabled green logistics, while highlighting the importance of deeper theoretical alignment and improved conceptual consistency in subsequent studies.

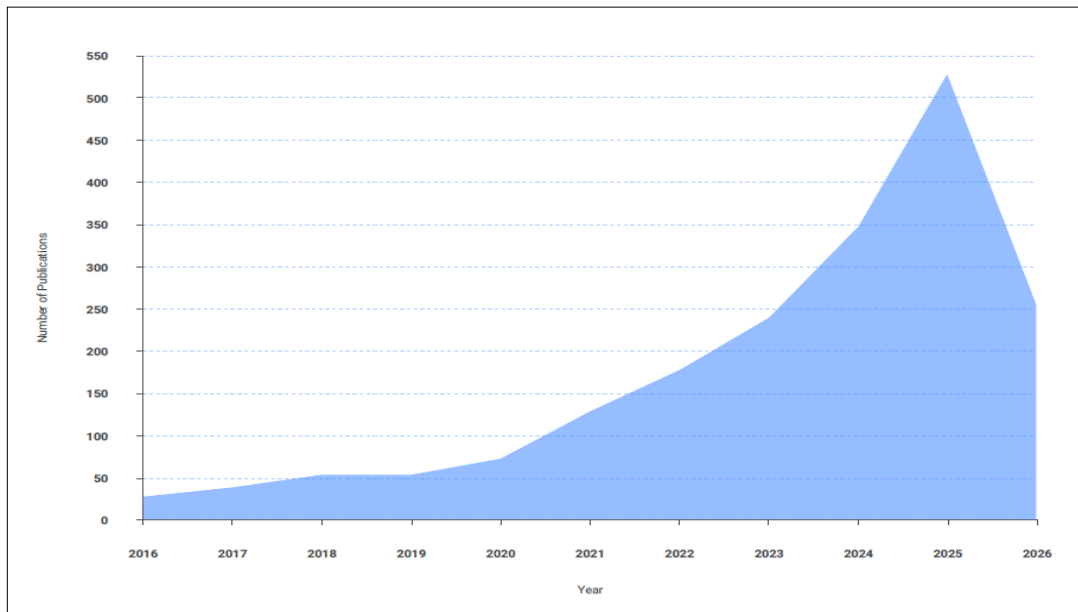


Figure 1: Trend of publications on artificial intelligence in green logistics and environmental performance (2016-2026)

Table 3: Trend of publications on artificial intelligence in green logistics and environmental performance (2016-2026)

Year	Number of Publications	Percentage
2026	256	13.27
2025	530	27.48
2024	348	18.04
2023	240	12.44
2022	178	9.23
2021	129	6.69
2020	73	3.78
2019	54	2.80
2018	54	2.80
2017	39	2.02
2016	28	1.45

8.2 Which publications are the most influential in the field of Artificial Intelligence (AI) in green logistics for environmental performance, as measured by citation impact?

Table 4 reveals that the most highly cited publications are predominantly conceptual and review-oriented studies that integrate digital technologies, circular economy principles, and supply chain perspectives, rather than focusing solely on green logistics. The citation pattern presented reveals that the intellectual foundation of research on AI in green logistics for environmental performance is predominantly shaped by conceptual and integrative studies, rather than narrowly focused empirical investigations. The most frequently cited study (Genovese et al., 2017), with 1,245 citations, highlights the essential importance of sustainable supply chain management in facilitating circular economy transitions. These findings indicate that early influential research prioritised system-level thinking, where logistics is embedded within broader sustainability frameworks. Similarly, Kristoffersen et al. (2020) and Chauhan et al. (2022) emphasized the growing convergence between digitalisation

and circular economy strategies, reinforcing the argument that AI-enabled green logistics is conceptually rooted in Industry 4.0 frameworks as well as broader digital transformation paradigms. Moreover, the prevalence of publications in leading journals, including the *Journal of Cleaner Production*, *Journal of Business Research*, as well as *Technological Forecasting and Social Change*, indicates that influential interdisciplinary journals are central in defining and advancing this area of scholarship.

Table 4: Most cited author

No	Authors	Title	Year	Source title	Cited by
1	Genovese et al. (2017)	Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications	2017	Omega	1245
2	Kristoffersen et al. (2020)	The smart circular economy: A digital-enabled circular strategies framework for manufacturing companies	2020	Journal of Business Research	642
3	Chauhan et al. (2022)	Linking circular economy and digitalisation technologies: A systematic literature review of past achievements and future promises	2022	Technological Forecasting and Social Change	585
4	Fatorachian and Kazemi (2021)	Impact of Industry 4.0 on supply chain performance	2021	Production Planning and Control	564
5	Bressanelli et al. (2018)	Exploring how usage-focused business models enable circular economy through digital technologies	2018	Sustainability	559
6	Ren et al. (2019)	A comprehensive review of big data analytics throughout product lifecycle to support sustainable smart manufacturing: A framework, challenges and future research directions	2019	Journal of Cleaner Production	495
7	Nguyen et al. (2018)	Big data analytics in supply chain management: A state-of-the-art literature review	2018	Computers and Operations Research	472
8	Singh and El-Kassar (2019)	Role of big data analytics in developing sustainable capabilities	2019	Journal of Cleaner Production	443
9	Kubler et al. (2016)	A state-of-the-art survey & testbed of fuzzy AHP (FAHP) applications	2016	Expert Systems with Applications	432
10	Ding et al. (2018)	Applying gradient boosting decision trees to examine non-linear effects of the built environment on driving distance in Oslo	2018	Transportation Research Part A: Policy and Practice	415

From a critical perspective, the dominance of highly cited studies focusing on big data analytics and optimisation (Ren et al., 2019; Nguyen et al., 2018; Singh & El-Kassar, 2019) demonstrates that data-driven decision-making is central to advancing environmental performance. However, these studies are largely methodological or review-oriented, which explains their high citation counts due to broad applicability

across industries. In contrast, more specialised green logistics studies appear less frequently among top-cited works, suggesting a relative lack of field-specific theoretical consolidation. Furthermore, the inclusion of research like Kubler et al. (2016) and Ding et al. (2018), which are not explicitly focused on green logistics, indicates that the field draws heavily from adjacent disciplines, including operations research, transportation, and decision sciences.

This interdisciplinary dependence, while enriching the field, also exposes a significant shortcoming, namely the lack of unified frameworks that directly link AI, green logistics practices, and environmental performance. Therefore, the citation pattern suggests that impactful research is driven by broad, forward-looking, and integrative studies. It highlights the necessity for more empirically anchored and context-sensitive studies to strengthen theoretical coherence within AI-enabled green logistics.

8.3 What are the dominant and emerging research themes in Artificial Intelligence (AI) in green logistics for environmental performance, as identified through keyword co-occurrence analysis?

Building on the results presented in Figure 2, the keyword co-occurrence structure indicates that the development of AI in green logistics for environmental performance is strongly technology-centric, with machine learning (306 occurrences; total link strength = 578) and AI (251; 539) acting as dominant intellectual anchors. Closely associated terms, including reinforcement learning, deep learning, big data analytics, as well as decision support systems, further confirm that the literature is heavily driven by data-intensive and algorithmic approaches. The relatively high link strength of Industry 4.0 (221) and IoT (199) suggests that AI in green logistics is embedded within a broader digital transformation paradigm, where interconnected technologies facilitate real-time optimisation and support decision-making processes. This finding aligns with earlier research that highlights the importance of digital technologies and data analytics in the development of intelligent and sustainable supply chain systems (Ren et al., 2019; Nguyen et al., 2018; Singh & El-Kassar, 2019). However, a critical limitation arises from this pattern: the dominance of technical and methodological keywords suggests that research may be overly focused on computational efficiency, with insufficient attention to developing integrated theoretical frameworks that explicitly connect AI applications to environmental performance. These findings indicate a gap between technological advancement and conceptual development, highlighting the need for future research to move beyond algorithmic optimisation towards more theory-driven and context-specific models.

The next cluster, centred on transportation and environmental sustainability, further demonstrates the increasing relevance of low-carbon and energy-efficient logistics systems, as reflected by keywords such as electric vehicles (147; 280), transportation (111; 252), carbon emissions (47; 96), and energy efficiency (29; 65). The inclusion of circular economy, environmental sustainability, and reverse logistics highlights an emerging shift towards resource optimization as well as closed-loop supply chain systems, aligning with foundational contributions in sustainable supply chain and circular economy studies (Genovese et al., 2017; Kristoffersen et al., 2020; Chauhan et al., 2022). Nevertheless, the relatively low occurrence of green logistics (24; 62) compared to broader terms like supply chain management and transportation suggests that the field remains conceptually fragmented, with research often dispersed

across adjacent domains rather than consolidated within a unified framework. While this interdisciplinary nature enriches the field, it also highlights the need for greater theoretical integration and conceptual clarity to establish AI-enabled green logistics as a distinct and coherent research domain.

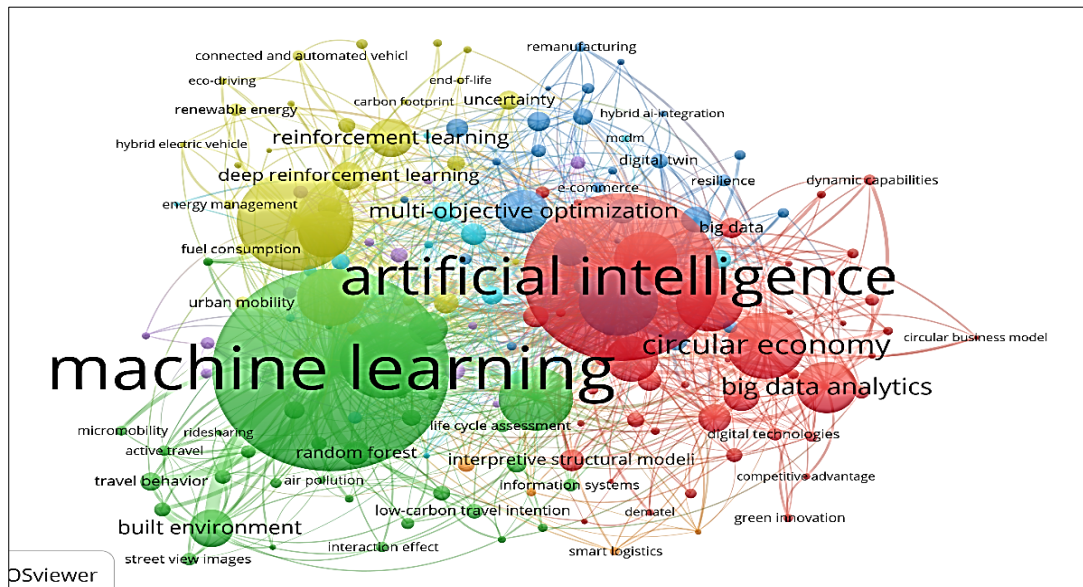


Figure 2: Network visualization map of keywords' co-occurrence

8.4 What patterns of international research collaboration can be identified in Artificial Intelligence (AI) in green logistics for environmental performance, based on country-level co-authorship networks?

The country-level co-authorship network in Figure 3 reveals that international collaboration in AI-enabled green logistics is highly concentrated among a few leading economies, while simultaneously expanding across a broader global landscape. China emerges as the leading contributor, producing 612 documents and accumulating 15,508 citations, alongside the highest total link strength of 511, indicating not only strong research productivity but also extensive international collaboration. This leadership position can be attributed to China's substantial investment in AI, smart transportation systems, and low-carbon development initiatives, which collectively drive research output in green logistics. Other major contributors include India (235 documents; TLS = 282), the United States (222; TLS = 296), and the United Kingdom (167; TLS = 317), all of which demonstrate strong research capacity and cross-border collaboration. Notably, the United Kingdom demonstrates a comparatively elevated citation count, totalling 8,847 citations, alongside link strength despite fewer publications, suggesting a greater influence and centrality within the global research network. This pattern indicates that while some countries lead in research volume, others play a more strategic role in knowledge integration and dissemination, as reflected in highly cited and integrative studies within the field (Genovese et al., 2017; Kristoffersen et al., 2020).

From a critical standpoint, the widening involvement of emerging economies, including Malaysia, Saudi Arabia, Turkey, as well as Pakistan, reflects an accelerating internationalisation of the research domain, driven by increasing environmental

pressures and digital transformation efforts. However, the network also reveals a persistent core-periphery structure, where countries with lower publication output, such as Indonesia, Vietnam, and several African nations, remain weakly connected, with limited citation impact and collaboration strength. This imbalance highlights structural inequalities in access to research funding, technological infrastructure, and international partnerships. Furthermore, the dominance of a few leading countries may shape the research agenda toward technologically advanced, resource-intensive solutions, potentially limiting the relevance of findings for less developed contexts. As suggested by studies on digitalisation and sustainability integration (Chauhan et al., 2022; Ren et al., 2019), collaborative networks are instrumental in facilitating knowledge diffusion. Nonetheless, unequal participation may constrain inclusive innovation. Therefore, while the field demonstrates increasing global collaboration, future research should emphasise more inclusive and balanced partnerships to ensure equitable knowledge development and broader applicability of AI-enabled green logistics solutions.

The co-authorship network further reveals a multi-layered collaboration structure, where a central core of highly connected countries is surrounded by emerging and peripheral participants. Nations including Turkey, Saudi Arabia, Malaysia, and the United Arab Emirates exhibit a growing degree of incorporation within the global research network, as reflected in their visible connections to major hubs, particularly China and India. This suggests that emerging economies are not merely passive contributors but are actively engaging in collaborative knowledge exchange, driven by growing investments in digital technologies and environmental initiatives. The network also highlights a clear hub-and-spoke pattern, with central countries dominating the flow of knowledge while peripheral countries such as Ghana, Morocco, and several smaller economies remain weakly connected with limited collaboration links.

From a critical perspective, this structure indicates that global research collaboration in AI-enabled green logistics is asymmetrical, with knowledge production and dissemination concentrated within a few dominant hubs. Such concentration may lead to imbalanced research agendas, in which technological solutions are shaped primarily by the priorities of leading economies, potentially limiting their applicability in less developed contexts. Furthermore, although the increasing participation of emerging countries reflects a positive trend towards internationalisation, their reliance on central hubs suggests a degree of dependency in knowledge networks. This finding aligns with prior research emphasizing how international collaboration, as well as digital transformation, influences knowledge diffusion and sustainability research (Chauhan et al., 2022; Ren et al., 2019). This pattern reinforces the existence of a core-periphery dynamic, in which inclusion in high-impact research is contingent on access to established collaboration networks. Thus, while the field is becoming more globally connected, there remains a need to promote more decentralised and inclusive collaboration structures to ensure equitable knowledge development and broader relevance of AI-enabled green logistics solutions.

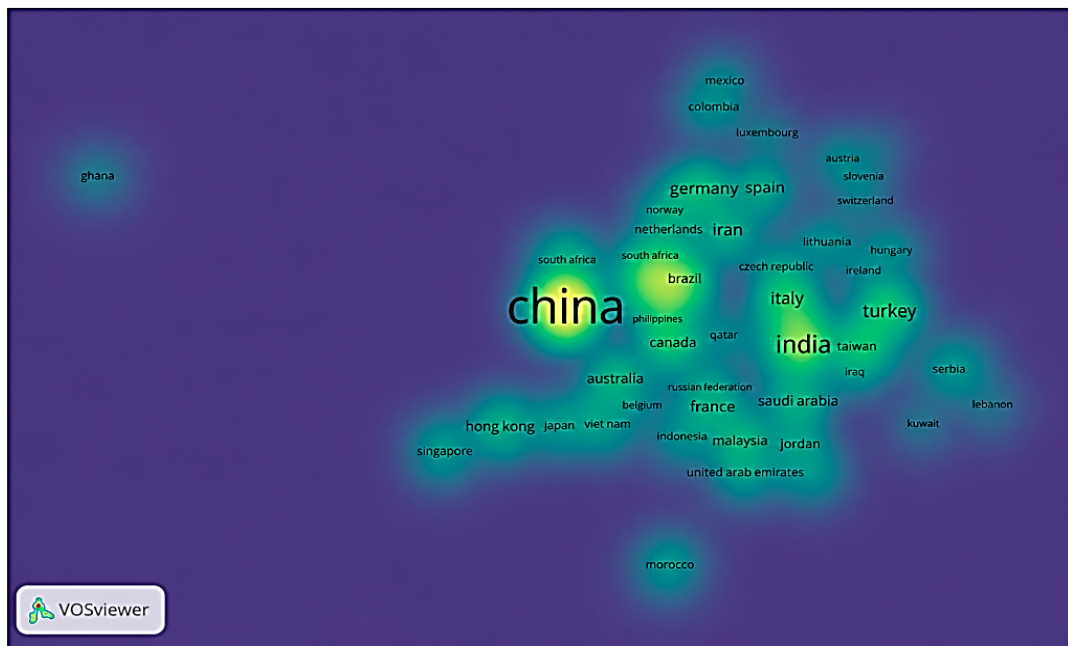


Figure 3: Co-authorship by countries' collaboration

9. CONCLUSION AND FUTURE RESEARCH

This study systematically examined research on AI in green logistics for environmental performance between 2016 and May 2026. Guided by four research questions addressing publication trends, influential contributions, thematic structures, and international collaboration patterns, the findings provide a broad and integrative depiction of the field's intellectual progression. The findings demonstrate a distinct and continuous rise in academic output, particularly from 2020 onwards, indicating that AI-enabled green logistics has evolved from an emergent area of inquiry into a swiftly expanding and progressively established research domain. Citation analysis further demonstrates that highly influential studies are predominantly conceptual and review-oriented, emphasising digital transformation, circular economy, and data-driven decision-making, rather than narrowly focused logistics applications. In parallel, thematic analysis highlights the dominance of machine learning, optimisation techniques, and intelligent transportation systems, alongside the growing integration of sustainability-oriented constructs such as carbon emissions reduction and energy efficiency.

Despite these advancements, a critical insight emerging from this study is the disproportionate emphasis on technological and optimisation-driven approaches, which may constrain the development of context-specific and theory-driven perspectives. While AI capabilities are extensively explored, their direct linkage to environmental performance outcomes remains insufficiently theorised and empirically validated. Furthermore, the collaboration analysis reveals a core-periphery structure in global research networks, in which leading economies dominate knowledge production, while emerging countries are increasingly involved but remain dependent on central hubs. This imbalance raises concerns regarding the inclusiveness and contextual applicability of existing research, particularly for developing regions facing distinct environmental and infrastructural challenges. Therefore, although the

field demonstrates strong growth and interdisciplinary integration, it remains conceptually fragmented and unevenly developed.

From a pragmatic standpoint, the results indicate that AI-enabled solutions hold significant potential to enhance environmental performance through improved resource efficiency, optimisation of logistics operations, and emissions reduction. However, the persistent gap between technological advancement and real-world implementation highlights the need for stronger alignment between AI capabilities, organisational strategies, and green logistics practices.

Subsequent research ought to place emphasis on constructing cohesive, theory-informed frameworks that explicitly connect AI adoption with environmental performance outcomes in logistics systems. In particular, empirical investigations that substantiate the real-world efficacy of AI deployments in real-world logistics contexts, especially within developing economies. Expanding the scope of analysis by including multiple databases, longitudinal comparisons, and mixed-methods approaches would further enhance the robustness of the findings. Additionally, emerging areas such as green AI (i.e., the environmental impact of AI systems themselves), policy-driven adoption, and implementation challenges warrant deeper investigation. Greater attention should also be given to fostering inclusive and decentralised research collaboration, ensuring that knowledge development is more globally representative.

Overall, while AI-enabled green logistics represents a promising and rapidly evolving field, its future advancement depends on stronger theoretical integration, greater contextual relevance, and greater practical applicability, thereby bridging the gap between technological innovation and environmental performance.

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