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Navigating Global Disruptions: A Systematic Review of Technological and Environmental Challenges in Modern Supply Chains

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Abstract

In a time of increasing global uncertainty, supply chains encounter unparalleled challenges caused by geopolitical instability, climate change, and swift technical advancement. This paper performs a systematic review of 35 peer-reviewed articles published from 2020 to 2025, examining how contemporary disruptions such as the COVID-19 pandemic, the Russia–Ukraine conflict, and the emergence of Industry 4.0/5.0 technologies are transforming global supply chain resilience tactics. The review delineates four primary categories of disruption: geopolitical, environmental, technical, and health-related, and analyzes their operational, economic, and social ramifications. Research indicates that whereas digital technologies like AI, blockchain, and IoT enhance visibility, agility, and adaptability, they concurrently add cyber security vulnerabilities and escalate systemic complexity. Environmental concerns and increasing environmental, social and governance (ESG) compliance mandates are compelling organizations to reevaluate sourcing strategy, risk governance, and sustainability priorities. The study presents a conceptual framework that connects kinds of disruption to strategic responses, such as digital transformation, supply base diversification, and improved public-private partnership, providing concrete strategies for resilience.

Keywords
Supply chain disruptions, Resilience, Climate disruption, Industry 4.0, Sustainability

1. Introduction
Global supply chains have evolved into highly complex, interconnected networks spanning multiple regions, industries, and stakeholders. While this interconnectedness enables efficiency and cost optimization, it also increases vulnerability to a broad spectrum of disruptions, including geopolitical instability, environmental hazards, technological change, and public health crises. Recent events such as the COVID-19 pandemic and the Russia–Ukraine conflict have exposed critical weaknesses in just-in-time logistics and concentrated global sourcing, triggering cascading effects across sectors and borders and impacting the flow of food, energy, raw materials, pharmaceuticals, and consumer goods (Katsaliaki et al., 2022; McDougall & Davis, 2024; Ovezmyradov, 2022; Ginn & Saadaoui, 2025).

The aim of this paper is to systematically examine how major disruption types influence global supply chain performance, resilience strategies, and sustainability priorities. This is achieved through conducting a systematic review of peer-reviewed academic literature published between 2020 and 2025. The research is guided by the following questions:

- What are the dominant categories of disruptions affecting global supply chains in recent years?
- How do these disruptions influence operational performance, cost structures, and sustainability objectives?
- What strategic and technological responses have been deployed to strengthen resilience?

- How do governance frameworks, stakeholder collaboration, and digital tools shape the effectiveness of these responses?

A systematic review of recent academic literature (2020–2025) reveals that disruptions affecting global supply chains can be broadly categorized as geopolitical, environmental, technological, and health. Geopolitical disruptions—such as trade wars, sanctions, and armed conflicts—undermine cross-border flows and create uncertainty in sourcing and market access (Herold & Marzantowicz, 2023; Ginn & Saadaoui, 2025).

Environmental disruptions, including climate change-induced extreme weather events, threaten production continuity and logistics infrastructure. Technological disruptions, while enabling efficiency through digitalization, AI, and IoT, also introduce cyber security vulnerabilities and systemic complexity (Song et al., 2024; Li et al., 2022). Health-related disruptions, most notably the COVID-19 pandemic, have revealed the limitations of lean, globally dispersed supply chains in coping with sudden demand shocks (McDougall & Davis, 2024; Ovezmyradov, 2022; Ginn & Saadaoui, 2025).

These disruptions influence operational performance by causing supply shortages, demand surges, transportation delays, and production stoppages, leading to increased costs, reduced service levels, and long-term market share erosion (. Sustainability goals are also affected, as firms must balance resilience with and social governance (ESG) priorities (Aguila & ElMaraghy, 2020; Baghersad & Zobel, 2021; Ginn & Saadaoui, 2025).

Strategic and technological responses include supply base diversification, adoption of digital technologies for visibility and predictive analytics, and a shift toward nearshoring and reshoring to reduce dependence on distant suppliers. Firms are also integrating green logistics, circular economy practices, and ethical sourcing into their risk governance frameworks to align resilience with long-term sustainability (Song et al., 2024).

The effectiveness of these responses is shaped by governance frameworks, stakeholder collaboration, and digital tools. Strong governance, multi-stakeholder collaboration, and adaptable policy frameworks are essential for building collective resilience (Herold & Marzantowicz, 2023; Kovács & Sigala, 2020; Duong & Chong, 2020; Song et al., 2024). Digital technologies such as AI, blockchain, and IoT improve real-time monitoring and risk prediction but require robust cybersecurity and skilled human capital (Song et al., 2024; Li et al., 2022). Public–private partnerships and joint crisis management platforms are emerging as critical enablers of resilience (Herold & Marzantowicz, 2023; Kovács & Sigala, 2020).

To this point, global supply chains are navigating an era of heightened uncertainty where resilience and sustainability are essential. The literature underscores the need for integrated strategies that link disruption categories to operational and governance responses, offering actionable insights for building adaptable, ESG-aligned supply chains (McDougall & Davis, 2024; Herold & Marzantowicz, 2023; Ovezmyradov, 2022; Song et al., 2024; Li et al., 2022; Ginn & Saadaoui, 2025).

2. Methodology

This study utilizes a systematic review methodology in accordance with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, a well-established standard for structured literature reviews in supply chain research. This methodology facilitates a transparent and replicable approach for discovering, filtering, and synthesizing academic literature regarding supply chain disruptions, resilience, and digitalization. The review concentrated on peer-reviewed journal articles published from January 2020 to April 2025, utilizing prominent academic databases such as Scopus, Web of Science, and Google Scholar, recognized for their extensive coverage of interdisciplinary supply chain research (Korder et al., 2024; Tubis et al., 2023; Chauhan et al., 2023).

A systematic keyword search was performed utilizing phrases such as “supply chain disruption,” “technological change,” “climate risk,” “resilience,” “digitalization,” and “geopolitical risk” to encompass the scope of pertinent research. The inclusion criteria mandated that studies be published in English, focus on technological, environmental, or geopolitical disruptions impacting supply chains, and offer conceptual models, empirical data, or thorough reviews (Chauhan et al., 2023; Korder et al., 2024; Tubis et al., 2023). Articles that concentrated exclusively on theoretical viewpoints without practical ramifications or relevance to resilience and sustainability were omitted to ensure practical significance (Chauhan et al., 2023).

From an initial collection of about 300 publications, duplicates were eliminated and abstracts were evaluated for relevance, leading to the review of 100 full-text articles for inclusion. In conclusion, 35 papers fulfilled all requirements for qualitative synthesis. Each chosen article was meticulously examined for disruption type, sectoral emphasis, methodological framework, and suggested mitigation strategies, guaranteeing a thorough and nuanced synthesis of the existing research landscape in this domain (Tubis et al., 2023). Table 1 presents the number of articles identified, screened, and ultimately included in the systematic review, categorized by academic database. The review followed PRISMA guidelines to ensure methodological rigor.

Table 1. Summary of Literature Screening and Inclusion Process

Database	**Articles Identified**	**Screened**	**Included**
Scopus	120	40	15
Web of Science	100	35	12
Google Scholar	80	25	8
Total	**300**	**100**	**35**

Subsequent to data extraction, thematic synthesis was employed to discern overarching patterns and typologies of disruption. This entailed categorizing the content of chosen publications by disruption type, analytical approach, and suggested responses. The supplementary bibliometric study validated the co-occurrence of keywords within the chosen literature. Table 2 summarizes the dominant types of supply chain disruptions identified in the literature and the corresponding strategic responses documented across the 35 reviewed studies.

Table 2. Categorization of Disruption Types and Strategic Responses

Disruption Type	**Description**	**Common Strategic Responses**
Geopolitical	Trade wars, sanctions, military conflicts (e.g., Russia–Ukraine)	Nearshoring, supplier diversification, policy scenario planning
Health-Related	Pandemics like COVID-19 causing global shutdowns and labor shortages	Buffer inventory, health protocols, decentralized sourcing
Technological	Adoption of digital tools (AI, IoT, blockchain) and cybersecurity threats	Digital transformation, cybersecurity protocols, smart forecasting
Environmental	Climate-related disasters, emissions targets, ESG compliance pressures	ESG integration, green logistics, climate risk modeling

3. Types and Sources of Disruption

The studied literature directly answers the designed research questions by defining the sorts of disruptions, their repercussions, and the measures employed to minimize them, while also emphasizing governance and technical facilitators.

3.1 Categories and Origins of Disruptions

Systematic assessments generally categorize supply chain disruptions into four predominant types: geopolitical, health-related, technological, and environmental. Geopolitical disruptions, such as sanctions, trade restrictions, and armed conflicts, impede logistics and sourcing, resulting in operational bottlenecks and market access uncertainty (Roshani et al., 2024; Xiong et al., 2024; Herold & Marzantowicz, 2023; Ginn & Saadaoui, 2025). The U.S.–China trade war, Brexit, and more recently the Russia–Ukraine conflict illustrate how sudden regulatory changes and restrictions on cross-border flows can alter sourcing strategies overnight (Herold & Marzantowicz, 2023; Roshani et al., 2024). Research indicates that firms embedded in global value chains often lack contingency planning for political risks, making them vulnerable to cascading effects such as raw material shortages, port congestion, and fluctuating energy prices (Ginn & Saadaoui, 2025; Xiong et al., 2024). Emerging studies also highlight that geopolitical shocks disproportionately affect sectors reliant on critical raw materials—such as semiconductors and rare earths—because of high concentration risks (Maemunah, 2024).

Health-related disruptions, notably the COVID-19 pandemic, resulted in extensive lockdowns, labor shortages, and significant supply-demand imbalances, revealing the vulnerability of just-in-time systems, particularly within

healthcare and food supply chains (Rahman et al., 2022; Qrunfleh et al., 2022; Arji et al., 2023; McDougall & Davis, 2024; Ovezmyradov, 2022). Beyond COVID-19, literature points to a heightened need for pandemic preparedness protocols, workforce resilience, and integration of health crisis scenarios into enterprise risk management systems (McDougall & Davis, 2024).
Technological disruptions are dual-faceted: although AI, blockchain, and IoT enhance supply chain visibility and responsiveness, they simultaneously introduce new vulnerabilities, such as cyberattacks and swift obsolescence (Korder et al., 2024; Spieske & Birkel, 2021; Kassa et al., 2023; Dura et al., 2025; Song et al., 2024). Spieske and Birkel (2021) argue that Industry 4.0 technologies contribute to supply chain robustness through simulation-driven scenario planning, yet adoption varies significantly across firm size and sector. SMEs, in particular, face barriers related to digital literacy, financial capacity, and lack of organizational readiness (Pourmorshed & Durst, 2022).

Environmental disturbances—arising from climate change, severe weather, and alterations in ESG regulations—endanger production continuity and the integrity of infrastructure (Bier et al., 2020; Maharjan & Kato, 2022; Dura et al., 2025; McDougall & Davis, 2024). ESG compliance has emerged as both a regulatory requirement and a competitive differentiator. However, Tsang et al. (2024) note the absence of standardized cross-border ESG reporting frameworks, complicating supplier assessments and benchmarking. Recent research also shows growing alignment between resilience strategies and sustainability initiatives, with firms adopting circular economy practices, low-carbon logistics, and renewable energy sourcing (Agrawal & Jain, 2021; Salamah et al., 2023).

3.2 Effects on Supply Chain Efficiency and Sustainability

The examined literature highlights substantial operational, economic, and institutional ramifications of disruptions:

- Operational implications encompass supplier shortages, transportation delays, manufacturing interruptions, and escalating logistics expenses (Rahman et al., 2022; Al-Qasimi et al., 2024).
- Economic repercussions encompass inflationary pressures, unemployment, and modified trade flows that disrupt regional and global markets (Roshani et al., 2024; Xiong et al., 2024).
- Institutional effects arise from policy ambiguity and a decline in confidence when governance responses lack consistency (Rahman et al., 2022; Bier et al., 2020; Maharjan & Kato, 2022).
- Corporate sustainability objectives are frequently undermined as companies favor short-term stability over ESG obligations, despite certain disruptions—such as governmental alterations—encouraging corporations to adopt more environmentally friendly practices (McDougall & Davis, 2024; Ovezmyradov, 2022).

3.3 Governance, Collaboration, and Institutional Factors

A recurring theme in the literature is the central role of governance and multi-stakeholder collaboration in managing disruptions. Kovács and Sigala (2020) emphasize lessons from humanitarian logistics, where public–private partnerships and joint crisis management platforms have proven critical. Strong governance frameworks help mitigate institutional uncertainty and foster alignment between corporate and regulatory priorities (Herold & Marzantowicz, 2023). From a theoretical perspective, dynamic capabilities theory is increasingly applied to explain how firms reconfigure resources in response to shocks, while institutional theory highlights the role of regulatory environments and stakeholder pressures in shaping resilience strategies.

3.4 Strategic and Technological Response Approaches

Identified mitigation strategies in the literature encompass:

- Diversification and regionalization of the supply base to mitigate dependence on sole-source providers (Roshani et al., 2024; Maemunah, 2024; Xiong et al., 2024).
- Digital technology, including blockchain for traceability, artificial intelligence for predictive analytics, and simulation tools for scenario planning (Korder et al., 2024; Spieske & Birkel, 2021; Kassa et al., 2023; Dura et al., 2025; Song et al., 2024).
- Governance frameworks linked with ESG principles that incorporate ethical sourcing, sustainable logistics, and circular economy concepts (Rahman et al., 2022; Agrawal & Jain, 2021; Dura et al., 2025; McDougall & Davis, 2024).
- Collaborative crisis management encompassing public–private collaborations and multi-stakeholder platforms (Herold & Marzantowicz, 2023; Kovács & Sigala, 2020).

Although these methods bolster resilience, the literature cautions that many are still reactive, highlighting the necessity for proactive and simulation-based preparedness, especially in essential product categories (Rahman et al., 2022; Korder et al., 2024; Maharjan & Kato, 2022).

3.5 Research Gaps and Future Directions

Despite growing consensus, literature exhibits several gaps. First, most studies focus on short-term disruption responses, with limited longitudinal research assessing long-term resilience and ESG outcomes (Tubis et al., 2023; Bouraya & Korchi, 2025). Second, empirical evidence remains concentrated in manufacturing and logistics sectors, leaving healthcare, maritime shipping, and agriculture underexplored. Third, few studies evaluate the trade-offs between resilience investments and financial performance—an area critical for SMEs facing capital constraints. Finally, the emergence of technologies such as quantum computing, advanced IoT, and digital twins presents new opportunities, but their practical application remains embryonic and largely restricted to well-capitalized firms (Bouraya & Korchi, 2025).

3.6 Theoretical Framework

Based on the examined literature, Figure 1 illustrates a comprehensive framework connecting types of disruption, their effects, and response measures, contextualized within governance and technical facilitators. The framework is directly aligned with the research questions:
RQ1 corresponds to Disruption Types
RQ2 pertains to Impacts
RQ3 pertains to Response Strategies
RQ4 pertains to Governance and Digital Enablers

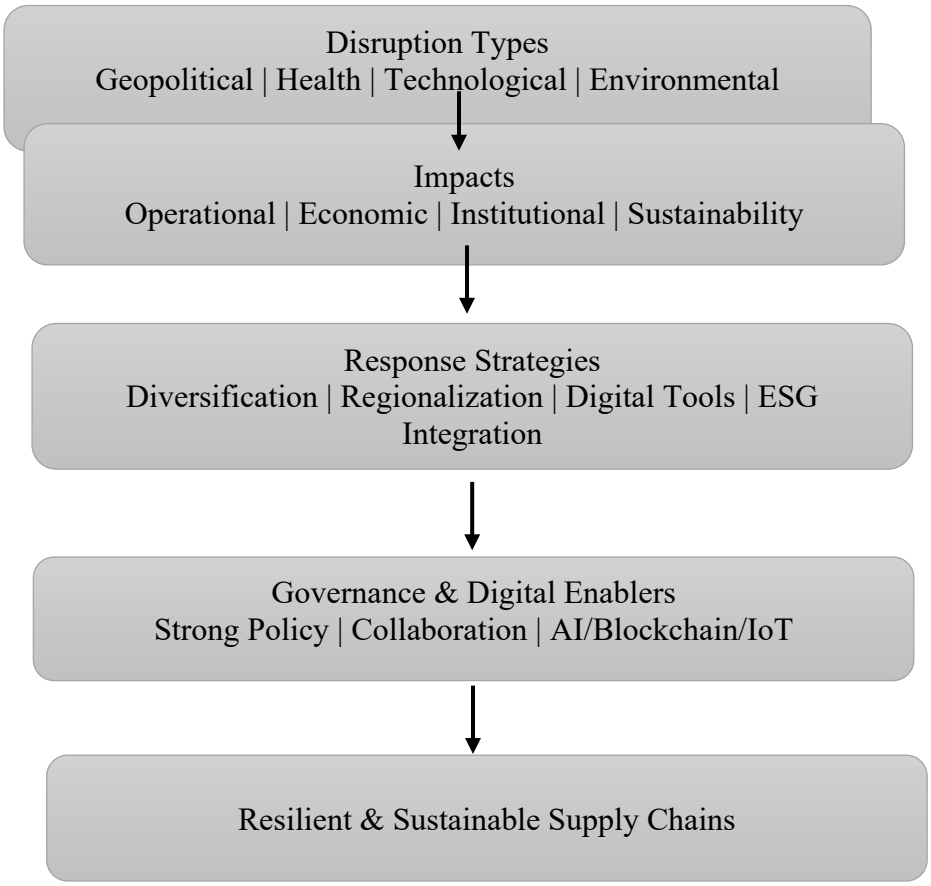

Figure 1. Conceptual Framework: Navigating Global Supply Chain Disruptions

4. Discussion

Three major theories provide useful perspectives for understanding resilience and sustainability in supply chains. Dynamic Capabilities Theory explains how firms must continuously reconfigure and realign resources in response to

disruptions (Eisenhardt & Martin, 2017). Adoption of digital tools, nearshoring, or ESG practices can be viewed as dynamic capabilities that enhance adaptability under uncertainty. Institutional Theory sheds light on the influence of regulatory pressures, global reporting frameworks, and stakeholder expectations (Scott, 2014). Variations in ESG adoption across regions often stem from differences in institutional environments, which create both coercive and normative pressures. The Resource-Based View (RBV) emphasizes how digital infrastructure, skilled personnel, and ESG-driven supplier networks act as strategic resources (Barney, 1991; Abdelbary et al., 2023). Firms that effectively leverage these resources can turn resilience into a source of sustained competitive advantage.

While dynamic capabilities, institutional pressures, and strategic resources offer a strong explanatory basis for understanding how firms should respond to disruptions, the reality is that adoption remains uneven. Digitization and ESG integration hold a great deal of potential for supply chain transformation, yet execution continues to be inconsistent across different company sizes and geographical locations. According to Pourmorshed and Durst (2022) and Liu et al. (2022), large organizations tend to adopt digital technologies and ESG practices at a faster rate than small and medium-sized enterprises (SMEs), which frequently confront obstacles related to limited digital strategy, resource restrictions, and challenges in organizational culture and operations. This digital divide is further worsened by the complexity and cost of integrating modern technologies such as artificial intelligence, Internet of Things, and blockchain, as well as the requirement for experienced individuals and resilient infrastructure (Sah et al., 2024; Shoomal et al., 2024; Nozari et al., 2022). Pourmorshed and Durst (2022) argue that SMEs in particular require individualized frameworks and support to successfully traverse digitalization and ESG integration.

According to Tsang et al. (2024) and Tsoulfas (2024), the absence of common measurements and reporting frameworks across borders is a significant obstacle to effective ESG integration. This lack of standardization leads to variations in ESG data collection, supplier compliance, and performance evaluation. It makes benchmarking more difficult and complicates comparisons of ESG achievements, particularly for businesses that operate in multiple jurisdictions. Additionally, governance difficulties arise as a result of competing interests between private enterprises and national regulations. Government support and policy alignment play a crucial role in mitigating the impact of digital transformation on ESG performance (Lu et al., 2023; Tsang et al., 2024).

Chen et al. (2024), Zhang and Huang (2024), Tian et al. (2024), and Wu et al. (2024) state that digitalization has the potential to improve ESG performance by increasing transparency, decreasing information asymmetry, and enabling real-time monitoring and risk management. This is despite challenges such as organizational reluctance, interoperability issues, and cyber security risks (Sah et al., 2024; Shoomal et al., 2024; Nozari et al., 2022). The literature also indicates the need for more longitudinal studies to examine the long-term value and success of resilience and sustainability projects, since most existing research focuses on short-term impacts or case-specific outcomes (Tubis et al., 2023; Bouraya & Korchi, 2025).

To this extent, although digitalization and ESG integration are progressing, the uneven adoption of these technologies, the absence of standardization, and governance complexities present ongoing challenges that call for coordinated efforts and additional research (Lu et al., 2023; Tsoulfas, 2024; Pourmorshed & Durst, 2022; Tsang et al., 2024).
Beyond these structural and institutional challenges, the literature also reveals deeper strategic tensions in how organizations respond to disruptions.

A critical insight emerging from the reviewed literature is the need to balance competing strategic trade-offs when designing resilient and sustainable supply chains. First, the trade-off between cost efficiency and resilience remains a central challenge. While strategies such as supplier diversification, buffer inventory, and nearshoring enhance resilience, they often increase operational costs and reduce economies of scale. Second, the adoption of advanced digital technologies introduces a trade-off between technological capability and accessibility. Large firms are better positioned to invest in AI, blockchain, and IoT, whereas SMEs may struggle with financial and technical constraints, leading to unequal resilience capabilities. Third, organizations must balance sustainability objectives with profitability pressures. Although ESG integration supports long-term value creation and regulatory compliance, it may impose short-term financial burdens, particularly in resource-constrained environments. These trade-offs highlight that resilience and sustainability are not purely technical challenges but strategic decisions requiring careful prioritization and alignment with organizational capabilities.

5. Contributions and Implications

5.1 Theoretical Contribution

This study contributes to the literature by integrating multiple disruption categories within a unified framework that explicitly links disruption types, strategic responses, and underlying trade-offs. Unlike prior reviews that examine these dimensions in isolation, this paper provides a holistic perspective on how resilience and sustainability can be jointly managed under conditions of high uncertainty. By synthesizing these fragmented themes, the research offers a more nuanced understanding of the systemic interdependence within modern supply chains. However, to maintain academic rigor, the following limitations inherent in the study's scope must be acknowledged.

5.2 Managerial Contribution

For supply chain managers and policymakers, this study provides a roadmap for navigating the 'dual-transition' of digitalization and ESG compliance amidst global volatility. Practitioners should move beyond reactive 'buffer' strategies—such as merely increasing safety stock—and instead invest in dynamic capabilities through digital twins and AI-driven predictive analytics to enhance real-time visibility. Furthermore, the findings highlight that 'Resilience-as-a-Service' requires addressing the digital divide; large firms must foster closer collaboration and resource-sharing with their SME partners to ensure the entire supply network remains robust. Finally, managers are encouraged to adopt standardized ESG reporting frameworks early to mitigate the institutional uncertainty caused by fragmented international regulations, thereby turning compliance into a competitive advantage rather than a short-term cost.

6. Limitations and Future Research

While this study adopts a systematic review approach to synthesize recent literature, it is inherently dependent on the scope, quality, and methodological rigor of the selected studies. Although strict inclusion criteria were applied, variations in research design, sectoral focus, and geographical coverage across the reviewed articles may introduce potential bias into the synthesis.

This study does not generate primary empirical data, which limits its ability to validate the identified relationships in real-world operational settings. While the conceptual framework provides a structured understanding of disruption–response dynamics, future research could benefit from empirical testing across different industries and regions to enhance generalizability and practical applicability.

Finally, the rapidly evolving nature of global disruptions—particularly in relation to technological advancements and geopolitical instability—means that some findings may have limited temporal relevance. As digital technologies and regulatory environments continue to evolve, resilience strategies must be continuously reassessed. This highlights the need for ongoing research that captures emerging disruption patterns and adaptive responses over time.

7. Conclusion

In spite of the fact that the potential of digitization and ESG (environmental, social, and governance) integration in supply chains is widely acknowledged, the path to effective implementation is marked by large discrepancies and continuing hurdles (Chen et al., 2024; Liu et al., 2022; Pourmorshed & Durst, 2022). Research has shown that large companies, which have access to more resources and established digital strategies, tend to adopt advanced digital tools and ESG practices at a faster rate than small and medium-sized enterprises (SMEs), which frequently face obstacles concerning finances, technology, and organizational structures. This digital divide is further worsened by the complexity of integrating technologies such as artificial intelligence, Internet of Things, and blockchain, which require not only financial investment but also skilled personnel and robust infrastructure (Sah et al., 2024; Shoomal et al., 2024; Nozari et al., 2022).

Similar disparities are evident in ESG integration. The costs and difficulties of ESG data collection, supplier compliance, and reporting remain a challenge for many SMEs, despite the fact that top businesses are increasingly incorporating ESG principles into their supply chain management (Tsoulfas, 2024; Pourmorshed & Durst, 2022; Tsang et al., 2024). A significant obstacle is the absence of defined ESG measures and frameworks across international borders. This lack of standardization results in inconsistencies in data, complicates benchmarking, and hinders comparison of ESG outcomes for multinational corporations (Tsang et al., 2024). Regulatory requirements and stakeholder expectations can vary greatly from one jurisdiction to another, making this fragmentation particularly troublesome for firms operating across multiple regions.

Further complicating the scene are the governance issues. The goals of private companies frequently diverge from the priorities of national regulatory agencies, resulting in tension in the implementation of digital and ESG initiatives (Lu et al., 2023; Tsang et al., 2024). Studies have shown that supporting industrial policies can buffer the impact of digital transformation on ESG performance. As a result, regions with weaker marketization may enjoy less pronounced benefits from digital transformation (Lu et al., 2023; El Sakty, 2023). Therefore, government support and policy alignment are extremely important. Progress may be slowed by the interaction between public and private interests, particularly in situations where there is a lack of regulatory clarity or incentives.

Despite these challenges, digitalization has shown substantial benefits for ESG performance. The use of digital technologies helps minimize information asymmetry, improve transparency, and enable real-time monitoring of supply chain activities, all of which contribute to achieving operational efficiency and sustainability goals (Chen et al., 2024; Zhang & Huang, 2024; Tian et al., 2024; Wu et al., 2024). Artificial intelligence-driven analytics can optimize resource utilization and foresee risks (Sah et al., 2024; Shoomal et al., 2024; Salamah et al., 2023). Blockchain technology has the potential to enhance both authenticity and traceability. However, these advantages are not guaranteed; important obstacles remain, such as organizational resistance, interoperability challenges, and cybersecurity threats (Shoomal et al., 2024; Nozari et al., 2022).

Furthermore, the research emphasizes the significance of integrating supply chains and fostering collaboration. According to Setiawan et al. (2023), Liu and Chiu (2021), and Salamah et al. (2023), digitalization enables supply chain partners to coordinate more effectively, which is critical for both resilience and ESG compliance. Integration enhances green supply chain practices and helps firms respond more efficiently to disruptions; however, establishing this level of coordination is often more difficult for SMEs due to limited resources and expertise (Pourmorshed & Durst, 2022).

Another important concern is the lack of longitudinal research. The majority of current studies concentrate on short-term consequences or individual case studies, making it difficult to fully understand the long-term value and effectiveness of digitalization and ESG initiatives (Tubis et al., 2023; Bouraya & Korchi, 2025). Long-term studies are necessary to examine how these strategies shape resilience, sustainability, and competitive advantage over time.
Emerging technologies such as digital twins, quantum computing, and advanced Internet of Things applications present new potential to overcome existing restrictions; however, adoption remains in its early stages and is often limited to larger, more innovative companies (Sah et al., 2024; Bouraya & Korchi, 2025). Although issues of scalability, interoperability, and affordability persist, these technologies have the potential to further improve supply chain transparency, efficiency, and sustainability.

In conclusion, the application of digitalization and ESG integration is uneven and plagued with challenges relating to firm size, standards, governance, and technological complexity. Despite these obstacles, technological advancements are boosting supply chain management, though implementation remains inconsistent (Tsoulfas, 2024; Pourmorshed & Durst, 2022; Tsang et al., 2024; Chen et al., 2024; Sah et al., 2024; Lu et al., 2023). Addressing these challenges requires coordinated efforts among industry, policymakers, and researchers, alongside more comprehensive and long-term studies to guide future initiatives.

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