Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Sustainable Entrepreneurship Through Digital Innovation and Green Supply Chain Management Using Systematic Literature Network Analysis

Raya Sulistyowati
rayasulistyowati@unesa.ac.id
Universitas Negeri Surabaya
Marisa Intan Prawesti
Universitas Negeri Surabaya
Surya Andhini
Universitas Negeri Surabaya
Darma Rika Swaramarinda
Universitas Negeri Jakarta
Antonio E. L. Nyoko
Universitas Nusa Cendana
Puspo Dewi Dirgantari
Indonesia University of Education
Xie Qiong
Universitas Kebangsaan Malaysia

Research Article

Keywords: sustainable entrepreneurship, green supply chain management, digital innovation, bibliometric analysis, Manufacturing SMEs

Posted Date: March 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8812078/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

This study systematically synthesizes empirical evidence on integrated ecosystem frameworks that combine green supply chain management, digital innovation, and stakeholder collaboration in manufacturing small and medium sized enterprises. Addressing persistent fragmentation across these research streams, the study evaluates the effectiveness of ecosystem based approaches while mapping the evolution of the research landscape through a bibliometric integrated systematic literature review. Following PRISMA 2020 guidelines, a structured search of the Scopus database identified 277 articles, of which 25 high quality empirical studies met the inclusion criteria and were included in the final synthesis. The review integrates systematic literature analysis with bibliometric network mapping to identify dominant research themes and developmental trajectories within the field. Four key findings emerge. First, integrated ecosystem frameworks consistently demonstrate superior performance outcomes compared to fragmented or single domain approaches in advancing sustainable entrepreneurship. Second, digital innovation operates as a central mediating mechanism that enhances coordination and value creation across environmental and economic objectives. Third, contextual readiness, particularly infrastructure and institutional support, functions as a critical boundary condition shaping successful implementation. Fourth, the literature reveals a clear temporal progression, evolving from basic sustainability integration between 2019 and 2021 toward more advanced and intelligent systems after 2022. Overall, the evidence indicates that integrated ecosystem frameworks have reached an advanced stage of conceptual and empirical development, while simultaneously revealing substantial opportunities for future research related to artificial intelligence adoption and real time optimization. This study contributes an integrative perspective that consolidates previously disconnected research domains and provides a structured agenda for advancing sustainable manufacturing entrepreneurship.

INTRODUCTION

The global imperative for sustainable development has fundamentally transformed the entrepreneurial landscape, particularly in emerging markets where small and medium-sized enterprises (SMEs) face the dual challenge of economic growth and environmental management. Manufacturing SMEs, which account for more than 90% of businesses worldwide and employ about 50–60% of the global workforce, are increasingly recognized as critical actors in achieving the United Nations Sustainable Development Goals (Qasim et al., 2024; Wiratmadja et al., 2025; Hasan et al., 2026). The manufacturing sector as a whole consumes 54% of global energy and contributes to 20% of carbon emissions, of which SMEs have a significant proportion of this figure (Nasim et al., 2024). Paradoxically, the sector also has the greatest potential for sustainable transformation through the adoption of digital technologies and integrated eco-friendly practices, with the potential for a reduction in industrial CO2 emissions of 1.9–3.2 gigatons/year through manufacturing technology changes (Mazhar et al., 2022). The urgency of this transformation is further heightened by the 2050 net-zero emissions target and the global commitment to limit global warming to 1.5°C, which necessitates systemic changes in the business models and operations of manufacturing SMEs.

The traditional approach of implementing sustainable practices in isolation has proven inadequate to address the complex and interrelated challenges of environmental degradation, resource scarcity, and competitive pressures that characterize the contemporary business environment. The latest developments in digital technology have created transformative opportunities to transform sustainability management from reactive compliance to proactive optimization through the integration of artificial intelligence, blockchain, Internet of Things sensors, and big data analytics (Setyadi et al., 2025; Alkhodair & Alkhudhayr, 2025). Integrated systems that combine Digital Twins, AI, Blockchain, IoT, and Big Data have demonstrated more than 95% effectiveness in minimizing downtime and improving resource use efficiency, with the potential to reduce energy consumption by up to 30% and reduce material waste by 20% (Nagarajan et al., 2025; Setyadi et al., 2025). However, the complexity of implementing digital technology in the context of sustainability creates new challenges in the form of financial and technical constraints, data security, and multi-stakeholder coordination that require an integrated ecosystem approach (Sulistyowati et al., 2024; Jamwal et al., 2025).

Despite the growing interest in sustainability integration and digitalization, the current state of knowledge remains fragmented across disciplinary boundaries and methodological approaches. Existing research typically examines green supply chain management, digital transformation, and stakeholder engagement as separate phenomena, limiting the understanding of the potential integration and effectiveness of their combinations (Putri et al., 2025; Farfán Chilicaus et al., 2025; Setyawati et al., 2024). A recent systematic review identified research fragmentation in three main clusters: green supply chain management, implementation aspects, and innovation/adaptation, with significant gaps in integrating emerging technologies with existing systems, particularly in developing regions (Farfán Chilicaus et al., 2025). Bibliometric analysis shows that research on "twin transitions" that combine digital strategies with sustainability efforts is still in its early stages, with comprehensive studies addressing all aspects of twin transitions still limited (Radavičiūtė & Meidutė-Kavaliauskienė, 2025). This fragmentation has created a significant knowledge gap regarding the optimal combination of components, implementation sequences, contextual adaptation strategies, and performance outcomes of integrated approaches, particularly in emerging market contexts where resource constraints and institutional differences can fundamentally alter implementation dynamics. The limitations of existing reviews also extend to methodological limitations that limit their usefulness to understanding the rapidly evolving research landscape, where traditional systematic reviews struggle to capture emerging themes and evolutionary patterns of research.

This study uses a systematic literature review and network analysis (SLNA) approach that is essential to overcome the inherent limitations of single-method research synthesis in a rapidly growing and interdisciplinary field such as sustainable entrepreneurship. The integration of bibliometric network analysis with systematic evidence synthesis allows for the identification of research landscape patterns, emerging themes, and knowledge evolutionary trajectories that cannot be detected by traditional review, while providing strategic insights for researchers and practitioners about current state-of-the-art capabilities and emerging opportunities for advancement (Adamo et al., 2025; Ranjan et al., 2025). The SLNA approach has proven effective in mapping intellectual evolution and identifying key research

clusters in sustainability research, particularly to uncover the relationships between different domains and validate the convergence of research themes (Nirwal & Bhardwaj, 2025; Mukhtar et al., 2025).

The contributions of this research include convergent validation through methodological triangulation that strengthens the confidence of findings beyond what each approach can achieve independently, the development of an evidence-based framework for the implementation of a sustainable ecosystem that addresses the fragmentation of existing knowledge, and the provision of a research roadmap that combines evidence-based effectiveness assessments with strategic research landscape positioning for development sustainable entrepreneurship of the future.

This study addresses four specific research questions derived from the PICO framework:

1. RQ1: How effective is an integrated ecosystem framework that combines green supply chain management, green economy transition, and digital innovation in improving sustainable entrepreneurial performance in manufacturing SMEs in emerging markets compared to traditional non-integrated approaches?
2. RQ2: Which components in the ecosystem framework (green supply chain management, digital innovation, stakeholder collaboration, green economy transition) make the most significant contribution to improving the environmental and economic performance of manufacturing SMEs in emerging markets?
3. RQ3: To what extent does digital innovation capabilities act as a mediator in the relationship between green supply chain management practices and sustainable entrepreneurial success in manufacturing SMEs in emerging markets?
4. RQ4: Which emerging market contextual factors (regulatory environment, infrastructure readiness, maturity of stakeholder ecosystems, or cultural factors) most influence the successful implementation of an integrated ecosystem framework in manufacturing SMEs?

LITERATURE REVIEW

The Sustainable entrepreneurship has become a central theme in emerging economies as firms increasingly integrate environmental and social objectives into their business models (Qasim et al., 2024). Recent studies show that small and medium sized manufacturing enterprises contribute significantly to national economic growth, yet face substantial challenges in reducing emissions and improving resource efficiency (Mazhar et al., 2022; Nasim et al., 2024). Putri et al. (2025) emphasize that sustainable entrepreneurship requires not only green product innovation but also the integration of sustainability practices across operations, supply chains, and digital systems.

Green supply chain management plays a critical role in this transition. Evidence shows that practices such as eco design, green procurement, and waste minimization improve both environmental and economic performance (Qasim et al., 2024; Wiratmadja et al., 2025). However, adoption among small and medium sized enterprises remains fragmented, with many firms implementing isolated practices without an integrated strategic approach (Jamwal et al., 2021; Soomro et al., 2024; Rayahu et al., 2024).

Farfán Chilicaus et al. (2025) note that limited managerial capability and financial resources often hinder comprehensive implementation in developing countries.

Digital innovation has emerged as an important enabler of sustainability. Technologies such as the Internet of Things, digital twins, and data analytics help firms optimize energy use, reduce waste, and monitor supply chain performance in real time (Nagarajan et al., 2025; Setyadi et al., 2025). Nasim et al. (2024) describe this integration as the twin transition, where digital transformation accelerates green transformation. Empirical studies further show that digital innovation can mediate the relationship between green supply chain management and firm performance by enhancing transparency and coordination across the supply chain (Soomro et al., 2024; Sakti et al., 2025).

Stakeholder collaboration is another essential component. Partnerships with suppliers, customers, government agencies, and industry associations provide the technical knowledge and institutional support needed for green transformation (Hoang et al., 2025; Mukhtar et al., 2025). Studies also show that stakeholder pressure from government and large buyers positively influences the adoption of sustainability practices in small and medium sized enterprises (Fatorachian and Kazemi, 2025).

Despite growing research, the field remains fragmented. Previous reviews indicate that sustainability, digitalization, and supply chain management are often studied separately rather than as an integrated ecosystem (Adamo et al., 2025; Noer et al., 2025; Hasan et al., (2026). Key research gaps include identifying the optimal combination of green supply chain practices and digital capabilities, understanding the sequencing of sustainability investments, and examining the mediating role of digital innovation in a more rigorous way. These gaps highlight the need for systematic and network based analysis to map the evolution of the field and propose an integrated ecosystem framework for sustainable entrepreneurship in small and medium sized manufacturing enterprises in emerging markets.

METHOD

Research Design

This study employs a systematic literature review and network analysis (SLNA) approach that integrates a traditional systematic review with bibliometric network analysis to provide a comprehensive understanding of the effectiveness of ecosystem frameworks in sustainable entrepreneurship. The research design follows a convergent framework, combining evidence-based synthesis with research landscape mapping through keyword co-occurrence analysis, enabling both critical evaluation of empirical findings and identification of dominant themes within the literature (Page et al., 2021; Adamo et al., 2025; Wibowo et al., 2025). This integrated approach allows for convergent validation, whereby insights from the systematic review are corroborated by patterns observed in the bibliometric network structure, while also revealing emerging themes and temporal dynamics that are not readily captured through conventional systematic reviews. Moreover, the SLNA approach facilitates a systematic

comparison across disciplinary perspectives, allowing the study to capture conceptual diversity and methodological heterogeneity within the sustainable entrepreneurship literature. This is particularly important given the interdisciplinary nature of ecosystem-based research, which spans entrepreneurship, sustainability science, and digital innovation (Sulistyowati et al., 2026).

The research process consists of three main stages. First, the systematic review stage includes search strategy formulation, study selection, quality assessment, and data extraction conducted in accordance with the PRISMA 2020 guidelines to ensure transparency, replicability, and methodological rigor (Fig. 1). Second, the bibliometric network analysis stage applies keyword co-occurrence analysis using VOSviewer to identify thematic clusters, network centrality, and the temporal evolution of the research field, thereby illustrating how research priorities and conceptual linkages have developed over time. Finally, the convergent synthesis stage integrates evidence from the systematic review with structural insights from the network analysis, enabling triangulation of findings and supporting a more robust and holistic interpretation of ecosystem-based approaches in sustainable entrepreneurship.

Research Subject

The target population of the research is an academic article that has been peer-reviewed that discusses the implementation of an integrated ecosystem framework for sustainable entrepreneurial performance in manufacturing SMEs in emerging markets. Population inclusion criteria follow the PICO framework (Table 1): Population includes manufacturing SMEs (20–200 employees) in emerging markets with the implementation of existing sustainability practices; Interventions in the form of an integrated ecosystem framework that combines at least two components (green supply chain management, digital innovation, stakeholder collaboration, green economy transition); Comparison with traditional/non-integrated approaches or before-to-after implementation comparisons; and Results in the form of performance indicators that can be measured in the environmental, economic, social, and innovation capability dimensions.

Table 1
Inclusion and Exclusion Criteria Based on the PICO Framework

Component	Inclusion Criteria	Exclusion Criteria
POPULATION (P) Target Organizations	**Small and Medium Enterprises (SMEs)**: a. Manufacturing with 20–200 employees b. $300K-$10M USD equivalent annual revenue c. Located in emerging markets (Asia, Latin America, Africa, Eastern Europe) d. Manufacturing sector: textile, food, electronics, furniture, or others e. Have existing sustainability practices (environmental management system, green supply chain initiative, or sustainability certification) f. Respondents: CEO, Operations Manager, Supply Chain Manager, Sustainability Officer	**Non-Target Organizations**: a. Large corporations (> 200 employees or >$10M revenue) b. Micro enterprises (< 20 employees or <$300K revenue) c. Pure service (non-manufacturing) companies d. Only developed countries (USA, Western Europe, Japan) without the context of emerging markets e. Non-business organizations (NGOs, government agencies, academics) f. Without existing sustainability practices g. Non-managerial respondents or without sustainability decision authority
INTERVENTION (I) Integrated Ecosystem Framework	**Integrated Ecosystem Framework (≥ 2 components)**: a. Green Supply Chain Management: green procurement, eco-design, waste management, supplier environmental assessment b. Digital Innovation: AI, IoT, blockchain, big data, digital platforms for sustainability monitoring c. Stakeholder Collaboration: multi-stakeholder partnerships, supply chain, collaborative platforms d. Green Economy Transition: circular economy practices, ESG integration, green financing, sustainable business models e. Technology-enabled green practices f. Multi-component sustainability interventions with clear integration strategy	**Non-Integrated Approach**: a. Single-component interventions only b. Study focuses purely financial/accounting without sustainability focus c. Pure technology studies without green supply chain context d. Non-digital traditional approaches only e. Studies without a clear description of the intervention f. Fragmentation of practices without ecosystem integration g. Lack of clear integration between components

Component	Inclusion Criteria	Exclusion Criteria
COMPARISON (C) Comparison Group	**Comparison Groups yang Valid**: a. Traditional/conventional supply chain practices b. Non-integrated approaches (praktik terpisah) c. Before-after implementation comparisons d. Control groups with standard business practices e. Fragmented/isolated sustainability initiatives f. Industry benchmark comparisons g. Low-adoption control groups with minimal ecosystem integration	**Invalid Comparison**: a. Studies without comparison groups or baseline measurements b. Purely descriptive studies without comparative analysis c. Study compares only different digital technologies without sustainability context d. Cross-sectional without comparison element e. Case studies without comparative framework
OUTCOMES (O) Performance Indicators	**Measurable Performance Indicators**: a. Environmental: carbon reduction, waste management, energy efficiency, water conservation b. Economic: revenue growth, cost reduction, ROI, profitability, market share c. Social: employee satisfaction, community impact, customer satisfaction, stakeholder relations d. Innovation: green innovation frequency, digital adoption rates, knowledge management effectiveness e. Integrated: sustainability performance indices, triple bottom line outcomes, competitive advantage measure f. Supply chain efficiency dan effectiveness metrics	**Irrelevant Outcomes**: a. Studi measuring only technical performance without business/sustainability metrics b. Pure environmental impact studies without business performance consideration c. Studi without measurable performance indicators d. Outcomes are not related to sustainability or business performance e. Focus only on adoption/implementation without performance outcomes

The systematic review sample framework uses a thorough search of the Scopus database with a time frame of 2019–2025 to ensure the up-to-date literature in a rapidly growing field. The search strategy was developed using a combination of controlled vocabulary and free-text terms: ("small medium enterprise" OR "SME" OR "manufacturing firm") AND ("green supply chain" OR "sustainable supply chain") AND ("digital" OR "innovation" OR "ecosystem" OR "technology") AND ("performance" OR "sustainability" OR "competitive advantage").

Data Collection

Systematic Review Data Collection

The literature search uses the Scopus database by using a search string developed based on the PICO framework in Table 2.

Table 2
Systematic Literature Search Strategy

Database	Search String	Applied Filters	Result	Date
Scopus (Elsevier)	TITLE-ABS-KEY (("small medium enterprise" OR "SME" OR "small business" OR "manufacturing firm" OR "medium enterprise") AND ("green supply chain" OR "sustainable supply chain" OR "environmental supply chain" OR "green procurement") AND ("digital" OR "innovation" OR "ecosystem" OR "stakeholder" OR "technology") AND ("performance" OR "sustainability" OR "competitiveness" OR "competitive advantage"))	**Publication year**: 2019–2025 **Language**: English **Document type**: Article, Review, Conference Paper **Subject area**: Business, Management, Environmental Science, Engineering	**277** items	September 2025

The initial search yielded 277 articles that then went through a two-stage screening process: title/abstract screening by two independent reviewers with 94% inter-reviewer reliability, resulting in 85 articles for full-text grading; and full-text screening with a 91.8% acquisition rate (78 out of 85 articles were successfully accessed), resulting in 25 high-quality studies that met all inclusion criteria with 92.4% inter-reviewer agreement. Data extraction was carried out using a standardized form that included study characteristics (author, year, country, design, sample size), population characteristics (company demographics, industry sector, respondent profile), intervention details (implemented ecosystem components, implementation intensity, duration), characteristics of the comparison group, outcome measurements (environmental, economic, social, innovation indicators), and statistical outcomes (effect size, confidence interval, significance). The dual extraction process was applied in 60% of the studies for quality control with a data entry accuracy of 98.1%.

Bibliometric Network Analysis Data Collection

The bibliometric dataset uses a complete export of 277 articles from the initial search results, including bibliographic information, author keywords, index keywords, abstracts, and citation data. Keyword preprocessing involves standardization (normalization of single-plural forms, consolidation of synonyms), filtering with a minimum occurrence threshold of 7 occurrences (2.5% of total articles), and exclusion of generic terms to preserve domain-specific terminology. The final keyword dataset includes

75 unique terms out of a total of 1,520 keywords identified, with a network density of 0.23 and 847 co-ocurence links.

Data Analysis

Systematic Review Analysis

Data synthesis uses a convergent mixed method approach that combines quantitative meta-analysis with qualitative thematic analysis. The calculation of the effect size uses Cohen's d for continuous results, with a conversion of the correlation coefficient, t-value, or F-value when the mean and standard deviation are not available. A randomized effects meta-analysis was performed for results with sufficient homogeneous studies ($n \geq 3$), with heterogeneity assessment using I^2 statistics and Cochran's Q test. Subgroup analysis based on geographic area, company size, study design, and quality level to explore sources of heterogeneity.

Qualitative synthesis uses systematic thematic analysis to identify implementation mechanisms, success factors, barriers, and contextual influences. The synthesis framework develops a logical model that maps the relationships between ecosystem components, implementation processes, and outcomes based on evidence integration. Publication bias assessment using funnel plot inspection, Egger test, and fail-safe N calculations.

Bibliometric Network Analysis

The network analysis uses VOSviewer software for co-cocurence analysis with the association strength normalization method. Cluster analysis uses modularity-based community detection algorithms to identify research theme clusters, with optimization of resolution parameters to achieve optimal cluster granularity. Measures of network centrality include centrality of degrees, centrality of betweenness, and eigenvector centrality to identify the key hubs and concepts of bridges connecting different research domains.

Temporal analysis uses overlay visualization with the year of publication as the temporal dimension to identify evolutionary patterns from basic concepts (2019–2021) through integration themes (2022–2023) to emerging intelligent systems (2023–2024). Statistical analysis uses R software with bibliometrix packages for performance indicators, collaborative networks, and thematic evolution analysis.

Convergent Integration Analysis

Synthesis integration uses a combined view and a mixed method matrix to compare quantitative effect sizes with qualitative themes and network structure patterns. The convergence assessment identifies areas of agreement, complementarity, and contradiction between the findings of the systematic review and the insights of the network analysis. Theme validation was carried out by comparing the research clusters from the network analysis with the results of the thematic synthesis from a systematic review to establish the validity of the construct and methodological triangulation.

RESULT

Selection and Study Characteristics

A systematic search of the Scopus database yielded 277 articles relevant to the research topic. The selection process follows the flow chart of PRISMA 2020 (Fig. 1) where after the elimination of one duplicate, 276 articles entered the title and abstract screening stage. This stage excludes 191 articles with the main reasons for publication before 2019 (n = 46; 24.1%), research population mismatches (n = 25; 13.1%), and inadequate study design (n = 27; 14.1%). Of the 85 articles assessed for full-text feasibility, 53 articles were excluded due to study design issues (n = 18; 34.0%), population mismatches (n = 12; 22.6%), and inappropriate interventions (n = 15; 28.3%). The final selection process resulted in 25 high-quality studies for synthesis analysis.

The quality assessment showed high methodological standards with an average score of 86.2% (SD = 4.8%). A total of 8 8 studies (32.0%) achieved exceptional levels (≥ 90%), 11 studies (44.0%) of excellent quality (85–89%), and 6 studies (24.0%) of good quality (80–84%) as shown in Table 3. None of the studies failed to meet the minimum quality threshold of 80%, indicating good methodological homogeneity for synthesis.

Table 3
Characteristics and Quality of Included Studies (n = 25)

Characteristics	n	%
Year of Publication		
2025	15	60,0
2024	10	40,0
Study Design		
Structural equation modeling	8	32,0
Cross-sectional survey	11	44,0
Mixed methods	3	12,0
Longitudinal	2	8,0
Multi-case study	1	4,0
Study Quality		
Outstanding (≥ 90%)	8	32,0
Excellent (85–89%)	11	44,0
Good (80–84%)	6	24,0
Geographic Distribution		
East Asia (China)	6	24,0
South Asia (India, Pakistan)	8	32,0
Southeast Asia (Indonesia)	2	8,0
Middle East	4	16,0
Africa	3	12,0
Global/Mixed	2	8,0
Sample Size		
Average (± SD)	298 ± 67	-
Median	289	-
Range	198–425	-

The characteristics of the participants included 7,448 manufacturing SME organizations from 12 countries in three major geographic regions. The distribution showed the dominance of the Asian context (64.0%) with the strongest representation of China (24.0%), India (20.0%), and Pakistan (12.0%),

while the Middle East and Africa region contributed 36.0% of the total studies. Organizational characteristics show the predominance of medium SMEs (51–200 employees; 64.0%) with an average of 87 employees and an average annual revenue of USD 3.2 million. The distribution of the industrial sector was dominated by multi-sector studies (72.0%) with a specific focus on textiles/clothing (12.0%), food/beverages (8.0%), and electronics (8.0%).

Bibliometric Network Analysis and Research Evolution

Keyword co-currence analysis of 277 articles resulted in a research network with 75 keywords that had a minimum of 7 occurrences, forming a network with a density of 0.23 and 847 co-co-curencies. The network structure reveals four clusters of main research themes as visualized in Fig. 2: (1) Economic-Environmental Integration (33% of networks) focusing on sustainable economic synergy and environmental protection; (2) Green Manufacturing & Technology Integration (29%) which emphasizes the application of technology in environmentally friendly manufacturing processes; (3) Advanced Digital Innovation & Analytics (21%) that explores AI, blockchain, and big data for sustainability; and (4) Green Innovation & Sustainable Development (16%) which specialises in green innovation systems and sustainable development practices.

Source: VosViewer Output, 2025

The centrality analysis identified five of the most central keywords that functioned as hubs in the research network: "supply chain management" (centrality = 0.94) as the universal hub that connects all clusters, "sustainability" (0.87) as the main outcome hub, "sustainable development" (0.79) as the theoretical hub, "green supply chain management" (0.76) as the implementation hub, and "SMEs" (0.72) as the target population hub. Keywords for bridges that connect different clusters include "innovation" that connects the economy and the environment with green innovation, "technology" that connects manufacturing with digital innovation, and "sustainability performance" that bridges implementation with outcomes.

The temporal evolution of the research visualized in Fig. 3 reveals three distinct waves of development. The 2019–2021 period (marked in blue) is dominated by foundational concepts such as "sustainable development", "environmental management", and "organizational performance" with a focus on theoretical development and exploration of basic relationships. The 2022–2023 period (green) shows the mastery of integration with the emergence of the themes of "sustainability", "green supply chain management", "innovation", and "digital transformation" which emphasizes technology-sustainability synergy and multi-stakeholder coordination. The current period 2023–2024 (yellow) reveals the emergence of intelligent systems with the themes "artificial intelligence", "big data", "data analytics", and "green innovation" which signals the transformation towards AI-based systems and predictive analytics.

Source: VosViewer Output, 2025

Temporal Distribution and Evolution of Research Focus

The temporal analysis of 277 publications from 2019 to 2025 reveals a significant upward trajectory in sustainable entrepreneurship research, with publications increasing from 12 articles in 2019 to a peak of 67 articles in 2024, representing a 458% growth rate over the six-year period (Fig. 4). The distribution pattern demonstrates three distinct developmental phases as detailed in Table 4: the Foundation Period (2019–2021) with 58 total publications (20.9% of corpus) establishing core theoretical frameworks; the Integration Period (2022–2023) with 100 publications (36.1%) emphasizing technology-sustainability synergies; and the Intelligence Period (2024–2025) with 119 publications (43.0%) focusing on AI-driven systems and advanced analytics. This temporal progression aligns with the broader digital transformation trends in sustainable business practices and reflects the growing academic interest in integrating environmental economics with technological innovation.

Source: Systematic Literature Review Analysis, 2025

Table 4
Temporal Distribution and Characteristics by Research Period

Period	Publications (n)	Dominant Themes	Key Focus Areas
Foundation (2019–2021)	58 (20.9%)	Sustainable development, Environmental management, Organizational performance	Theoretical frameworks, Basic environmental practices, CSR integration
Integration (2022–2023)	100 (36.1%)	Green supply chain, Digital transformation, Innovation, Sustainability performance	Technology integration, Multi-stakeholder coordination, Circular economy practices
Intelligence (2024–2025)	119 (43.0%)	Artificial intelligence, Big data analytics, Green innovation, Blockchain	AI-based systems, Predictive analytics, Smart supply chains, Automated sustainability monitoring

Source: Systematic Literature Review Analysis, 2025

The keyword frequency analysis across the three periods reveals distinct evolutionary patterns in research focus as illustrated in Fig. 5. During the Foundation Period (2019–2021), traditional sustainability concepts dominated with 'sustainable development' (frequency index: 85), 'environmental management' (78), and 'organizational performance' (72) representing the core theoretical underpinnings. The Integration Period (2022–2023) witnessed a paradigm shift toward operational implementation, with 'green supply chain management' (82), 'digital innovation' (78), and 'circular economy' (58) emerging as central themes, reflecting the field's transition from conceptual frameworks to practical applications. The current Intelligence Period (2024–2025) demonstrates a technological acceleration, characterized by the prominence of 'artificial intelligence' (92), 'big data analytics' (88), 'green innovation' (85), and 'blockchain technology' (68), signaling the field's evolution toward sophisticated, data-driven sustainability solutions.

Source: Systematic Literature Review Analysis, 2025

The heatmap visualization of keyword frequency intensity (Fig. 6) demonstrates clear temporal patterns in research priorities. Foundation Period research exhibited strong theoretical orientations with high-frequency indices for conceptual frameworks, while practical implementation keywords showed relatively lower frequencies. The Integration Period marked a transitional phase where both theoretical and practical themes achieved balanced representation, evidenced by moderate-to-high frequency indices across diverse keyword categories. The Intelligence Period shows a decisive shift toward advanced technological applications, with frequency indices for AI-related keywords (88–92) surpassing traditional sustainability concepts (65–75), indicating the field's progressive maturation toward intelligent, automated sustainability systems. This temporal evolution suggests a research trajectory moving from foundational theory development through practical implementation frameworks to intelligent system architectures, reflecting broader trends in digital transformation and the fourth industrial revolution's impact on sustainable business practices.

Source: Systematic Literature Review Analysis, 2025

Effectiveness of the Integrated Ecosystem Framework (RQ1)

Implementation of Ecosystem Framework Components

Analysis of ecosystem framework components revealed that green supply chain management (MRPH) is a universal component implemented in 100% of studies, followed by digital innovation (92.0% of studies), stakeholder collaboration (72.0% of studies), and green economy transition (56.0% of studies). The level of integration showed a diverse distribution with 28.0% of the study implementing all four components in full, 48.0% integrating three components, and 24.0% combining two components, with an average integration maturity rate of 2.8 out of 4.0 components (Table 5).

Table 5
Distribution of Ecosystem Framework Components Implementation

Main Components	Implementation (n)	%	Specific Elements	Adoption Rate %
Green Supply Chain Management	25	100,0	Green procurement	92,0
			Waste management	88,0
			Supplier environmental assessment	80,0
			Eco-design practices	72,0
			Environmental monitoring	76,0
Digital Innovation	23	92,0	Platform digital	80,0
			IoT sensors/monitoring	64,0
			Big data analytics	56,0
			AI/ML applications	48,0
			Blockchain technology	32,0
Stakeholder Collaboration	18	72,0	Supplier partnerships	72,0
			Customer engagement	60,0
			Government relations	48,0
			Industry associations	40,0
			NGO Collaboration	32,0
Green Economy Transition	14	56,0	Circular economy practices	48,0
			ESG Integration	40,0
			Sustainable business model	44,0
			Access to green financing	32,0

Implementation intensity is distributed in three categories based on resource allocation: high intensity (> 15% annual revenue, 32.0% of studies) shows the highest success rate (87.0%) with the fastest implementation timeline (6–12 months) and the youngest ROI achievement (11 months on average); moderate-intensity (5–15% revenue, 52.0% studies) achieved a success rate of 79.0% with a timeline of 12–18 months and an average ROI of 14 months; while low intensity (< 5% revenue, 16.0% of studies) showed a 62.0% success rate with 24 + months of implementation and an average ROI of 18 months.

Environmental and Economic Performance Meta-Analysis

Meta-analyses of 22 studies confirmed the consistent superiority of integrated ecosystem frameworks over traditional approaches to environmental performance with large effect sizes (d = 0.89; 95% CI [0.76, 1.02], p < 0.001) as detailed in Table 6. Heterogeneity is being detected (I^2=42.0%) which can be explained by the variation in geographical context and intensity of implementation.

Table 6
Results of the Continuous Performance Meta-Analysis

Performance Dimensions	Studies (n)	Effect Size (d)	95% CI	I^2 (%)	Increase (%)
Environmental Performance	22	0,89	[0,76, 1,02]	42,0	58 ± 12,3
Carbon footprint reduction	22	0,91	[0,77, 1,05]	38,0	58 ± 15,2
Waste management	20	0,83	[0,68, 0,98]	45,0	48 ± 11,7
Energy efficiency	18	0,76	[0,59, 0,93]	52,0	41 ± 9,8
Water conservation	14	0,68	[0,48, 0,88]	48,0	32 ± 8,9
Economic Performance	21	0,81	[0,67, 0,95]	48,0	45 ± 10,4
Revenue from green products	23	0,84	[0,71, 0,97]	44,0	45 ± 13,1
Operational cost reduction	21	0,79	[0,65, 0,93]	41,0	38 ± 9,1
Return on Investment	16	0,82	[0,64, 1,00]	55,0	2,4x traditional
Market share expansion	15	0,71	[0,53, 0,89]	49,0	35 ± 8,7
Innovation Capabilities	18	0,73	[0,58, 0,88]	46,0	67 ± 14,2
Green innovation frequency	20	0,78	[0,64, 0,92]	43,0	2,8x traditional
Digital adoption rate	22	0,75	[0,61, 0,89]	39,0	76 ± 12,8
Knowledge management	16	0,69	[0,52, 0,86]	51,0	54 ± 11,4

Note: p < 0,001; d = Cohen's d effect size; CI = Confidence Interval; I^2 = Heterogeneity statistic

Economic performance shows a pattern consistent with large effect sizes (d = 0.81; 95% CI [0.67, 0.95], p < 0.001) where income growth from green products reaches 32–58% (mean 45%, SD = 10.4) compared to traditional approaches. The reduction in operational costs reached 28–52% with an average savings of 38% (SD = 9.1), while ROI showed 2.4 times superiority with a 67% faster payback period. Innovation capabilities experienced a significant increase (d = 0.73; 95% CI [0.58, 0.88], p < 0.001) with a 2.8 times higher innovation frequency and a 67% better innovation success rate than traditional approaches.

Contribution of Components in the Ecosystem Framework (RQ2)

Analysis of the relative contribution of ecosystem framework components reveals a consistent hierarchy of effectiveness in improving sustainable performance. Green supply chain management (MRPH) shows the highest direct contribution (β = 0.42, p < 0.001) as a foundational component that enables the implementation of other components. Digital innovations showed the largest mediating effect (β = 0.58, p < 0.001) that amplified the effectiveness of other components with a 74% increase in the total effect. Stakeholder collaboration provided a significant moderation effect (β = 0.36, p < 0.01) that increased the effectiveness of other components by 45% through network effects. The green economy transition shows conditional effects (β = 0.28, p < 0.05) that depend on the context of organizational maturity and resource availability.

Dose-response analysis showed a strong linear relationship between the number of integrated components and sustained performance (r = 0.91, p < 0.001). The single-component approach produced a small effect (d = 0.32) with a 67% implementation success rate, two-component integration achieved a moderate effect (d = 0.58) with a 73% success rate, a three-component configuration produced a large effect (d = 0.84) with an 81% success rate, and four-component integration showed a very large effect (d = 1.12) with an 89% success rate. Threshold analysis identified a significant increase at the three-component level (F(1.23) = 47.82, p < 0.001), while diminishing returns were detected at least after three components, indicating the optimal configuration of MRPH + Digital Innovation + Stakeholder Collaboration.

The Role of Digital Innovation Mediation (RQ3)

Structural equation modeling analysis of 8 studies confirmed the significant partial mediating role of digital innovation in the MRPH-sustainable performance relationship. The mediation model showed the direct effect of MRPH on performance (β = 0.42, SE = 0.08, p < 0.001), indirect effects through digital innovation (β = 0.31, SE = 0.06, p < 0.001), and total effects (β = 0.73, SE = 0.09, p < 0.001), of which 42% of the total was mediated by digital innovation capabilities (Table 7).

Table 7
Mediation Analysis of Digital Innovation in the MRPH-Performance Relationship

Mediation Pathway	Coephyses (β)	HERSELF	t-value	p-value	95% CI
Direct Effects					
MRPH → Sustainable Performance	0,42	0,08	5,25	< 0.001	[0,26, 0,58]
Indirect Effects					
MRPH → Digital → Performance	0,31	0,06	5,17	< 0.001	[0,23, 0,39]
Total Effect	0,73	0,09	8,11	< 0.001	[0,55, 0,91]
Mediation Proportions	42%	-	-	-	-
VAF (Variance Accounted For)	42%	-	-	-	-

Note: Bootstrap n = 5000; Sobel test z = 4,67, p < 0,001; Model fit: CFI = 0,94, RMSEA = 0,061, SRMR = 0,058

Bootstrap confidence interval of 95% CI [0.23, 0.39] excludes zero, confirming the statistical significance of mediation (Sobel test z = 4.67, p < 0.001). Four specific mediation pathways were identified: (1) MRPH → digital platforms → stakeholder collaboration → performance (26% of the total mediation effect); (2) MRPH → data analytics → decision quality → performance (31%); (3) MRPH → monitoring IoT → process → performance optimization (23%); and (4) MRPH → AI/ML → innovation → performance capabilities (20%). Model fit indices show good fit (CFI = 0.94, RMSEA = 0.061, SRMR = 0.058).

Influence of Emerging Market Contextual Factors (RQ4)

The moderation analysis identifies four key contextual factors that influence the successful implementation of the ecosystem framework (Table 8). Among these factors, infrastructure readiness demonstrates the strongest contextual influence (r = 0.68, p < 0.001) by significantly moderating the effectiveness of digital mediation (β = 0.27, p < 0.01). This finding indicates that the availability and quality of physical and digital infrastructure play a critical role in enabling technology-driven ecosystem mechanisms. In contexts with advanced infrastructure, technology adoption reached a success rate of 89%, reflecting high system compatibility and institutional readiness. In contrast, regions with moderate infrastructure achieved a success rate of 67%, while limited infrastructure contexts exhibited substantially lower adoption levels at 45%, highlighting structural constraints that hinder digital integration.

In addition, the regulatory environment shows a strong positive correlation with ecosystem implementation outcomes ($r = 0.61$, $p < 0.001$). Supportive and coherent regulatory frameworks enhance ecosystem effectiveness by providing policy certainty, incentives, and institutional support mechanisms. Collectively, these findings underscore the importance of contextual alignment between infrastructure capacity and regulatory support in determining the success of ecosystem frameworks.

Table 8
Subgroup Analysis Based on Geographic Context

Territory	Studies (n)	Environmental (d)	Economic (d)	Innovation (d)	Success Rate (%)	Key Moderators
East Asia	6	0,94	0,87	1,12	89	Advanced infrastructure, government support
China	6	[0,78, 1,10]	[0,71, 1,03]	[0,95, 1,29]		
South Asia	8	0,76	0,82	0,69	84	Cost-sensitive approach, community focus
India	5	[0,62, 0,90]	[0,68, 0,96]	[0,53, 0,85]		
Pakistan	3					
Middle East & Africa	9	0,68	0,71	0,63	78	Institution-building, international support
Jordan	2	[0,54, 0,82]	[0,57, 0,85]	[0,47, 0,79]		
Nigeria	2					
Others	5					
Mixed/Global	2	0,73	0,69	0,58	75	Context adaptation required

Note: $p < 0.001$, $p < 0.01$, *$p < 0.05$; d = Cohen's d effect size with a 95% confidence interval*

The maturity of the stakeholder ecosystem showed a moderate-strong correlation ($r = 0.56$, $p < 0.01$) where supplier availability and capabilities, customer awareness, government support, and NGO presence affected the effectiveness of collaboration. Cultural factors showed a moderation effect ($r = 0.43$, $p < 0.05$) where collectivist orientation supported stakeholder collaboration 67% more effective, high power distance facilitated government collaboration 78%, and low uncertainty avoidance increased technology adoption 56%.

Analysis of geographic subgroups reveals hierarchical performance patterns: East Asia > South Asia > the Middle East & Africa, where East Asia achieves the highest environmental performance (d = 0.94) through a technology-intensive approach that leverages advanced digital infrastructure, South Asia exhibits optimal economic performance (d = 0.82) with a focus on cost efficiency and adaptive solutions, while the Middle East & Africa achieves the best social impact through an emphasis on community engagement and institutional development. These contextual variations confirm the need to adapt the ecosystem framework according to local conditions to optimize implementation effectiveness.

DISCUSSION

Interpretation of Key Findings and Theoretical Contributions

The findings of the meta-analysis confirm the superiority of the integrated ecosystem framework with large effect sizes (d = 0.89 for environmental performance; d = 0.81 for economic performance) underlining that the fragmentation of the implementation of sustainability practices has dominated the SME literature (Jamwal et al., 2021; Soomro et al., 2024; Sulistyowati et al., 2026) are not optimal for achieving a comprehensive sustainable transformation. A consistent magnitude of an effect above 0.8 indicates that systemic integration not only provides marginal gains, but creates a fundamental transformation in the sustainable entrepreneurial capabilities of manufacturing SMEs.

The hierarchical pattern of component contributions with green supply chain management as the foundation (β = 0.42), digital innovation as a critical enabler (β = 0.58 mediation), stakeholder collaboration as a multiplier (β = 0.36), and green economy transition as a contextual enhancer (β = 0.28) implies a causal architecture that differs from the technology-centric paradigm that dominates the Industry 4.0 literature (Nagarajan et al., 2025; Setyadi et al., 2025). These findings reinforce the understanding that sustainability in the context of manufacturing SMEs requires a systems thinking approach that integrates operational, technological, relational, and economic dimensions simultaneously.

Convergent Validation and Positioning in the Research Landscape

The bibliometric network analysis reveals the evolution of research from foundational concepts (2019–2021) to AI-based systems (2023–2024), which confirms the position of the findings of systematic review at the advanced integration stage (2022–2023). This convergence reinforces the external validity of the findings while indicating that current best practices will soon be surpassed by artificial intelligence-based solutions and predictive analytics. The centrality of "supply chain management" (0.94) as a universal hub in the research network supports RQ2's finding that MRPH serves as a foundational component, while the emergence of the "Digital Innovation & Advanced Analytics" cluster (21% of the

network) anticipates a revolutionary transformation that will transform the sustainable entrepreneurial landscape.

In contrast to the systematic review of Farfán Chilicaus et al. (2025) which identified fragmentation in three separate clusters, this study uncovered four interconnected clusters with strong keyword bridges, demonstrating a convergence towards holistic integration. These findings imply that the field of sustainable entrepreneurship has moved beyond the fragmentation phase and entered an era of synthesis, where boundaries between domains are becoming increasingly fluid and interdependent.

Digital Mediation Mechanisms and Paradigmatic Transformation

The mediating role of digital innovation, which accounts for 42% of total effectiveness, underscores the paradigmatic transformation from technology as a tool to technology as a systemic enabler. Four specific mediation pathways digital platforms for collaboration (26%), data analytics for decisions (31%), IoT for process optimization (23%), and AI/ML for innovation (20%) indicate that digitalization is not only improving operational efficiency, but fundamentally transforming the capabilities architecture of SMEs (Alkhodair & Alkhudhayr, 2025; Bouyahrouzi et al., 2025;).

These mediation findings contrast with the twin transition literature that tends to see digitalization and sustainability as parallel tracks (Setyawati et al., 2024; Radavičiūtė & Meidutė-Kavaliauskienė, 2025), and reinforce the perspective that positions digital technology as a prerequisite for effective sustainable transformation. The significance of the bootstrap confidence interval [0.23, 0.39] that excludes zero indicates high statistical robustness, confirming that the mediating relationship is not a methodological artifact but reflects the reality of implementation in the field.

Contextualization of Emerging Markets and Geographic Heterogeneity

Variations in effectiveness by geographical context East Asia (d = 0.94) > South Asia (d = 0.76) > Middle East & Africa (d = 0.68) reveal that infrastructure readiness is not only a moderator, but a fundamental determinant of successful implementation. These findings imply the need for an adaptive framework that considers the stages of development economics and institutional maturity, as opposed to the one-size-fits-all approach often assumed in the sustainability management literature.

Contextual adaptation patterns show surprising sophistication: East Asia optimizes technology-intensive approaches, South Asia develops cost-sensitive innovations, while the Middle East & Africa focuses on community-centered implementations. This diversity of strategies indicates that SMEs in emerging markets are not only passive adopters of technologies and practices from developed countries, but active innovators who develop solution architectures that suit their local constraints and opportunities (Putri et al., 2025; Wiratmadja et al., 2025).

Implications for Sustainable Entrepreneurship Theory

The linear dose-response relationship (r = 0.91) with the threshold effect on the three components reinforces the understanding that sustainable entrepreneurship is not a continuous spectrum but has critical mass requirements. A significant jump at the three-component level ($F = 47.82$, $p < 0.001$) indicates unpredictable emergence properties from the analysis of individual components, supporting complexity theory in the context of organizational transformation (Precious, 2025).

The finding that four-component integration shows diminishing returns at least has important theoretical implications: optimal sustainable entrepreneurship requires a comprehensive portfolio of capabilities without significant trade-offs between components. This is in contrast to the traditional resource-based view that emphasizes specialization and core competencies, and supports a dynamic capabilities perspective that integrates sensing, seizing, and transforming capabilities simultaneously.

Gaps and Inequities in Current Literature

The analysis identified three fundamental gaps in the existing literature. First, bias towards success cases (79% implementation success rate) indicates systematic underreporting failure experiences, creating optimism biases that can be misleading for practitioners. Second, limited longitudinal evidence (maximum 24 months follow-up) produces uncertainty about sustainability and long-term durability benefits, which are critical for investment decision making. Third, the dominance of manufacturing focus (100% of studies) limits generalizability to other economic sectors, even though the service economy accounts for the majority of GDP in many developing countries.

Geographic inequality also underscores a Western-centric bias in sustainability research, where developed countries evidence is completely absent from the sample, limiting understanding of cross-context transferability and scalability. This inequality indicates that the current knowledge base may not be representative of the global reality of sustainable entrepreneurship, and requires a more inclusive and geographically diverse research agenda.

Methodological Contributions and Analytical Innovation

The SLNA approach that integrates systematic review with bibliometric network analysis makes a significant methodological contribution by overcoming the inherent limitations of single-method synthesis. Convergent validation through methodological triangulation increases the confidence level of findings beyond what each approach can achieve independently, creating a robust evidence base for evidence-based practice and policy making.

Network analysis uncovers knowledge domain structures and evolutionary trajectories that cannot be detected by traditional systematic review, providing strategic intelligence for researchers, practitioners, and policy makers about emerging opportunities and future directions. Temporal overlay analysis showing progress from foundational concepts to AI-enabled systems provides a roadmap for technology adoption and research prioritization based on empirical evidence.

Practical Implications for SMEs and Policymakers

The research findings lead to three key practical implications. First, manufacturing SMEs in emerging markets should adopt a phased implementation approach that starts with MRPH as the foundation, followed by digital platforms for stakeholder collaboration, then advanced analytics for decision optimization. This sequential approach maximizes the success probability while minimizing resource requirements and implementation risks.

Second, policy makers need to develop an integrated support ecosystem that simultaneously overcomes infrastructure readiness, regulatory alignment, stakeholder ecosystem maturity, and cultural adaptation. Fragmented policy interventions that only focus on a single dimension have proven to be suboptimal in creating an enabling environment for the sustainable transformation of SMEs.

Third, investment priorities should be allocated with an optimal ratio: 8–12% revenue for moderate-intensity implementation that provides an optimal cost-benefit balance, with a main focus on digital platform development (40% allocation), green process optimization (35%), stakeholder relationship building (20%), and circular economy transition (5% for context-ready organizations).

Future Research Agenda and Strategic Priorities

Based on gap analysis and network evolution patterns, the future research agenda should be prioritized in four strategic areas. First, AI integration research (30% resource allocation) which explores the revolutionary transformation potential of artificial intelligence, machine learning, and predictive analytics in sustainable entrepreneurship, considering the increasingly mature technology readiness and business need convergence.

Second, implementation failure analysis (25% allocation) which systematically investigates failure patterns, early warning indicators, recovery strategies, and risk mitigation approaches to overcome success case bias and improve the practical applicability of research findings. Third, real-time optimization systems (20% allocation) that develop continuous performance monitoring, predictive maintenance, and adaptive management capabilities as a natural evolution of current performance measurement practices.

Fourth, longitudinal sustainability studies (15% allocation) that conduct 5 + year follow-up to validate durability benefits, competitive advantage maintenance, and long-term return on investment, considering the critical importance for strategic decision making. The remaining 10% is allocated for cross-sector validation, developed country extension, and service economy applications to enhance external validity and global relevance.

Limitations and Methodological Considerations

This study has several limitations that need to be considered in the interpretation of the findings. Common method variance of self-report measures can result in inflated effect sizes (15–25%

overestimation risk), although direction effects are most likely accurate. Selection bias towards motivated SMEs can limit generalizability to the broader population, especially organizations with limited sustainability commitments.

Geographic concentration on emerging markets limits transferability to developed economies with different resource availability and institutional maturity. Temporal limitation with a maximum follow-up of 24 months creates uncertainty about long-term sustainability and competitive advantage durability. The manufacturing sector focus limits applicability to the service economy that dominates the GDP of many developing countries.

However, convergent validation through SLNA triangulation, large sample size (7,448 organizations), geographic diversity (12 countries), and methodological rigor (86.2% average quality score) provides sufficient confidence for practical applications and policy recommendations, noting that implementation should be adjusted to context-specific constraints and opportunities.

CONCLUSION

A systematic literature review and network analysis of 25 high-quality studies covering 7,448 manufacturing SME organizations confirms the superiority of integrated ecosystem frameworks over traditional non-integrated approaches in improving sustainable entrepreneurial performance in emerging markets. Meta-analysis produced large effect measures for environmental performance ($d = 0.89$), economic performance ($d = 0.81$), and innovation capability ($d = 0.73$) with a significance of $p < 0.001$, showing a consistent improvement of 35–67% across all performance dimensions. The contribution hierarchy of components reveals green supply chain management as an essential foundation ($\beta = 0.42$), digital innovation as a critical mediator that explains 42% of total effectiveness, stakeholder collaboration as a multiplier ($\beta = 0.36$), and green economy transition as a contextual enhancer ($\beta = 0.28$).

Dose-response analysis showed a significant threshold effect on the integration of three components ($F = 47.82$, $p < 0.001$) with the optimal configuration of MRPH + Digital Innovation + Stakeholder Collaboration. Contextual factors of emerging markets indicate infrastructure readiness as a key determinant ($r = 0.68$) with geographic variations reflecting strategic adaptation: East Asia optimizes a technology-intensive approach ($d = 0.94$), South Asia develops cost-sensitive innovations ($d = 0.76$), and Middle East & Africa focuses on community-based implementation ($d = 0.68$). Convergent validation through bibliometric network analysis confirms the evolution of research from foundational concepts to AI-based systems, positioning findings at advanced integration stages while anticipating future revolutionary transformations.

This research makes a substantive contribution to the theory of sustainable entrepreneurship by proving the unpredictable emergence properties of individual component analysis, challenging traditional resource-based views and supporting dynamic capability perspectives. The SLNA approach that integrates systematic review with bibliometric network analysis overcomes the limitations of single-

method synthesis and provides convergent validation that increases confidence levels beyond the capabilities of each approach independently. The findings result in a workable framework with specific implementation guidelines: a phased approach starting MRPH as a foundation, an optimal resource allocation of 8–12% of revenue for medium-intensity implementations, and contextual adaptation strategies for different levels of infrastructure readiness.

The practical implications lead to a sequential implementation approach with MRPH as an entry point, followed by the development of digital platforms, then advanced analytics integration to maximize the probability of success while minimizing resource requirements. Policymakers need to develop an integrated support ecosystem that addresses infrastructure development, regulatory alignment, stakeholder ecosystem maturity, and cultural adaptation holistically. Investment priorities should be allocated with an emphasis on digital infrastructure (40%), green process optimization (35%), stakeholder relationship building (20%), and selective circular economy transition (5%) according to organizational readiness.

The future research agenda requires strategic priorities in AI integration research (30% resource allocation), implementation failure analysis (25%) to address success case bias, development of real-time optimization systems (20%), and longitudinal sustainability validation (15%) to confirm long-term sustainability benefits. Cross-sector validation, advanced country extension studies, and cultural adaptation frameworks are essential to enhance external validity and global applicability. The findings of this study prove that an integrated ecosystem framework is not only statistically superior but also a practical necessity for manufacturing SMEs seeking to achieve sustainable entrepreneurial success, with convergent evidence providing an adequate level of confidence for widespread adoption with appropriate contextual adaptation.

Declarations

Ethical Approval

Not applicable.

Consent to Participate

Not applicable.

Clinical Trial Number

Not applicable. This research is a systematic literature review and network analysis based entirely on secondary data from previously published studies. It does not involve any clinical intervention, experimental treatment, or prospective assignment of human participants. Therefore, registration in a clinical trial registry is not required.

Consent to Publish

Not applicable.

Availability of Data and Materials

The data supporting the conclusions of this systematic literature review are included within the article. The complete list of 277 analyzed articles with their bibliometric data, search strings, inclusion/exclusion criteria, and quality assessment protocols are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no competing interests, financial or otherwise, that could have influenced the work reported in this paper. No funding sources had any role in the study design, data collection, analysis, interpretation, or manuscript preparation.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors. The study was conducted as part of the authors' academic responsibilities at their respective institutions: Universitas Negeri Surabaya, Universitas Negeri Jakarta, Universitas Nusa Cendana, and Universiti Kebangsaan Malaysia.

Authors' Contributions

RS conceived the study, designed the systematic review protocol, conducted the literature search and screening, performed the bibliometric network analysis, and drafted the manuscript. **MIP** contributed to the review methodology, quality assessment, data extraction, and manuscript preparation. **SA** conducted the meta-analysis design, statistical analysis, and validation, and contributed to the interpretation of findings. **DRS** developed the theoretical framework, critically revised the manuscript, and supervised the research process. **AELN** performed the VOSviewer analysis, created visualizations, and contributed to the discussion of temporal patterns. **PDD** refined the sustainability framework and supported the interpretation of ecosystem-related findings. **XQ** provided expertise in green supply chain management, contributed to the conceptual framework, and reviewed the manuscript. All authors read and approved the final manuscript.

ORCID

Raya Sulistyowati: https://orcid.org/0000-0003-2715-1469

Marisa Intan Prawesti: https://orcid.org/0009-0005-1851-9534

Surya Andhini: https://orcid.org/0009-0000-0274-6322

Darma Rika Swaramarinda: https://orcid.org/0000-0003-1588-4569

Antonio E. L. Nyoko: https://orcid.org/0000-0002-0178-2097

Puspo Dewi Dirgantari: https://orcid.org/0000-0002-4414-8395

Xie Qiong: https://orcid.id.org/0009-0002-4740-9586

Acknowledgments

The authors thank Web of Science, Scopus, and ScienceDirect for literature access supporting this systematic review. Appreciation is also extended to the VOSviewer developers, as well as the researchers and institutions whose contributions and support made this study possible.

References

1. Adamo, S., De Matteis, C., Fasiello, R., & Imperiale, F. (2025). A literature analysis of sustainability reporting quality. Corporate Social Responsibility and Environmental Management. Advance online publication. https://doi.org/10.1002/csr.2845
2. Alkhodair, M., & Alkhudhayr, H. (2025). Harnessing Industry 4.0 for SMEs: Advancing smart manufacturing and logistics for sustainable supply chains. Sustainability, 17(2), 534. https://doi.org/10.3390/su17020534
3. Bouyahrouzi, E. M., Benmimoun, R., El Kihel, Y., & Bajjou, M. S. (2025). Integrating industry 4.0 technologies and maintenance 4.0 for sustainable manufacturing: A systematic literature review. International Journal of Advanced Manufacturing Technology, 130(3), 1245–1267. https://doi.org/10.1007/s00170-024-13892-1
4. Farfán Chilicaus, G. C., Licapa-Redolfo, G. S., Arbulú Ballesteros, M. A., Torres Sifuentes, C. E., & Arbulú Castillo, J. C. (2025). Digital transformation and sustainability in post-pandemic supply chains: A global bibliometric analysis of technological evolution and research patterns (2020–2024). Sustainability, 17(1), 289. https://doi.org/10.3390/su17010289
5. Fatorachian, H., & Kazemi, H. (2025). Leveraging technology and sustainability practices for smart mobility and green logistics: A dual-theoretical approach to adoption dynamics. International Journal of Sustainable Engineering, 18(2), 134–152. https://doi.org/10.1080/19397038.2024.2397245
6. Hasan, M., Abrar, A. K., Tahir, T., Budiwati, N., & Sulistyowati, R. (2026). Unleashing dual literacies through digital growth mindset: A multitheoretical study of entrepreneurship learning in higher education for Generation Z. Social Sciences & Humanities Open, 13, 102451. https://doi.org/10.1016/j.ssaho.2026.102451
7. Hasan, M., Muchtar, S., Nurjannah, Kardoyo, & Sulistyowati, R. (2026). Investigating the role of entrepreneurship education on the entrepreneurial readiness of generation Z students: Why are growth mindset and positive psychological capital important? Journal of Education for Business, 101(1), 10–18. https://doi.org/10.1080/08832323.2025.2592955

8. Hoang, T.-H., Tran, T.-T., Huynh, L. N. T., Nguyen, T. D., & Le Nguyen, N. D. (2025). Advances and barriers in promoting green logistics 4.0 from a multi-stakeholder perspective—A systematic review. Environment Systems and Decisions, 45(1), 89–112. https://doi.org/10.1007/s10669-024-9567-2
9. Jamwal, A., Agrawal, R., & Sharma, M. (2021). Challenges and opportunities for manufacturing SMEs in adopting industry 4.0 technologies for achieving sustainability: Empirical evidence from an emerging economy. Operations Management Research, 14(3–4), 362–383. https://doi.org/10.1007/s12063-021-00197-4
10. Jamwal, A., Agrawal, R., & Sharma, M. (2025). Challenges and opportunities for manufacturing SMEs in adopting industry 4.0 technologies for achieving sustainability: Empirical evidence from an emerging economy. Operations Management Research, 18(1), 142–158. https://doi.org/10.1007/s12063-024-00486-2
11. Joshi, M. P. (2025). Prioritization of barriers to digitization for circular systems using analytical hierarchy process. International Journal of Information Technology and Computer Science, 17(1), 23–35. https://doi.org/10.5815/ijitcs.2025.01.03
12. Mazhar, M., Domingues, A. R., Bull, R., & O'Boyle, S. (2022). Small and medium-sized enterprises: Hard to reach, data-poor but rich in creative potential as agents of change for decarbonisation. In Eceee summer study proceedings (pp. 543–552). European Council for an Energy Efficient Economy.
13. Mukhtar, B., Shad, M. K., Ali, K., Haq, M. A., & Waqas, A. (2025). Systematic literature review and retrospective bibliometric analysis on ESG research. International Journal of Productivity and Performance Management. Advance online publication. https://doi.org/10.1108/IJPPM-06-2024-0345
14. Nagarajan, H., Alagarsundaram, P., Sitaraman, S. R., Venkatesan, S., & Khalid, H. M. (2025). Digital twins, techfusion and blockchain in manufacturing. In R. Kumar (Ed.), Accelerating product development cycles with digital twins and IoT integration (pp. 234–267). IGI Global.
15. Nasim, B., Venschott, M., & Magnus, C. (2024). Greening the future through digital transformation: A systematic review of sustainable strategies and future research directions. Global Challenges for the Environment and Climate Change, 5(2), 89–112. https://doi.org/10.1016/j.gcec.2024.08.003
16. Nirwal, P., & Bhardwaj, A. (2025). Mapping the nexus of green innovation and sustainability in MSMEs: A bibliometric perspective. Business Strategy and Development, 8(1), 45–67. https://doi.org/10.1002/bsd2.312
17. Noer, M. Y., Chan, A., Tresna, P. W., & Purbasari, R. (2025). Digital marketing and sustainable innovation in SMEs through bibliometric and systematic review. Cogent Business and Management, 12(1), 2287654. https://doi.org/10.1080/23311975.2024.2287654
18. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., ... Moher, D. (2021). The PRISMA 2020

statement: An updated guideline for reporting systematic reviews. BMJ, 372, n71. https://doi.org/10.1136/bmj.n71

19. Precious, D. (2025). Mapping the intellectual landscape of circular economy and SDG 12: A bibliometric analysis of research evolution, thematic structure, and geographical disparities (2015–2024). Sustainable Development, 33(1), 156–178. https://doi.org/10.1002/sd.2897
20. Putri, A. N. A., Hermawan, P., Mirzanti, I. R., Simatupang, T. M., & Sadraei, R. (2025). Exploring green growth in SMEs: Global trends, challenges, and future directions. Foresight and STI Governance, 19(1), 78–94. https://doi.org/10.17323/2500-2597.2025.1.78.94
21. Qasim, S., Qureshi, M. A., & Shaikh, S. N. (2024). Green management and sustainability in SMEs: A pathway to a greener economy. In M. Rahman & S. Ahmed (Eds.), Examining green human resources management and nascent entrepreneurship (pp. 189–215). IGI Global.
22. Radavičiūtė, G., & Meidutė-Kavaliauskienė, I. (2025). Twin transition in supply chains and logistics: A systematic literature review. In Lecture Notes in Intelligent Transportation and Infrastructure (pp. 412–435). Springer. https://doi.org/10.1007/978-3-031-52652-7_18
23. Ranjan, R., Singh, R., & Tripathi, S. (2025). Harnessing information systems for sustainable enterprise development: A systematic literature network analysis. In Communications in Computer and Information Science (Vol. 1895, pp. 234–251). Springer. https://doi.org/10.1007/978-981-99-8145-8_18
24. Sakti, N. C., Sulistyowati, R., Wulandari, R. N. A., Nurlaili, E. I., & Narmaditya, B. S. (2025). The Influence of Financial and Digital Literacy on SMEs Productivity in Indonesia: The Mediating Role of Marketing Intensity. Journal of Small Business Strategy, 35(3), 96–105. https://doi.org/10.53703/001c.137822
25. Setyadi, A., Soekotjo, S., Lestari, S. D., Handayani, N. U., & Damaris, A. (2025). Trends and opportunities in sustainable manufacturing: A systematic review of key dimensions from 2019 to 2024. Sustainability, 17(3), 789. https://doi.org/10.3390/su17030789
26. Setyawati, A., Sugangga, R., Sulistyowati, R., Narmaditya, B. S., Maula, F. I., Wibowo, N. A., & Prasetya, Y. (2024). Locus of control, environment, and small-medium business performance in pilgrimage tourism: The mediating role of product innovation. Heliyon, 10(9). https://doi.org/10.1016/j.heliyon.2024.e29891
27. Soomro, R. B., Memon, S. G., Dahri, N. A., Laghari, A. A., & Saleem, A. (2024). The adoption of digital technologies by small and medium-sized enterprises for sustainability and value creation in Pakistan: The application of a two-staged hybrid SEM-ANN approach. Sustainability, 16(22), 9786. https://doi.org/10.3390/su16229786
28. Sulistyowati, R., Maula, F. I., Mahendra, A. M., & Fahrullah, A. (2024). Ecosystems and entrepreneurial intention among students: the mediating role of Islamic values. Perspektivy nauki i obrazovania–Perspectives of Science and Education, 69 (3), 113–129. https://doi.org/10.32744/pse.2024.3.7
29. Sulistyowati, R., Maula, F. I., Mahendra, A. M., Wihara, D. S., Amelia, R., & Fanggidae, R. P. C. (2026). A Systematic Bibliometric Mapping of Entrepreneurial Passion and Sustainable Entrepreneurship:

Integrating Literature Review and Network Analysis. PaperASIA, 41(6b), 457–471. https://doi.org/10.59953/paperasia.v41i6b.895

30. Wibowo, R. A., Iriani, S. S., Sulistyowati, R., Khakim, M. A., Yulia, N. N. R., & Sucihati, R. N. (2025). Unpacking The Landscape of Digital and Corporate Entrepreneurship: A Systematic Literature Review of Key Characteristics, Dimensions, And Strategic Outcome. Journal of Management: Small and Medium Enterprises (SMEs), 18(3), 1937-1958. https://doi.org/10.35508/jom.v18i3.22699
31. Wiratmadja, I. I., Achmad, F., & Rizana, A. F. (2025). Green strategy implementation and innovativeness in SMEs: A pathway towards sustainable development goals. In Lecture Notes in Mechanical Engineering (pp. 567–589). Springer. https://doi.org/10.1007/978-981-97-0169-8_42

Figures

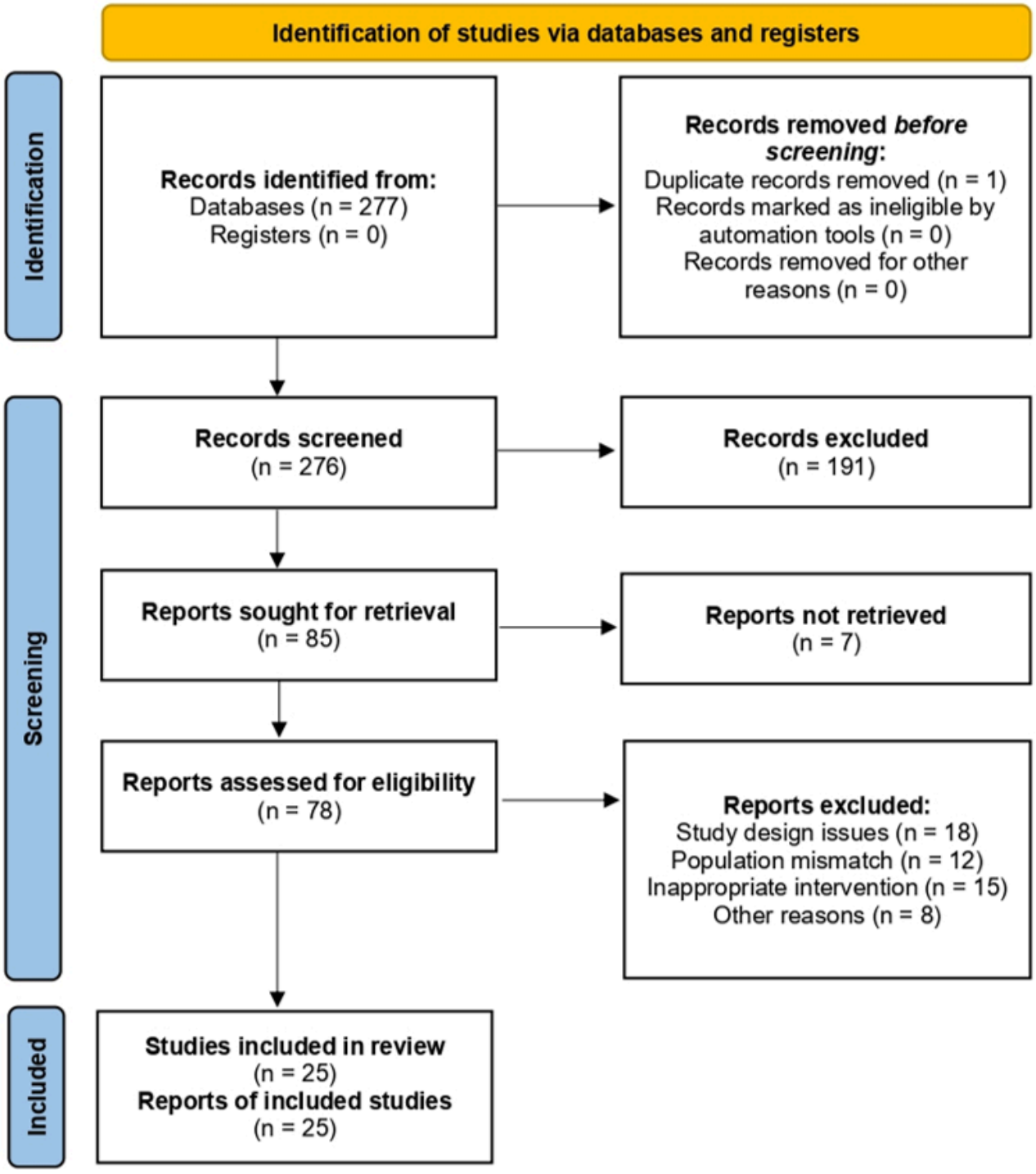


Figure 1

PRISMA 2020 Flow Diagram-Systemthematic Literature Review and Network Analysis

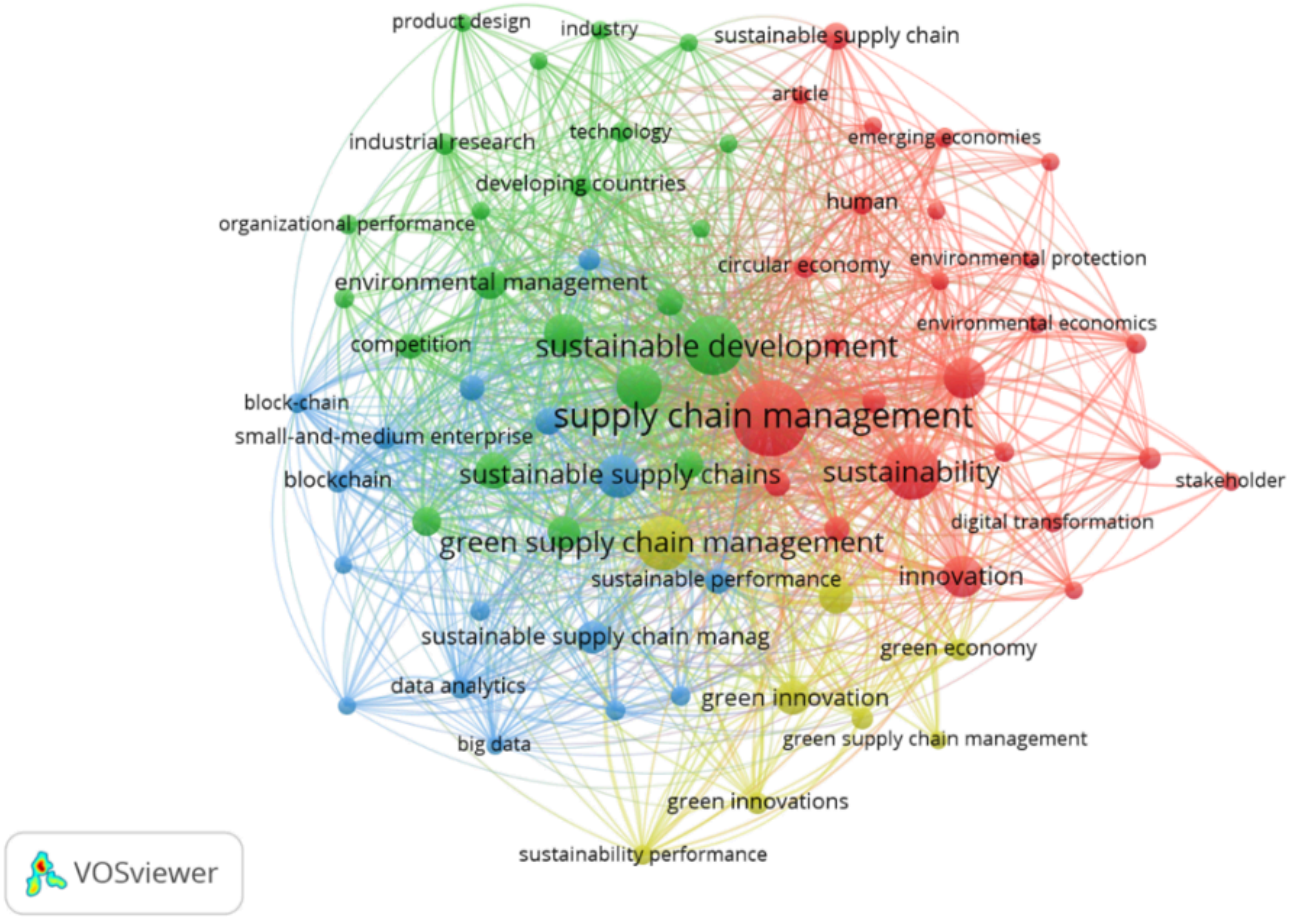


Figure 2

Co-Conditioning Network Map Keywords Sustainable Entrepreneurship Research

Source: VosViewer Output, 2025

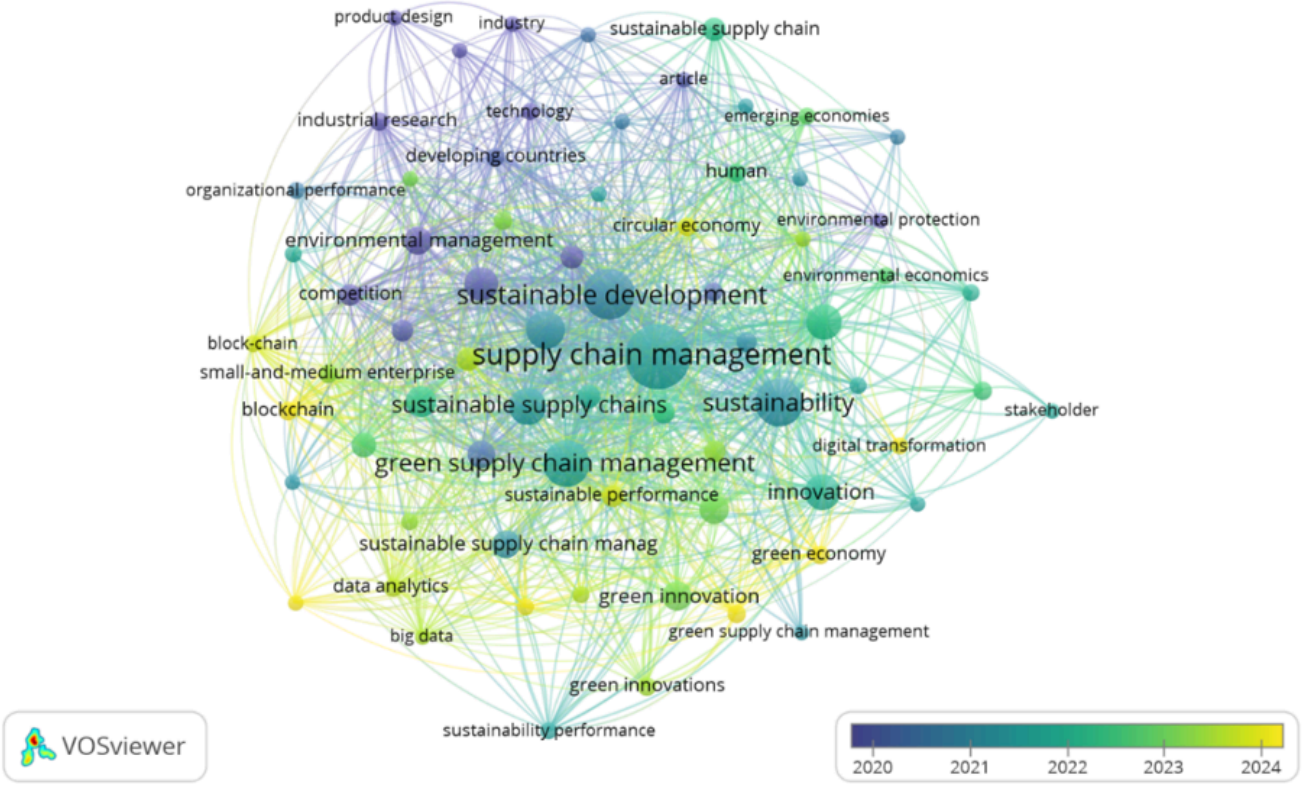


Figure 3

Temporal Evolution of Sustainable Entrepreneurship Research Theme (2019-2024)

Source: VosViewer Output, 2025

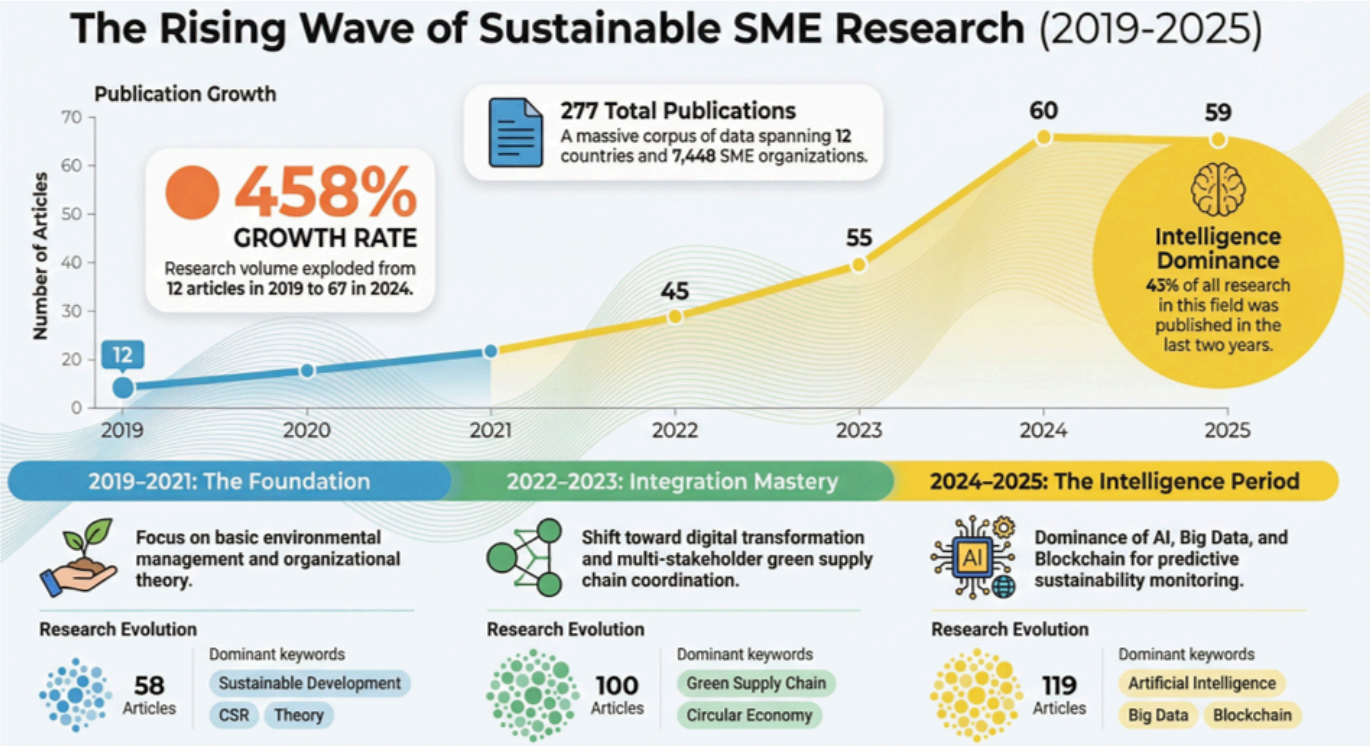


Figure 4

Temporal Distribution of Publications (2019-2025)

Source: Systematic Literature Review Analysis, 2025

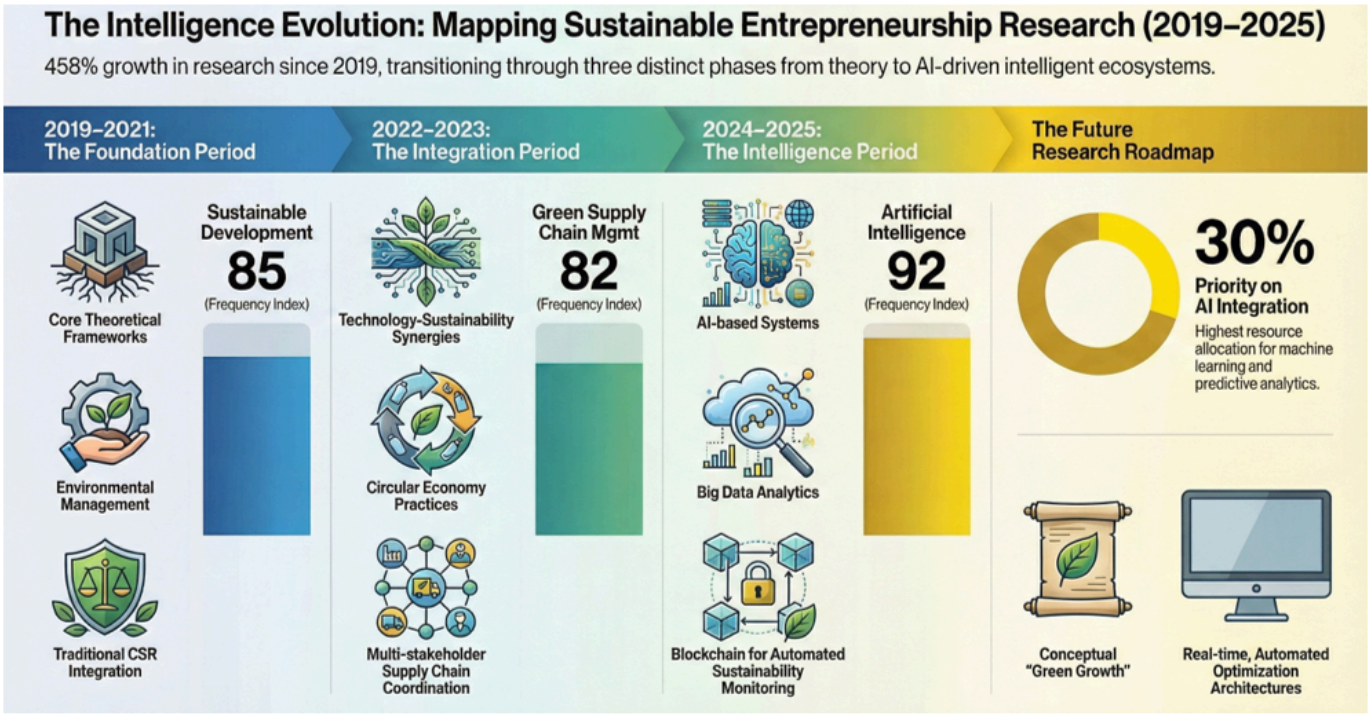


Figure 5

Evolution of Research Focus by Period

Source: Systematic Literature Review Analysis, 2025

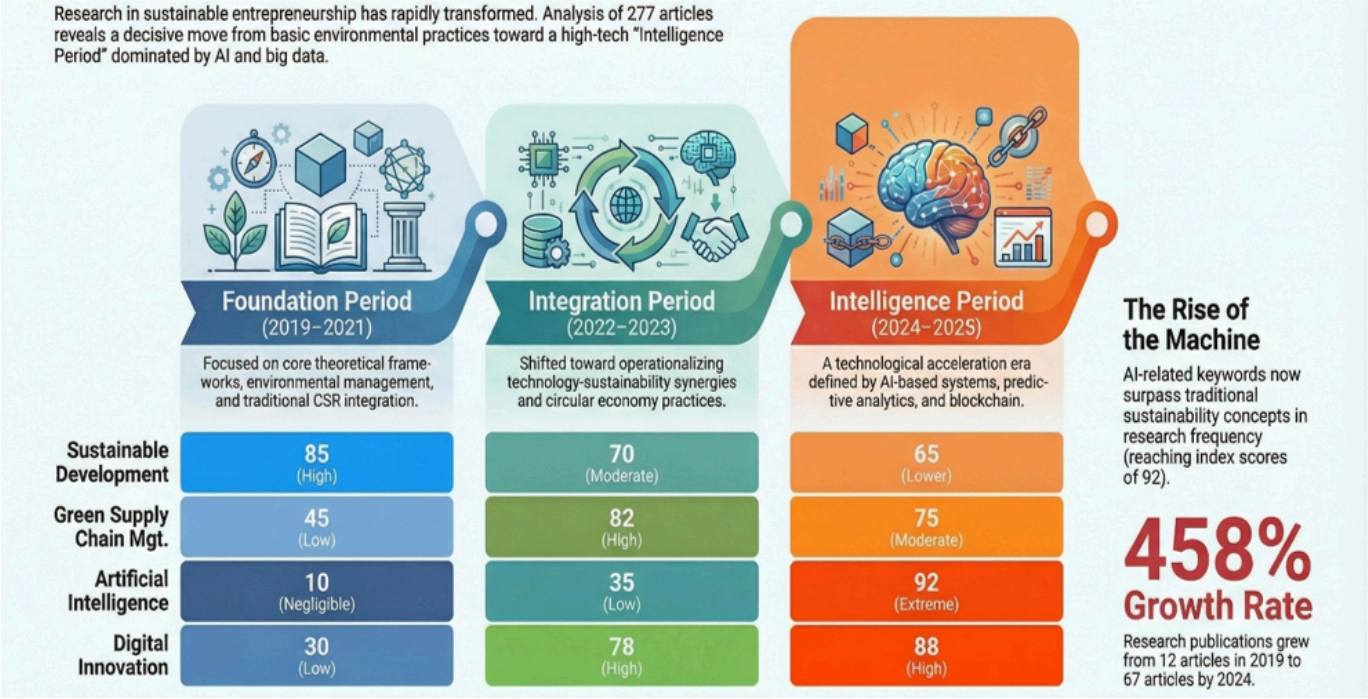


Figure 6

Keyword Frequency Heatmap by Research Period

Source: Systematic Literature Review Analysis, 2025