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# From Mine to Metropolis: A Systematic Review of Green Mining Innovations for Sustainable Urban Logistics

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**Abstract:** Urban logistics contributes significantly to environmental degradation, challenging the achievement of Sustainable Development Goals. Concurrently, the green mining industry has developed robust technological innovations with potential applicability in urban contexts, yet this cross-sectoral knowledge transfer remains underexplored. This study aims to bridge this gap through a systematic literature review of 30 peer-reviewed articles to identify transferable technologies and the determinants influencing their implementation. The methodology followed the PRISMA guidelines, analyzing literature from Scopus and Web of Science and assessing their quality using the CASP checklist. Results reveal three key transferable domains: (1) fleet electrification, (2) autonomous systems, and (3) circular economy models. Key enablers include policy incentives and long-term economic benefits, while high initial capital expenditure and regulatory uncertainty are primary barriers. The primary contribution of this research is a novel conceptual framework that provides an actionable roadmap for policymakers to accelerate the decarbonization of urban freight by leveraging proven industrial innovations. This study offers significant practical implications for enhancing urban sustainability.

**Keywords:** Logistics, Mining, Sustainability, Technology, Decarbonization

## INTRODUCTION

The 2030 Agenda for Sustainable Development (Walsh et al., 2022) has established a global imperative to create sustainable and resilient urban environments. Urban logistics, the system responsible for moving goods within cities, is a critical enabler of economic activity but also presents a sharp paradox. The sector is a primary contributor to negative externalities, including traffic congestion, noise pollution, and greenhouse gas (GHG) emissions, directly challenging the achievement of key Sustainable Development Goals (SDGs), notably SDG 11 (Sustainable Cities) and SDG 13 (Climate Action). As urbanization accelerates, the demand for efficient yet sustainable urban freight transport becomes increasingly urgent. However, the search for proven, scalable, and robust technological solutions to decarbonize this complex sector remains a significant challenge. This study posits that a rich repository of field-tested innovations may be found in an unlikely sector: the mining industry.

The novelty of this study lies in bridging the critical inter-industry knowledge gap between the green mining and urban logistics sectors. Previous research has predominantly focused on these fields in isolation, creating a significant research gap where the potential for leveraging mature technologies from a leading heavy industry to accelerate the sustainability transition in urban logistics remains systematically unexamined. Therefore, this systematic literature review aims to address this gap by answering three key research questions (RQs): **(RQ1)** What are the primary domains of green mining innovation technically transferable to the urban logistics sector? **(RQ2)** What are the key drivers, barriers, and sociotechnical factors that moderate the implementation of these innovations in an urban context? **(RQ3)** How can these findings be synthesized into an integrated conceptual framework aligned with the SDGs?

To answer these questions, the remainder of this article is structured as follows. Section 2 outlines the systematic methodology employed for literature selection and analysis. Section 3 presents the results and discussion, beginning with a descriptive analysis of the literature landscape and a detailed qualitative synthesis of the 30 included articles. It then proceeds to a thematic synthesis that identifies the key determinants of technology transfer (addressing RQ1 and RQ2), and culminates in the presentation of an integrated conceptual framework, a future research agenda, and actionable recommendations (addressing RQ3). Finally, Section 4 provides the concluding remarks.

## METHOD

This study was designed and executed as a Systematic Literature Review (SLR), adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement (Page et al., 2021). The methodology was structured to systematically explore the cross-sectoral transfer of green innovations from the mining industry to urban logistics through three phases: study selection, data extraction, and quality appraisal.

### Search Strategy and Selection Criteria

A systematic literature search was conducted in October 2025 across the Scopus and Web of Science databases, covering the period from 2014 to 2025. The search string was designed to identify articles at the intersection of green mining, urban logistics, and sustainability, using the following query:

((TITLE-ABS-KEY("green mining" OR "sustainable mining" OR "mine automation" OR "mine electrification")) AND (TITLE-ABS-KEY("urban logistics" OR "urban freight" OR "city logistics")) AND (TITLE-ABS-KEY("sustainability" OR "technology transfer" OR "decarbonization")))

To ensure the relevance and quality of the final sample, a strict set of inclusion and exclusion criteria was predefined and applied during the screening process, as detailed in Table 1

**Table 1. Inclusion and Exclusion Criteria for Study Selection**

| Criteria | Code | Description |
|---|---|---|
| **INCLUSION CRITERIA** | *(Studies had to meet all criteria)* | |
| Publication Type | IC1 | Peer-reviewed journal article or conference proceeding. |

| | | |
|---|---|---|
| Thematic Relevance | IC2 | Explicitly discusses the intersection of (a) green mining innovations AND (b) sustainable urban logistics. |
| Language | IC3 | Published in English. |
| Timeframe | IC4 | Published between January 2014 and December 2025. |
| **EXCLUSION CRITERIA** | *(Studies were excluded if they met any criterion)* | |
| Document Type | EC1 | Editorials, book reviews, commentaries, and other non-peer-reviewed gray literature. |
| Isolated Focus | EC2 | Focuses solely on one domain (mining or logistics) without a clear cross-sectoral link. |
| Narrow Scope | EC3 | Scope considered too technical or narrow for generalization (e.g., analysis of a single component without systemic implications). |

The four-stage PRISMA flow, including the number of articles screened and reasons for exclusion at each stage, is visualized in **Figure 1**.

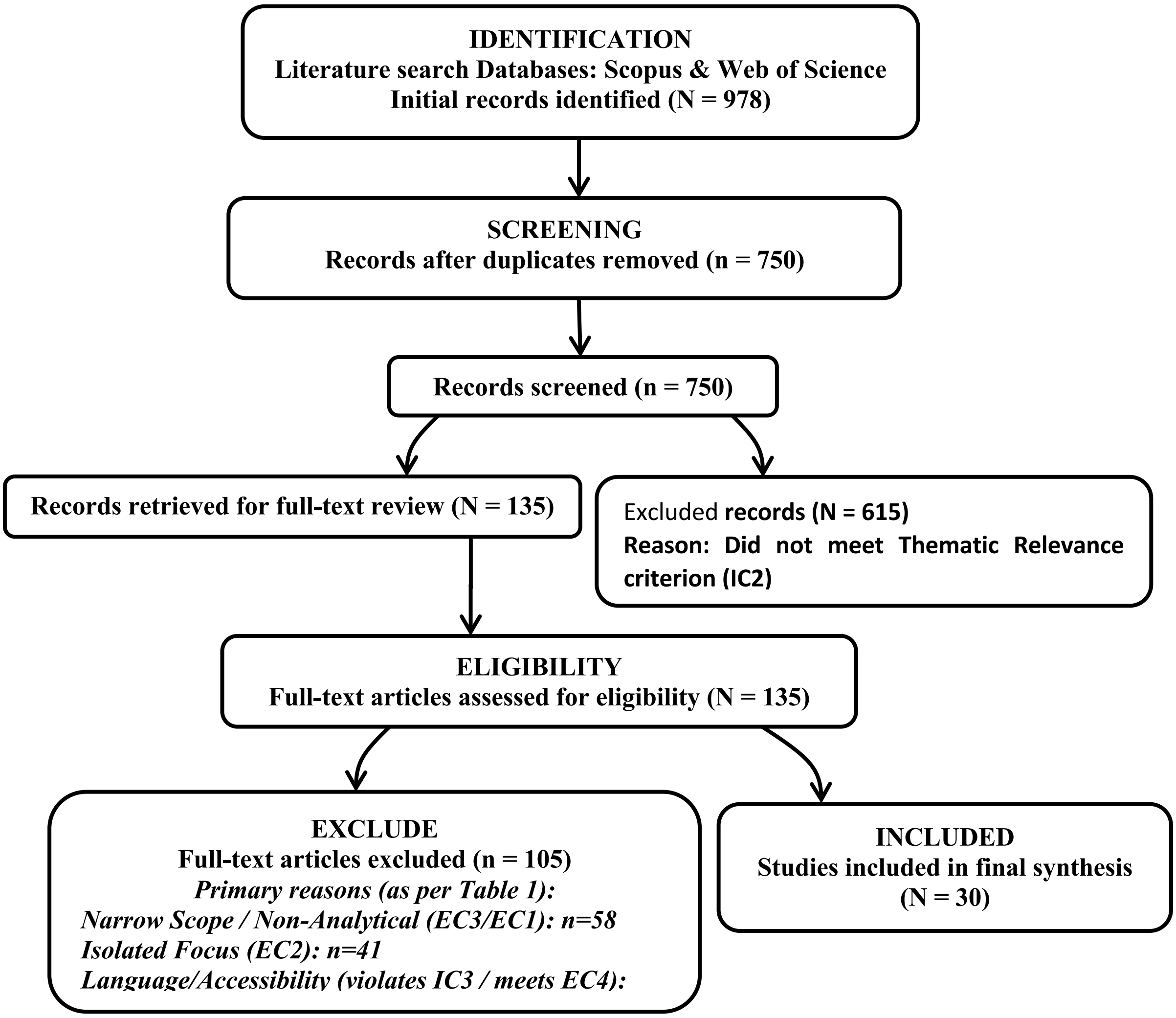


**Figure 1. PRISMA 2020 Flow Diagram for Study Selection**

## Data Extraction and Synthesis

A standardized data extraction form was utilized to systematically collect key information from each of the 30 included studies. The extracted data covered bibliographic details, methodologies, geographical focus, and key findings related to technologies, drivers, and barriers. The data were subsequently synthesized using a thematic analysis approach (Braun &

Clarke, 2006). This qualitative method involved an iterative process of identifying, analyzing, and reporting patterns or "themes" to directly address the research questions.

**Critical Quality Appraisal**

The methodological quality of the 30 included articles was critically appraised by two independent researchers using the Critical Appraisal Skills Programme (CASP) Systematic Review Checklist (CASP, 2018). Each article was scored on a 4-point scale across 10 criteria to assess its rigor and validity. This appraisal was conducted to establish confidence in the evidence base, with the aggregated results presented in Table 2.

## RESULTS AND DISCUSSION

This This section presents the findings from the systematic literature review, beginning with a descriptive analysis of the selected literature, followed by a detailed qualitative synthesis, and a thematic analysis of key determinants. The section culminates in the presentation of an integrated conceptual framework and actionable recommendations.

**Descriptive Analysis and Qualitative Synthesis**

The final sample of 30 studies forms a robust evidence base for this review. A descriptive analysis of this literature is presented visually through a series of figures. The temporal distribution of the studies, detailed in **Figure 2**, reveals a significant increase in publication activity since 2020. The geographical focus of the research, presented in **Figure 3**, shows a clear concentration of studies in Europe and Asia, pointing to a research gap in the Global South. Furthermore, the methodological quality score for each individual study is visualized in **Figure 4**. Collectively, these figures illustrate a high-quality research landscape with growing academic interest. The aggregated results of the quality appraisal are summarized in **Table 2**, confirming that all included literature is of 'High' or 'Medium' quality, which provides strong confidence in the subsequent analysis.

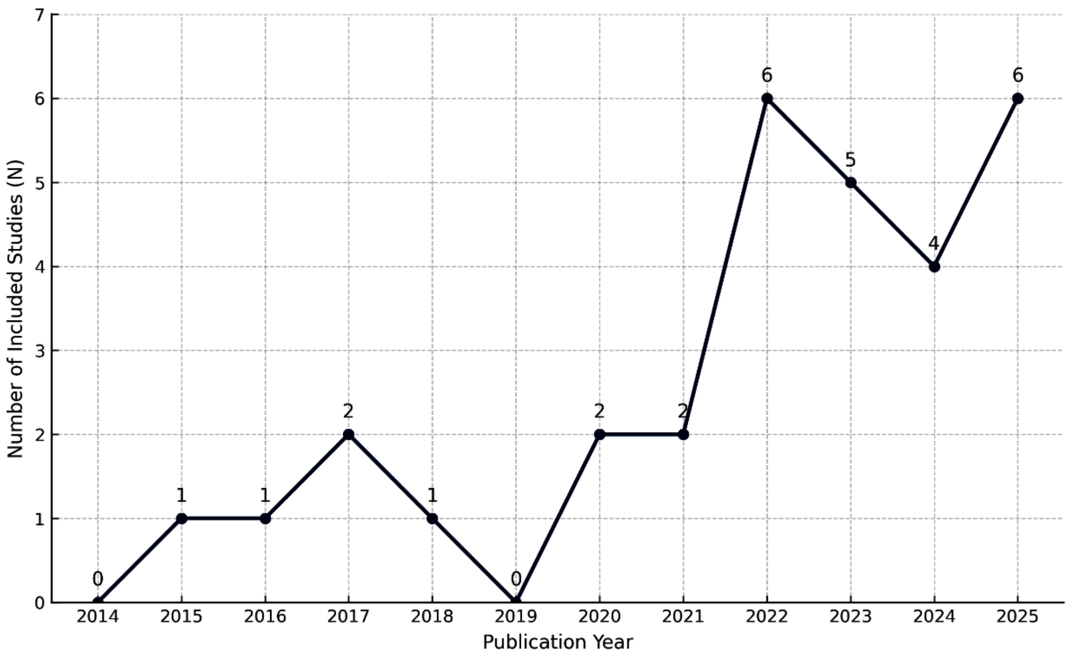


**Figure 1. Distribution of Selected Studies by Publication Year (2014–2025)**

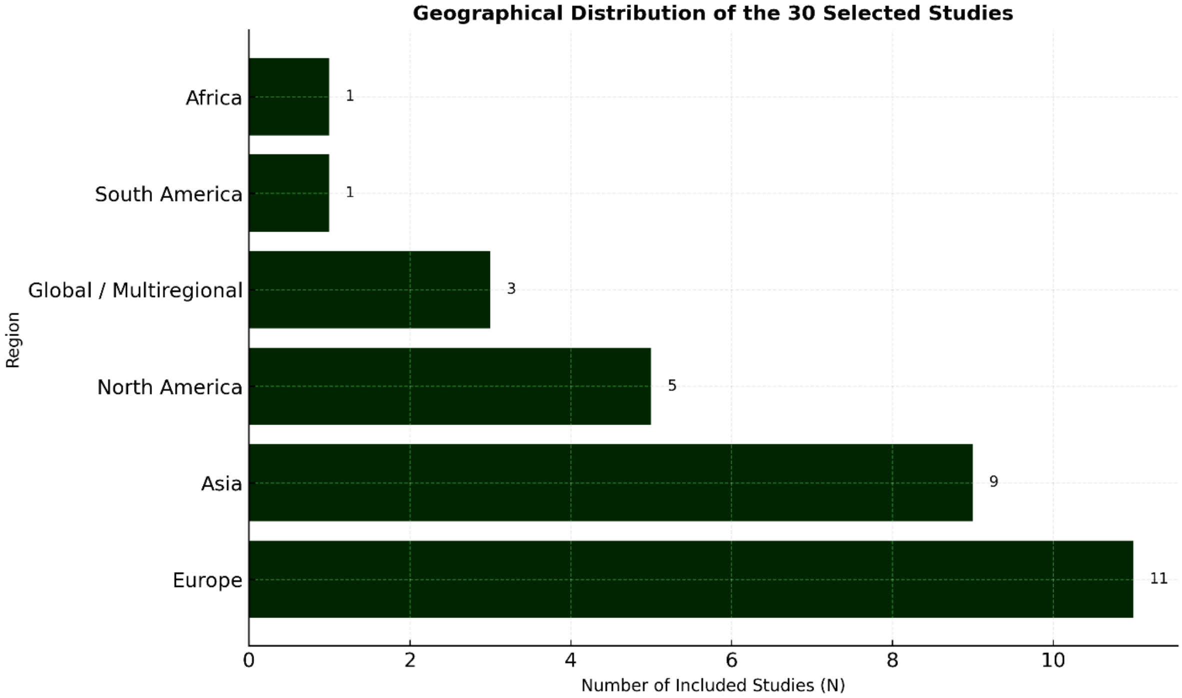


**Figure 2. Geographical Distribution of the 30 Selected Studies**

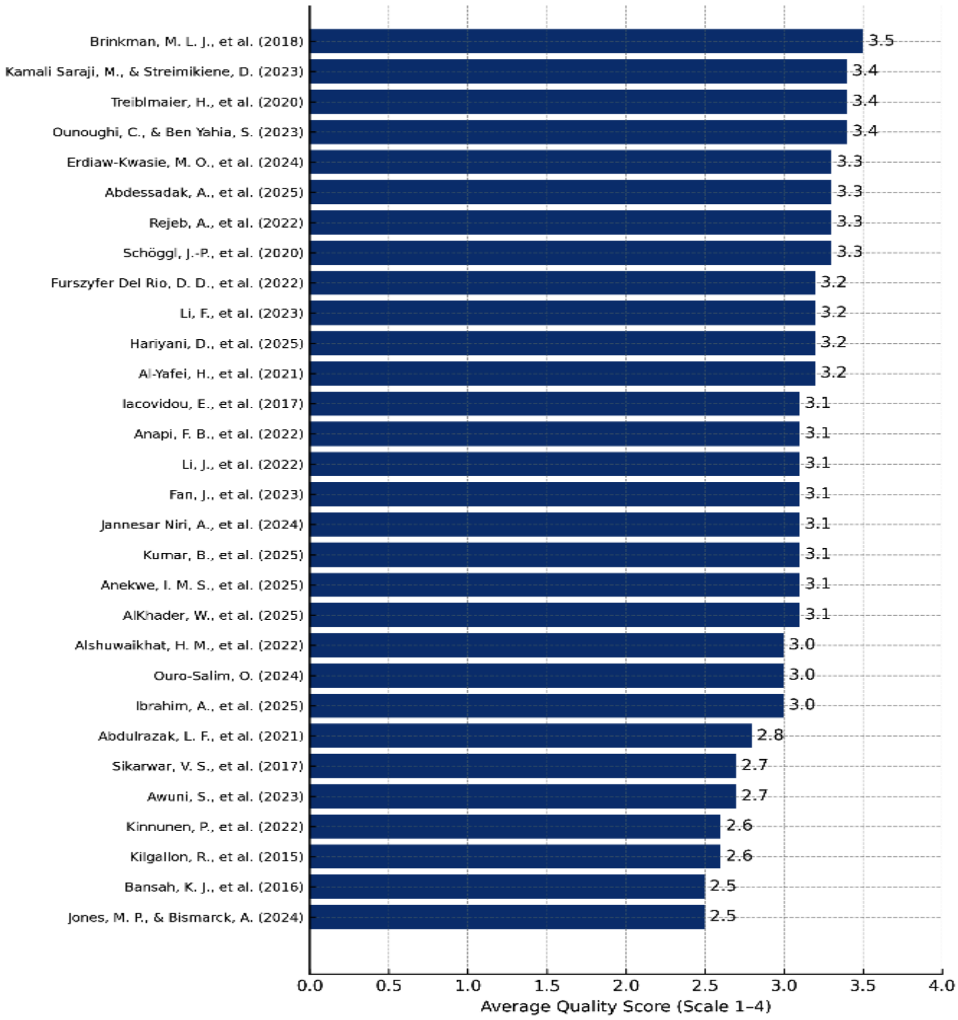


**Figure 4. Methodological Quality Assessment of Included Studies (N=30)**

**Table 2. Methodological Quality Appraisal of Included Studies (N=30)**

| Quality Rating | Score Range | Frequency (N) | Percentage (%) | Key Methodological Characteristics / Flaws |
|---|---|---|---|---|
| **High** | > 30 | 19 | 63.3% | Studies typically featured a comprehensive search strategy, clear research questions, and a robust synthesis method (e.g., SLR, bibliometric analysis). |
| **Medium** | 21–30 | 11 | 36.7% | Studies generally employed a sound methodology but often lacked a key element, such as a formal quality appraisal of their included literature. |
| **Low** | < 21 | 0 | 0% | No studies included in the final sample were rated as low quality. |
| **Total** | | **30** | **100.0%** | |

Source: Authors' analysis based on the CASP Systematic Review Checklist (CASP, 2018).

A detailed overview of each of the 30 included articles, outlining their core focus, method, scope, and key novelty, is presented in Table 3. This table serves as the foundational evidence for the subsequent thematic synthesis.

**Table 3. Overview of Included Studies and their Key Findings**

| No. | Author(s) (Year) | Core Focus & Method (Scope) | Key Insight / Novelty |
|---|---|---|---|
| 1 | Kilgallon et al., (2015) | Safety protocols for CO2 pipelines *(Critical Review; UK)* | Provides a safety analogy for future hydrogen logistics. |
| 2 | Bansah et al. (2016) | Hazards in small-scale mining *(Case Study; Ghana, 4 mines)* | Empirically links policy gaps to environmental degradation. |
| 3 | Iacovidou et al. (2017) | Metrics for circular economy *(Critical Review; Global)* | Proposes a new framework for holistic, multi-dimensional value metrics. |
| 4 | Sikarwar et al. (2017) | Biofuel from biomass gasification *(Narrative Review; Global)* | Synthesizes key technological hurdles in syngas cleaning and integration. |
| 5 | Brinkman et al. (20 18) | Socio-economics of ethanol *(Input-Output Model; Brazil)* | Quantifies interregional economic disparities from biofuel expansion. |
| 6 | Schöggl, J.-P., et al. (2020) | Evolution of CE research *(Mixed-Methods Review; Global, 30 papers)* | Critically highlights the neglect of social dimensions in CE literature. |
| 7 | Treiblmaier et al. (2020) | The Physical Internet (PI) paradigm *(SLR; Global, 100+ docs)* | Proposes the first comprehensive framework for the PI concept. |
| 8 | Ounoughi & Ben Yahia (2023) | Data fusion for Intelligent Transport Systems (ITS) <br> *(SLR; Global)* | Provides a comprehensive SLR on data fusion methods specifically for ITS. |
| 9 | Abdulrazak et al. (2021) | Energy sustainability in Bangladesh <br> *(Critical Review; Bangladesh)* | Connects policy deficits to underutilization of renewables for transport. |
| 10 | Al-Yafei et al. (2021) | Sustainability of the LNG industry *(SLR; Global, 168 studies)* | Identifies a critical gap in Life Cycle Sustainability Assessment (LCSA). |
| 11 | Bucci Ancapi et al. (2022) | Policy for circular built environment *(SLR; Global, 53 pubs)* | Develops a new "toolbox" framework for classifying policy instruments. |
| 12 | J. Li et al. (2022) | E-waste management <br> *(Bibliometric SLR; Global, 8149 articles)* | Maps the knowledge domain, revealing a technology-collection disconnect. |
| 13 | Rejeb et al. (2022) | IoT for the circular economy *(SLR; Global, 170 articles)* | Proposes a research agenda for cost-effective IoT business models. |
| 14 | Furszyfer Del Rio et al. (2022) | Decarbonization of ceramics industry *(SLR; Global, 324 studies)* | Provides a holistic, sociotechnical review for a hard-to-abate industry. |
| 15 | Kinnunen et al. (2022) | CE for mine tailings *(Narrative Review; Finland)* | Critically assesses the gap between tech potential and economic reality. |
| 16 | Alshuwaikhat et al. (2022) | Urban computing in smart cities *(SLR; Saudi Arabia, 100+ docs)* | Proposes a new transformation framework for data governance. |

| | | | |
|---|---|---|---|
| 17 | Awuni et al. (2023) | Climate change adaptation in Ghana *(Critical Review; Ghana)* | Empirically links policy failure to specific political and financial shortcomings. |
| 18 | Fan et al. (2023) | Transport carbon emissions *(Bibliometric Analysis; Global, 1997-2023)* | Maps research evolution, identifying AI as an emerging trend for reduction. |
| 19 | (Kamali Saraji & Streimikiene, 2023) | Low-carbon energy transition *(SLR; Global, 123 articles)* | Systematically classifies 17 key challenges into a multi-domain framework. |
| 20 | F. Li et al. (2023) | ML & remote sensing for sustainability *(SLR; Global)* | Critically highlights the research bias towards physical over socio-economic factors. |
| 21 | (Erdiaw-Kwasie et al., 2024) | E-waste mining in developing countries *(SLR; Dev. Countries, 45 articles)* | Provides a review focused specifically on the context of developing nations. |
| 22 | Ouro-Salim (2024) | Global e-waste management *(SLR; Global, 124 studies)* | Develops a research agenda to address regulatory and stakeholder inclusion gaps. |
| 23 | Jannesar Niri et al. (2024) | EV battery value chain sustainability *(Lit. Review; Global)* | Provides a holistic, end-to-end analysis from mining to recycling. |
| 24 | Jones & Bismarck (2024) | "Mycomining" (biological mining) *(Perspective Review; Global)* | Introduces "mycomining" as a new supplementary technology for CE. |
| 25 | Kumar et al. (2025) | Finance for circular economy *(SLR; Global, 150 articles)* | Systematically maps the nexus between innovative finance and CE adoption. |
| 26 | Hariyani et al. (2025) | Blockchain in manufacturing *(SLR; Global, 480 papers)* | Critically identifies scalability, regulation, and interoperability as key unsolved issues. |
| 27 | Anekwe et al. (2025) | The hydrogen economy *(Critical Review; Global)* | Presents an integrated view of challenges (production, storage, safety, acceptance). |
| 28 | AlKhader et al. (2025) | Hydrogen economy research trends *(Bibliometric Review; Global)* | Maps the gap between academic research trends and current industry status. |
| 29 | Abdessadak et al. (2025) | Digital Twin & AI in energy *(SLR; Global, 42 studies)* | Synthesizes future directions for leveraging digital tools in the energy transition. |
| 30 | Ibrahim et al. (2025) | Lean construction in megaprojects *(Mixed-Method Review; Global)* | Identifies the lack of tailored performance metrics as a key implementation barrier. |

## Thematic Synthesis: Key Determinants of Technology Transfer

A deeper thematic analysis of the included studies was conducted to identify the key "determinants" influencing technology transfer (RQ1 & RQ2), which are summarized in **Table 4**. To synthesize these findings into an actionable model, an integrated conceptual framework was developed (RQ3), as illustrated in **Figure 5**. This framework is supported by a proposed research agenda (**Table 5**) and actionable recommendations for stakeholders (**Table 6**).

**Table 4. Key Determinants of Technology Transfer**

| Determinant | Indicators | Finding & Impact | Key References |
|---|---|---|---|
| | | **ENABLERS** | |
| **Technological Maturity** | • Electrification<br>• Autonomous Systems<br>• Circular Economy | **Strongly Positive.** Mature, field-tested innovations are technically ready, de-risking the transfer. | (Jannesar Niri et al., 2024; Schöggl et al., 2020) |

| | | | |
|---|---|---|---|
| **Policy & Regulatory Framework** | • Emission standards<br>• AV regulations<br>• CE mandates | **Strongly Positive.** A stable, supportive policy environment is the most critical prerequisite for investment. | (Bucci Ancapi et al., 2022; Kamali Saraji & Streimikiene, 2023) |
| **Economic Feasibility** | • OPEX savings<br>• Total Cost of Ownership | **Positive / Context-Dependent.** Significant savings are a powerful driver, but viability is contingent on financial support. | (Brinkman et al., 2018; Kumar et al., 2025) |
| | | **BARRIERS** | |
| **Infrastructure Readiness** | • Lack of charging networks<br>• Insufficient 5G/6G | **Strongly Negative.** The absence of standardized infrastructure is the most significant barrier to deployment. | (Okika et al., 2025; Treiblmaier et al., 2020) |
| **High Initial Capital (CAPEX)** | • Cost of new fleets<br>• Cost of infrastructure | **Strongly Negative.** High CAPEX remains the dominant economic barrier, deterring widespread adoption. | (Anekwe et al., 2025; Kumar et al., 2025) |
| **Social Acceptance** | • Low public trust<br>• Job displacement concerns | **Inconsistent / High Uncertainty.** Concerns about jobs and safety create a major and unpredictable barrier. | (Furszyfer Del Rio et al., 2022; Tamasiga et al., 2025) |
| | | **MODERATING FACTORS** | |
| **Data & Digitalization** | • Interoperability<br>• Data governance | **High Potential with Caveats.** Digital tools are powerful enablers, but success is moderated by data security and integration challenges. | (Hariyani et al., 2025; Ounoughi & Ben Yahia, 2023) |
| **Supply Chain Resilience** | • Critical minerals access<br>• Geopolitical risks | **Growing Long-Term Risk.** Technology sustainability is linked to the resilience of its upstream supply chain, a critical systemic risk. | (Erdiaw-Kwasie et al., 2024; Jannesar Niri et al., 2024) |

Source: Authors' synthesis.

### To An Integrated Framework and Recommendations

A conceptual framework was developed to answer RQ3, as illustrated in **Figure 2**. This framework visually represents the pathway for translating the identified Technological Domains into Sustainable Outcomes. To operationalize this framework, an actionable research agenda is proposed in Table 5, and a set of policy and managerial recommendations is summarized in Table 6.

synthesize these multifaceted determinants into an actionable model, an integrated conceptual framework was developed to answer RQ3, as illustrated in Figure 2. This framework visually represents the pathway for translating the identified Technological Domains into Sustainable Outcomes aligned with the SDGs. While the framework provides a clear strategic guide, the review also revealed significant knowledge gaps. To address these, an actionable research agenda is proposed in **Table 4**. Finally, the practical takeaways are translated into a set of policy and managerial recommendations targeted at key stakeholders, as summarized in **Table 5**.

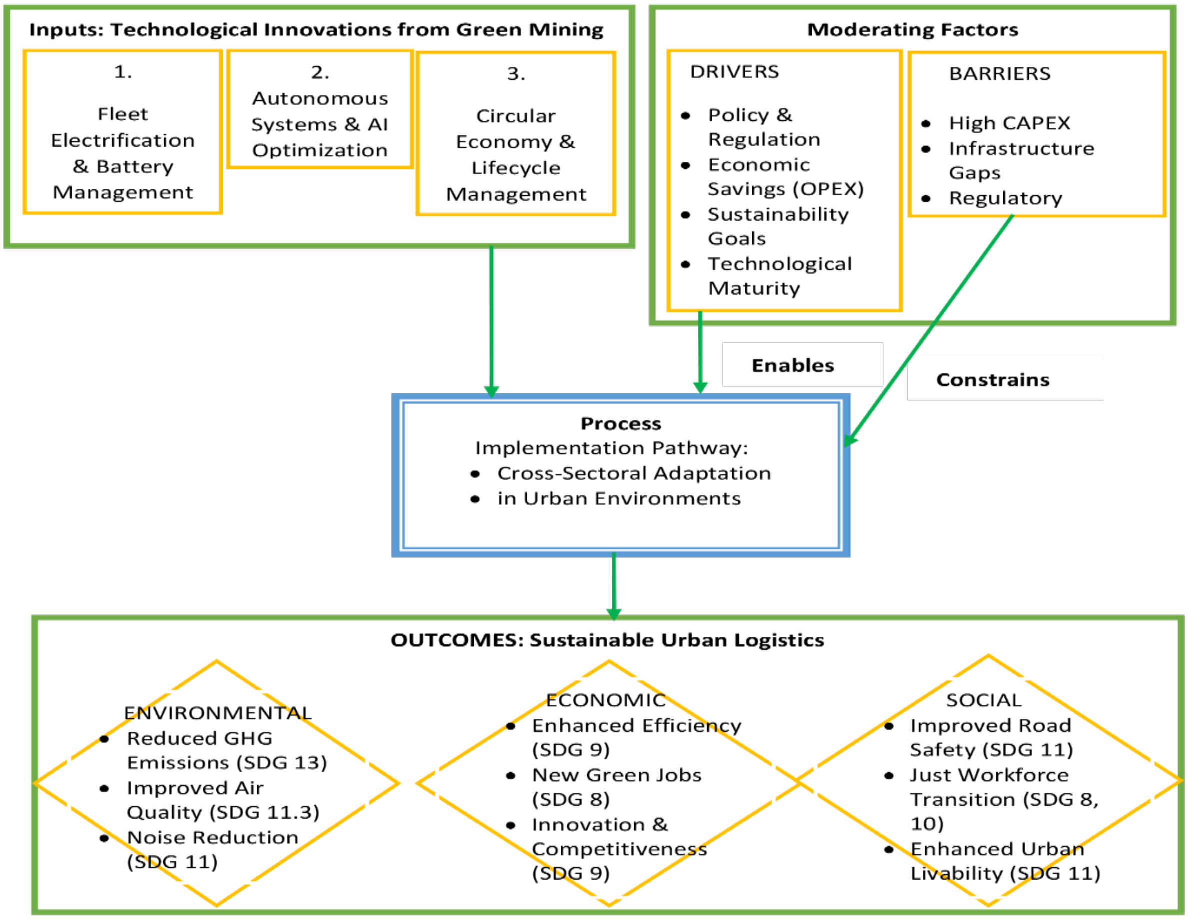


**Figure 5. Conceptual Framework for SDG-Aligned Technology Transfer Transfer from Green Mining to Urban Logistics**

**Table 5. A Proposed Research Agenda**

| No. | Research Theme | Key Research Questions / Directions | Rationale and Potential Impact | Relevant SDGs |
|---|---|---|---|---|
| 1 | **Techno-Economic Feasibility & Scalability** | • What are the specific TCO models for heavy-duty EVs/AVs across different urban typologies?<br>• How can business models like BaaS reduce high initial CAPEX for SMEs? | Economic viability is a primary barrier. Context-specific studies are crucial to develop viable business cases, attract investment, and enable scalable adoption, as noted by (Kumar et al., 2025). | SDG 8, 9, 11 |
| 2 | **Infrastructure & Urban Planning Integration** | • What are the optimal network designs for shared charging/swapping hubs?<br>• How can urban planning be redesigned to support autonomous logistics? | Infrastructure readiness is a critical bottleneck. This research will inform smart city planning and ensure seamless integration of new logistics systems, as highlighted by (Alshuwaikhat et al., 2022). | SDG 7, 9, 11 |
| 3 | **Policy, Regulation, & Governance** | • What adaptive regulatory frameworks are needed for safe AV operation?<br>• How can data sharing and interoperability standards be developed, leveraging technologies like blockchain (Hariyani et al., 2025)? | Regulatory uncertainty stifles investment. This research is essential to de-risk investment, ensure public safety, and create a stable governance structure, a gap noted by (Kamali Saraji & Streimikiene, 2023). | SDG 9, 11, 16 |

| | | | | |
|---|---|---|---|---|
| 4 | **Socio-Technical & Human Factors** | • What are the long-term impacts of automation on the urban labor market and what constitutes a "just transition"? • How can HMI lessons from mining be adapted for safe AV-human interaction? | Social acceptance is a major uncertainty. This research is crucial to design an equitable transition, mitigate social resistance, and build public trust, as emphasized by (Tamasiga et al., 2025)). | SDG 8, 10, 11 |
| 5 | **Full Lifecycle Sustainability & Circularity** | • What is the full lifecycle environmental impact (LCA) of these technologies? • How can "urban mining" facilities for EV batteries be integrated into city logistics networks (Erdiaw-Kwasie et al., 2024)? | To avoid problem-shifting. Comprehensive LCA and circular design research are needed to ensure true, holistic sustainability, a theme raised by (Iacovidou et al., 2017). | SDG 12, 13 |

Source: Authors' analysis of identified research gaps.

**Table 6. Actionable Recommendations for Stakeholders**

| No. | Target Stakeholder | Actionable Recommendation | Key References |
|---|---|---|---|
| 1 | **National & City Governments (Policymakers)** | **Develop an Adaptive Regulatory Framework.** Create clear, phased regulations for autonomous freight and establish mandates for circular economy practices. | (Bucci Ancapi et al., 2022; Kamali Saraji & Streimikiene, 2023) |
| 2 | **Urban Planners & Infrastructure Agencies** | **Integrate Smart Logistics into Master Plans.** Proactively plan and co-invest in a network of shared, interoperable infrastructure. | (Treiblmaier et al., 2020); (Alshuwaikhat et al., 2022) |
| 3 | **Financial Institutions & Government Agencies** | **Create Targeted Green Finance Mechanisms.** Develop green bonds, tax credits, and loan guarantees to mitigate high initial CAPEX. | (Anekwe et al., 2025; Kumar et al., 2025) |
| 4 | **Logistics & Freight Companies (Managers)** | **Adopt a Phased, Data-Driven Adoption Strategy.** Begin with pilot projects in controlled environments and use data analytics to validate ROI. | (Abdessadak et al., 2025; Ibrahim et al., 2025) |
| 5 | **Technology Providers & Industry Associations** | **Champion Interoperability and Open Standards.** Collaborate to develop universal standards for charging and data platforms. | (Hariyani et al., 2025; Rejeb et al., 2022) |
| 6 | **Educational Institutions & Labor Unions** | **Co-develop "Just Transition" Upskilling Programs.** Create forward-looking curricula for emerging roles in partnership with industry. | (Bansah et al., 2016; Tamasiga et al., 2025) |
| 7 | **All Stakeholders** | **Foster Cross-Sectoral Ecosystems for a Circular Economy.** Establish public-private partnerships to create closed-loop systems. | (Flores Lara et al., 2025; Schöggl et al., 2020) |

Source: Authors' synthesis of recommendations derived from the reviewed literature.

## CONCLUSION

This systematic literature review has established that technologies pioneered within the green mining sector—specifically advanced fleet electrification, autonomous systems, and circular economy practices—offer a significant and viable pathway to accelerate the sustainability transition of urban logistics. The synthesis of 30 high-quality studies demonstrates that while these innovations are technically mature, their successful implementation is contingent upon overcoming critical economic, infrastructural, and regulatory barriers that define the complex urban sociotechnical landscape. The conceptual framework developed in this study provides a novel roadmap for stakeholders, highlighting that a holistic approach is required, where policy interventions, infrastructure development, and financial incentives must be aligned to support technology adoption. By bridging the knowledge gap between these two industrial sectors, this research provides a practical and evidence-based foundation for policymakers and industry leaders to leverage cross-sectoral learning, thereby making a direct and impactful contribution to achieving the Sustainable Development Goals for cleaner, more efficient, and resilient cities.

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