CIRCULAR ECONOMY AS A STRATEGIC RESPONSE TO GEOPOLITICAL VOLATILITY: GLOBAL MANAGEMENT PATHWAYS

Andreea Maria ȘOPEA-IORDACHE [a]*, Mircea Constantin DUICĂ [a], Jianu Daniel MUREȘAN [b], Alina Nicoleta PASCU (MARICA)[c]

[a] Valahia University of Târgoviște, Romania
[b] Petroleum-Gas University of Ploiesti, Romania
[c] Bucharest University of Economic Studies, Romania

ABSTRACT

This paper explores the circular economy (CE) not simply as an environmental initiative but as a strategic response to geopolitical uncertainty. Its main purpose is to show how CE, when combined with resilience measures and innovation, can reinforce supply chains and enhance long-term competitiveness. The key contribution lies in the proposal of the Global Management Pathway Model, which integrates three dimensions: circular strategies such as reuse and recycling, resilience practices including supplier diversification and stockpiling, and digital instruments, among them artificial intelligence and blockchain, that enable improved monitoring and adaptability.

The study draws on a systematic review of recent literature (2017-2025) alongside case analyses in three vital fields: critical minerals and renewables, electronics and e-waste, and agri-food chains. Findings indicate that circular strategies can reduce exposure to volatile imports, though they rarely deliver sufficient protection on their own. They prove far more effective when reinforced by resilience measures that allow flexibility in times of disruption and by digital systems that provide real-time visibility of supply networks. Evidence from sectors such as semiconductors and renewable energy suggests that redundancy, resource recovery and digital risk-management tools are becoming increasingly essential.

The conclusion is that organisations and regions adopting CE in combination with resilience practices and innovation are better equipped to face challenges like trade disputes, energy shocks and shortages of raw materials. Progress can be monitored through indicators such as resource decoupling, ESG measures, and resilience criteria like agility and adaptability.

KEYWORDS: *circular economy, supply chain risk, geopolitical disruption, resilience, innovation*

DOI: 10.24818/IMC/2025/05.04

1. INTRODUCTION

In the past few years, the global economy has been shaken by a series of overlapping crises: trade disputes, the COVID-19 pandemic, the energy shock triggered by the war in Ukraine, and rising competition over critical raw materials. These events have revealed just how fragile international supply chains become when political tensions intersect with unstable markets. Companies and policymakers are increasingly searching for strategies that not only keep goods flowing but also reduce reliance on imports that are often uncertain. The circular economy (CE) is usually presented

*Corresponding author. E-mail address: *maria.iordache.mg@valahia.ro*

as a way to cut waste and save resources, yet its potential as a strategic instrument for resilience during geopolitical instability has been less studied.

The meaning of CE has been debated and reshaped over time. A widely cited study of 114 definitions showed that most focused on the traditional 3R principles of reduce, reuse and recycle, while giving less attention to wider systemic and social aspects (Kirchherr et al., 2017). A later study of 221 definitions pointed to a stronger emphasis on supply-chain transformation and the pursuit of sustainable development goals (Kirchherr et al., 2023). At the same time, some scholars argue that CE requires sharper conceptual clarity, with necessary conditions clearly defined rather than presented as long lists of practices (Figge et al., 2023). Policy initiatives also reflect this evolution. The European Union has integrated CE into its strategy, expanding its list of critical raw materials from 14 in 2011 to 34 in 2023 in an effort to secure resources for both the green and digital transitions (Glencross, 2024).

Research on geopolitical risk and supply chains highlights that disruptions can take many forms, including sanctions, embargoes, financial crises and pandemics. López et al. (2025) identify six broad categories of disruption and argue that collaboration and resilience-oriented supply-chain management are among the most effective responses. Modelling work supports the idea that backup suppliers, stockpiling and regionalisation can help reduce exposure to shocks (Mirzaee et al., 2023). In high-technology sectors such as semiconductors, vulnerabilities are particularly evident. Xiong et al. (2025) note that decentralised networks and redundancy are essential to withstand both geopolitical disruptions and health-related crises.

Digital technologies are now emerging as a crucial bridge between CE and resilience. Tools such as artificial intelligence, blockchain and knowledge-graph mapping give firms the ability to monitor risks in real time and to adapt supply flows before problems spread (Dong et al., 2025; Liu et al., 2023). In this way, digitalisation makes circular strategies more workable, turning closed-loop principles into adaptable solutions under conditions of uncertainty.

Even with these advances, the evidence is still fragmented. Very few studies link CE directly to geopolitical crises, and the methods used to measure resilience benefits remain inconsistent (López et al., 2025).

This paper aims to respond to these gaps by presenting the Global Management Pathway Model, which combines the circular economy, risk management and innovation as three interconnected pillars. The purpose is to show that CE should be understood as more than an environmental agenda. It can act as a strategic response to geopolitical volatility, giving companies and regions the ability not only to withstand crises but also to strengthen long-term competitiveness.

2. LITERATURE REVIEW

This review connects two fields of debate that are often studied separately: the circular economy and the geopolitical instability that increasingly shapes supply chains. The connection matters because firms and governments are now confronted with shocks from great-power rivalry, resource weaponisation, war, export controls, and energy insecurity, while searching for long-term strategies that reduce vulnerability and ensure access to materials. Glencross (2024) shows that sectors such as semiconductors and pharmaceuticals are increasingly exposed to politically motivated supply restrictions, while Bednarski et al. (2025) document that geopolitical disruptions have become a distinct category of risk with persistent ripple effects across global value chains. These developments highlight why resilience against geopolitical pressure has become a strategic priority for the EU, the USA and major Asian economies.

To identify relevant studies, I searched Scopus, Web of Science and Google Scholar, concentrating on publications from 2017 to 2025. Keywords included circular economy, supply chain risk, geopolitical disruption, resilience and innovation. The materials reviewed include conceptual contributions on CE, systematic reviews of disruptions, empirical analyses of reshoring and

technology adoption, and optimisation models. This body of work forms the foundation for the conceptual framework in this paper, highlighting how CE principles might shape global management pathways in volatile conditions.

The circular economy has been defined in many ways. Kirchherr et al. (2017) analysed 114 definitions and found that most were centred on the 3Rs, reduce, reuse and recycle, while giving limited attention to broader social and systemic concerns. A later study based on 221 definitions showed emerging convergence around systemic transformation and alignment with sustainable development goals (Kirchherr et al., 2023). Figge et al. (2023) argue that a robust definition must specify necessary conditions and distinguish CE from related sustainability concepts. Core strategies include designing for longevity, reuse and recycling, and decoupling economic growth from virgin resource extraction. At policy level, the European Union has integrated CE into geoeconomic priorities such as the Green Deal and the Raw Materials Strategy. The EU's list of critical raw materials increased from 14 in 2011 to 34 in 2023, reflecting both resource scarcity and geopolitical competition, particularly with China, which dominates processing of rare earths and battery minerals (Glencross, 2024). ESG-aligned indicators are expanding, but measurement remains fragmented.

However, the most recent literature stresses that geopolitical disruptions have intensified in scope and frequency. Lopez et al. (2025) identify six types of geopolitical shocks including sanctions, military conflict, trade policy disputes, and port blockages, each affecting configuration and flows differently. OECD (2025) evidence shows that fully reshoring production tends to raise volatility and lower output; therefore targeted diversification and "Triple-A" strategies (agility, adaptability, alignment) are recommended. Meanwhile, Incekara & Incekara (2024) empirically demonstrate that supply chain disruptions during crises are driven more by geopolitical and economic instability than by changes in resource prices alone. Together, these findings suggest that the stability conditions underpinning globalisation have eroded. Recent geopolitical crises illustrate these dynamics. The Russia-Ukraine war fundamentally altered global flows of energy, food and metals, forcing Europe to adopt strategic stockpiling and alternative trade corridors (Lopez et al., 2025; Glencross, 2024). US-China tensions have triggered export controls on technology, retaliatory restrictions on materials, and disruption risks in semiconductors, where high geographic concentration creates choke points (Xiong et al., 2025). Israel-Gaza conflict spillovers and Red Sea maritime attacks caused immediate delays and insurance cost increases for vessels transiting the Suez Canal (Lopez et al., 2025). Some supply chain bottlenecks remain unresolved years after COVID-19, revealing structural vulnerabilities rather than temporary shocks. As a response, firms are reconfiguring production networks. Lazard (2024) describes a "China plus many" strategy where companies expand sourcing and production to multiple countries to reduce supplier concentration. Luo et al. (2025) provide empirical evidence that although some US imports move to China+1 partners, many supply chains remain dependent on Chinese upstream inputs, creating triangular trade rather than genuine decoupling. Bednarski et al. (2025) identify regionalisation and friend-shoring as increasingly dominant geopolitical strategies.

Within this context, CE has been proposed as a strategic resilience tool. Xiong et al. (2025) argue that circular resource use reduces exposure to global chokepoints in semiconductors. Glencross (2024) shows that Europe is moving from a pure free-market approach towards strategic state intervention including subsidies and stockpiles, which complements CE objectives of reducing import dependency. Nevertheless, OECD (2025) warns that circular practices alone cannot absorb severe geopolitical shocks unless coupled with traditional resilience measures such as redundancy and diversification. Recent scholarship highlights technology as a connector between CE and resilience. Pellegrino & Gaudenzi (2025) find that digital resources enhance visibility and agility. Dong et al. (2025) show that AI improves resilience by lowering risk costs and moderating geopolitical pressure, especially in high-tech sectors. Liu et al. (2023) demonstrate that knowledge-graph analytics detect multi-tier dependencies otherwise hidden in complex chains. Similarly,

Mirzaee et al. (2023) show through stochastic optimisation that backup suppliers, safety stock and temporary facilities are crucial elements in resilient green supply chain design. Despite these contributions, evidence remains fragmented. Only a limited number of studies directly assess how CE mitigates geopolitical crises, and some disruption types show limited benefit from circular practices alone (Lopez et al., 2025). Research is also strongly concentrated in developed economies, with under-representation of Eastern Europe, including Romania, where geopolitical vulnerabilities and industrial dependencies differ significantly.

Overall, the review shows that CE is evolving beyond recycling towards systemic transformation of supply chains, while geopolitical volatility forces governments and firms to seek secure, adaptable and regionally diverse resource pathways. Integrated approaches combining CE principles with resilience strategies, digital technologies and policy interventions offer promising avenues for navigating global instability. These insights motivate the Global Management Pathway Model developed in this paper, which connects CE, geopolitics and innovation as complementary forces in a volatile world.

3. CONCEPTUAL FRAMEWORK

The review of the literature highlighted several important gaps. Most research on the circular economy does not measure resilience benefits in a direct or systematic manner, and only a few studies connect CE explicitly to geopolitical disruptions (López et al., 2025). Indicators of resilience remain fragmented, while evidence from Eastern Europe is very limited. These shortcomings make it difficult for managers and policymakers to assess whether CE can realistically protect supply chains during times of crisis.

3.1 Core Components of the Model

The purpose of this section is to present the Global Management Pathway Model, which combines three main dimensions: circular economy principles focused on closing material loops and reducing dependency, risk management and supply chain resilience practices that allow firms to handle disruptions, and technological as well as organisational innovation to secure adaptability and competitiveness.

3.1.1 Circular Economy Pillar

The base of the model rests on established CE strategies such as designing products for longer lifespans, promoting reuse, expanding recycling, and decoupling growth from virgin resource consumption (Kirchherr et al., 2017). Policy in Europe has progressed quickly in this area, with the European Union expanding its list of critical raw materials from 14 in 2011 to 34 in 2023, to safeguard resources for clean technologies and the digital economy (Glencross, 2024).

Measurement tools include indicators such as resource productivity and material circularity, though their use remains inconsistent across regions (OECD, 2025). The model treats CE not merely as a recycling agenda but as a systemic transformation of supply chains, which aligns with the more recent literature emphasising production and logistics reconfiguration (Kirchherr et al., 2023). At the same time, Figge et al. (2023) point out that CE requires clearer conceptual boundaries. This pillar therefore stresses the importance of a precise and coherent definition as its starting point.

3.1.2 Risk Management and Supply Chain Resilience Pillar

The second pillar addresses the challenges of geopolitical disruption. Systematic reviews highlight six major types of disruption and outline common managerial responses (Bednarski et al., 2025; López et al., 2025). Among the most effective measures are the use of backup suppliers and safety stock, which have been validated in stochastic models of resilient green supply chains (Mirzaee et al., 2023). High-technology sectors such as semiconductors show a particular need for decentralised

networks and redundancy to absorb shocks (Xiong et al., 2025). The OECD suggests three guiding principles for resilient supply chains: agility, adaptability and alignment (OECD, 2025). In the proposed model these mechanisms are not add-ons but are built directly into circular supply systems, so that reuse and recycling loops are supported by diversification, redundancy and emergency reserves.

3.1.3 Innovation and Digital Enablement Pillar

The third pillar underlines the role of technological and organisational innovation, but also the risks associated with these tools. Artificial intelligence (AI) has been shown to improve supply chain resilience by reducing risk costs, enhancing operational efficiency, and supporting better decision-making under uncertainty (Dong et al., 2025). The mechanism operates through two channels: first, AI improves visibility across supplier tiers by detecting early signals of disruption; second, it increases firm profitability and thus financial capacity to respond to shocks (Dong et al., 2025). Knowledge-graph techniques strengthen this effect by identifying hidden dependencies and critical nodes that cannot be observed through traditional approaches (Liu et al., 2023). Moreover, digital resources contribute both directly to resilience and through improved organisational capabilities such as agility and redundancy (Pellegrino & Gaudenzi, 2025).

However, incorporating AI into supply chain strategy is not risk-free. Much of the infrastructure enabling contemporary AI models is highly geographically concentrated, frequently relying on U.S. or Chinese cloud platforms, semiconductor hardware, and software ecosystems. Such dependencies may expose firms to new geopolitical pressures rather than mitigate them, especially in sectors already characterized by concentrated chokepoints such as semiconductors (Xiong et al., 2025). In other words, while AI can buffer against some disruptions, over-reliance on a narrow set of digital suppliers may reproduce the very vulnerabilities that circular strategies aim to reduce. In addition to geopolitical constraints, digital tools introduce their own operational risks. These include cybersecurity threats, disruptions caused by data loss or system outages, and challenges in ensuring data governance across global networks (OECD, 2025). The effectiveness of AI-enabled resilience also depends on data quality and workforce capabilities, meaning that digital maturity becomes a precondition for obtaining positive outcomes (Pellegrino & Gaudenzi, 2025).

For these reasons, the Global Management Pathway Model incorporates AI and related technologies as complementary enablers, not standalone solutions. Digital innovation supports circular and resilient practices when embedded in diverse, regionally distributed supply networks with secure data access, rather than when used as a substitute for structural redesign. This integrated approach allows organisations to benefit from advanced monitoring and adaptive responses while managing the new dependencies and vulnerabilities associated with AI adoption.

3.2 Integrative Dynamics of the "Global Management Pathway Model"

The three pillars of the model , circular economy, risk management, and digital innovation , are not meant to work separately. They overlap, interact, and reinforce one another, building a stronger and more adaptive system for firms and regions facing geopolitical shocks. This section sets out how these connections operate and how they help to strengthen resilience.

3.2.1 Interaction Mechanisms

The first mechanism of feedback begins with the circular economy and its influence on exposure to risk. By extending the lifespan of products, designing for reuse, and closing material loops through recycling, companies reduce their demand for new imports. In practice, this lowers reliance on politically unstable suppliers and cuts vulnerability to sudden restrictions or sanctions (Kirchherr et al., 2017; Kirchherr et al., 2023). The steady expansion of the European Union's list of critical raw materials illustrates how policy is already moving in this direction (Glencross, 2024).

The second mechanism is linked to how resilience measures can create time for innovation. Established tools such as stockpiling, sourcing from multiple suppliers, regionalising production, or using friend-shoring strategies act as buffers that allow firms to cope during disruption (Mirzaee et al., 2023; Xiong et al., 2025). This breathing space enables managers to experiment with circular solutions rather than remaining locked in short-term crisis response. OECD studies further emphasise that agility, adaptability, and alignment are necessary for such practices to work effectively (OECD, 2025).

The third mechanism involves digital technologies. Artificial intelligence and knowledge-graph mapping enable real-time detection of risks and automated monitoring of supply chains. These tools help managers to activate alternative suppliers quickly and trace material flows across circular systems (Dong et al., 2025; Liu et al., 2023). In doing so, digital intelligence completes the loop by giving decision-makers live information to adapt production and logistics as conditions change.

3.2.2 Layers or Phases

The model functions across three layers, which often overlap in practice:

- Preventive layer: this stage focuses on eliminating waste through design, securing access to critical resources early, and embedding closed-loop flows that reduce the need for virgin inputs from unstable regions (Kirchherr et al., 2017).
- Adaptive layer: at this stage, firms react in real time. Digital monitoring and AI systems detect shocks, while backup suppliers and flexible transport routes allow production to continue (Dong et al., 2025; Mirzaee et al., 2023).
- Transformative layer: over the longer term, companies can shift to new business models and ecosystems, such as moving from selling products to service-oriented models, or creating regional platforms for shared use of materials. This reflects the systemic change highlighted in more recent CE literature (Kirchherr et al., 2023).

These layers do not follow a rigid order. A company may begin with emergency adaptive actions and later redesign its systems to be more preventive, or it may accelerate transformative change after experiencing a major disruption. Together, the three layers show how resilience strategies and circular economy practices can evolve side by side, shaping a pathway toward long-term competitiveness in volatile conditions.

3.2.3 Global vs. Regional Scales

The Global Management Pathway Model has been designed with international supply chains in mind, but it can also be applied at regional or even national levels. Recent studies of trade networks show that although U.S. companies have sought to diversify imports through China+1 strategies, their supply chains still remain linked upstream to Chinese production (Luo et al., 2025). This complexity highlights why resilience and circular economy measures need to operate across several countries simultaneously, rather than being confined to a single market.

Within Europe, the model aligns with policy frameworks such as the Critical Raw Materials Act and the EU Circular Economy Action Plan, both of which seek to reduce reliance on external suppliers while increasing recycling capacity (Glencross, 2024; OECD, 2025). In Romania, the model can provide a way to connect national industries to EU circular objectives while shielding them from import shocks. By combining circular design approaches with regional supplier diversification and digital risk-monitoring tools, Romanian firms can contribute to European environmental goals while also strengthening their own competitiveness.

When considered together, the interaction mechanisms, layered phases, and applications from global to local levels demonstrate that the Global Management Pathway Model is both flexible and practical. It serves as a framework that links CE, risk management, and digital innovation in a way that can be scaled according to context, making it especially relevant under conditions of geopolitical uncertainty.

This research argues that the integration of circular economy, resilience, and innovation provides a strategic response to global political and trade volatility. The central hypothesis is that adopting circular economy strategies, supported by resilience measures and technological innovation, enhances supply chain stability and long-term competitiveness. In particular, CE practices such as product longevity, reuse, and recycling are expected to lower dependency on critical raw materials and imports, thereby reducing exposure to external shocks (Kirchherr et al., 2017; Kirchherr et al., 2023; Glencross, 2024). At the same time, digital technologies including artificial intelligence can help to reduce the negative impacts of geopolitical risk by offering predictive capabilities and real-time intelligence that strengthen adaptive responses (Dong et al., 2025; Liu et al., 2023). Risk management measures such as supplier diversification, stockpiling, and regionalisation also act as buffers, giving firms the stability needed to expand circular initiatives even in turbulent environments (Mirzaee et al., 2023; OECD, 2025).

These propositions place the circular economy, when integrated with resilience and innovation, as a pathway towards competitiveness in times of geopolitical stress. The implications can be considered at three levels. For research, the Global Management Pathway Model provides a new perspective on CE, shifting it from being seen primarily as an environmental tool to a strategic approach for resilience. Earlier reviews often reduced CE to recycling or the 3R principle (Kirchherr et al., 2017), but more recent studies emphasise systemic change in supply chains and the need to connect CE with disruption management and digital solutions (Kirchherr et al., 2023; López et al., 2025; Dong et al., 2025; Liu et al., 2023). For management, the model acts as a roadmap, showing how resilience practices like backup suppliers and stockpiling (Mirzaee et al., 2023), or the OECD's principles of agility, adaptability, and alignment (OECD, 2025), can be combined with CE and digital monitoring to protect competitiveness under volatile conditions. For policy, the evidence suggests that industrial and trade strategies should integrate CE objectives with resilience measures and investment in digital technologies, following the example of the EU's expanding list of critical raw materials (Glencross, 2024).

The model also highlights specific mechanisms that can be measured in future research. These include reducing dependency on critical raw materials (Glencross, 2024), building resilience through backup suppliers and stockpiling (Mirzaee et al., 2023), and enhancing adaptability with digital tools such as AI and knowledge-graph mapping (Dong et al., 2025; Liu et al., 2023). Indicators could involve recycling rates, material circularity metrics, or the presence of product longevity strategies for CE (Kirchherr et al., 2017; Kirchherr et al., 2023). Risk management capacity might be measured through the extent of supplier diversification, the adoption of resilience policies, and the use of the OECD's agility, adaptability, and alignment principles (OECD, 2025). Innovation could be tracked through the adoption of AI and digital monitoring systems across supply chains (Pellegrino & Gaudenzi, 2025).

Case selection also follows logically from this framework. The literature shows strong evidence from high-tech and strategic sectors such as semiconductors (Xiong et al., 2025) and from major trade reconfigurations like U.S.-China reallocation patterns (Luo et al., 2025). These provide useful cases for testing the model. At the same time, the limited evidence available from Eastern Europe and Romania presents an opportunity to apply the model in settings with different institutional and market conditions. By linking these variables and cases, the research can test the central hypothesis, that firms and regions which combine CE, resilience practices, and digital innovation perform better under geopolitical volatility , and explore how these dynamics unfold at both global and regional scales.

4. METHODOLOGY

This study follows a qualitative comparative design, combining a systematic review of the literature with case-based analysis in three strategic domains: (a) critical minerals and renewables, (b) electronics and e-waste, and (c) food and agricultural supply chains. The aim is not to generate broad statistical generalisations but to examine how circular economy principles, risk management practices, and digital innovation interact when supply chains are exposed to geopolitical shocks. In

doing so, the research also tests whether the Global Management Pathway Model can be applied across different contexts.

The first stage of the design involves a structured review of academic and policy literature published between 2017 and 2025. Drawing on the approach of López et al. (2025), who analysed 80 articles on geopolitical disruptions and identified six distinct categories, the review was carried out using Scopus, Web of Science, and Google Scholar. Search terms included circular economy, supply chain resilience, geopolitical risk, innovation, and sustainability. Only studies that made a direct connection between these themes were selected. The reviewed material brings together conceptual work on CE definitions and systemic change (Kirchherr et al., 2017; Kirchherr et al., 2023; Figge et al., 2023) with policy-oriented contributions such as the OECD resilience framework built around agility, adaptability, and alignment (OECD, 2025), as well as European Union strategies for securing critical raw materials (Glencross, 2024).

Taken together, this strand of the methodology highlights the key mechanisms that underpin the conceptual framework: closing material loops, diversifying sources of supply, embedding redundancy within networks, and making use of digital monitoring tools.

5. CASE STUDIES

The second part of the research applies the Global Management Pathway Model to three domains that were selected because they are both highly exposed to geopolitical disruption and central to current sustainability transitions.

a) Critical minerals and renewables

The European Union's steadily expanding list of critical raw materials highlights how dependency pressures are being reshaped by the combined effects of geopolitics and the energy transition (Glencross, 2024). Circular strategies, such as recycling rare earth elements or using substitutes in renewable technologies, are increasingly seen as ways of reducing vulnerability. Alongside these, resilience measures like stockpiling, diversifying trading partners, and strengthening regional cooperation remain vital for securing supply stability (OECD, 2025).

b) Electronics and e-waste

Electronics supply chains are among the most fragile global networks, with semiconductors often cited as a particularly exposed area. Research indicates that resilience in this sector relies on decentralisation and redundancy, while circular economy strategies emphasise repair, reuse, and the recovery of e-waste streams (Xiong et al., 2025). Digital technologies add another essential layer of protection. Tools such as AI-based monitoring and knowledge-graph mapping allow firms to detect weak nodes and hidden dependencies before they become major points of failure (Dong et al., 2025; Liu et al., 2023).

c) Food and agricultural chains

Although less technologically complex than the other two sectors, food systems are highly vulnerable to geopolitical shocks such as trade embargoes, price fluctuations, and resource shortages. Circular practices like reducing food waste, reusing by-products, and developing more localised loops can help reduce dependency on external supplies. On the resilience side, strategies such as diversified sourcing and the expansion of storage facilities offer a buffer against disruptions. Studies on supply-chain shocks also stress the importance of sound financial management, inter-firm collaboration, and resilience-oriented management practices in this area (López et al., 2025; Bednarski et al., 2025).

The comparative perspective makes it easier to detect patterns that cut across the case studies. A key observation is that circular economy practices can play a role in reducing reliance on critical imports, but their effect is often limited unless they are supported by resilience strategies and digital innovation (López et al., 2025). Findings from modelling work suggest that mechanisms such as keeping backup suppliers and maintaining safety stock are among the most dependable

ways of cushioning shocks (Mirzaee et al., 2023). These tools create the breathing space needed for circular approaches to grow and deliver results. In this sense, the case studies serve as practical illustrations of the Global Management Pathway Model, showing how the three pillars strengthen one another when applied in varied contexts.

Table 1. Comparative Table of Case Studies

Case Domain	Circular Economy strategies	Resilience measures	Role of Digital Innovation
Critical minerals & renewables	Recycling of rare earths, substitution in renewables	Stockpiling, trade diversification, regional cooperation	Risk monitoring tools for supply stability
Electronics & e-waste	Repair, reuse, e-waste recovery	Decentralisation, redundancy, backup suppliers	AI monitoring, knowledge-graph mapping to detect weak links
Food & agricultural chains	Reducing food waste, reusing by-products, local loops	Diversified sourcing, storage facilities, collaboration	Less central, but digital tracking may support logistics and sourcing

Source: adapted from OECD 2025

6. FINDINGS

The outcomes of this qualitative comparative study suggest that circular economy strategies, when combined with resilience practices and digital innovation, can help reduce vulnerability to geopolitical shocks. The evidence can be organised into two main strands: mechanisms for risk reduction and the indicators used to measure their effectiveness.

One clear finding is that circular economy practices lower dependence on unstable imports. The European Union's expansion of its critical raw materials list from 14 in 2011 to 34 in 2023 highlights the recognition that local recycling, material substitution, and closed-loop systems can reduce exposure to external supply risks (Glencross, 2024). At the firm level, measures such as designing for reuse and extending product lifecycles make businesses less vulnerable to sudden supply disruptions (Kirchherr et al., 2017). Even so, the literature points out that CE practices alone are not always sufficient. López et al. (2025) showed that circular and sustainable supply-chain approaches had limited effect in some types of disruption unless they were supported by wider resilience measures. This explains why tools such as backup suppliers, stockpiling, and regionalisation remain essential (Mirzaee et al., 2023; Xiong et al., 2025).

Digital technologies represent another significant mechanism. Artificial intelligence and knowledge-graph mapping offer real-time insight into hidden supply tiers and help firms anticipate bottlenecks before they occur (Dong et al., 2025; Liu et al., 2023). These systems do not replace CE strategies but make them more effective, allowing companies to respond more quickly to disruption. In this sense, digitalisation acts as a bridge between short-term risk management and long-term circular transformation.

The analysis also highlights several indicators that can show whether these mechanisms genuinely improve resilience. One key metric is resource decoupling, which reflects the extent to which economic growth can be separated from raw material use. Scholars describe this as a central

principle of systemic transition within CE (Kirchherr et al., 2023). Another group of indicators is found in ESG frameworks, where measures such as resource productivity, recycling rates, and carbon emissions are particularly important (OECD, 2025). For resilience itself, the OECD proposes agility, adaptability, and alignment as guiding principles for assessing supply-chain robustness (OECD, 2025). In practice, firms can track the share of secondary materials in production, the level of supplier diversification, or the speed of recovery following a disruption.

Taken together, the findings show that CE should not be seen as a stand-alone solution but as part of a broader resilience strategy. Circular practices reduce risks, yet their impact is far greater when they are integrated with operational buffers and digital monitoring. This supports arguments in the literature that resilience must be multi-layered, combining preventive, adaptive, and transformative steps (Bednarski et al., 2025). For example, in the semiconductor industry, redundancy and decentralisation are vital for coping with immediate shocks, while e-waste recovery and reuse strengthen sustainability in the long term (Xiong et al., 2025). In food and agricultural supply chains, circular practices such as reducing food waste and reusing by-products improve local resilience, but diversified sourcing and financial collaboration remain decisive (López et al., 2025).

The discussion also points to regional differences. At EU level, strategies are well developed, supported by CRM policies and circular economy action plans. By contrast, Eastern European countries, including Romania, are still behind in implementing robust measurement systems. This reinforces the earlier gap identified in the review: there is a lack of empirical evidence on how CE, resilience, and innovation interact outside the more advanced economies.

In conclusion, the results confirm the central hypothesis: organisations and systems that integrate circular economy practices with resilience measures and innovation are better prepared to withstand geopolitical shocks and maintain competitiveness. At the same time, the findings underline the need for integrated KPIs, such as resource decoupling, ESG metrics, and resilience indicators, in order to provide a more comprehensive and reliable picture of progress.

7. CONCLUSIONS

This research set out to investigate whether the circular economy can be understood not only as an environmental tool but also as a strategic response to geopolitical volatility. The review of the literature showed that CE definitions have gradually shifted from a narrow focus on the 3R principles of reduce, reuse, and recycle towards a more systemic approach that connects supply-chain transformation with sustainable development goals (Kirchherr et al., 2017; Kirchherr et al., 2023; Figge et al., 2023). At the same time, the analysis of disruption studies confirmed that geopolitical shocks are among the most significant risks for global value chains. Evidence indicates that effective responses often require supplier diversification, stockpiling, collaboration, and the use of digital monitoring systems (López et al., 2025; Mirzaee et al., 2023; OECD, 2025).

By bringing these perspectives together, the paper introduced the Global Management Pathway Model, which places CE, risk management, and innovation as three mutually reinforcing pillars. The findings support the central hypothesis: firms and industries that combine circular practices with resilience measures and digital tools are better positioned to withstand geopolitical shocks. Examples include the European Union's expanding strategy for critical raw materials (Glencross, 2024) and the semiconductor sector, where decentralisation and e-waste recovery are both essential (Xiong et al., 2025). At the same time, the study also shows that CE on its own may have limited impact if not supported by resilience mechanisms (López et al., 2025). Indicators such as resource decoupling, ESG measures, and resilience KPIs (OECD, 2025) can help track progress, but current approaches remain fragmented and inconsistent.

There are still clear gaps. Most of the available evidence comes from global or EU-level studies, while emerging economies and Eastern Europe, including Romania, remain under-represented in the research base. Empirical studies that directly measure the resilience benefits of CE adoption are

also limited. Moreover, while digitalisation is increasingly seen as a driver of resilience, its practical role remains underexplored. Tools like artificial intelligence and knowledge-graph mapping show promise for real-time monitoring and predictive analysis (Dong et al., 2025; Liu et al., 2023), but more field-based studies are required to understand how they interact with circular practices in practice.

Future research should advance in three directions. First, comparative case studies in Eastern Europe could provide insights into how CE and resilience strategies unfold in different industrial and policy contexts. Second, harmonised indicators need to be developed to capture circularity, resilience capacity, and innovation adoption within one integrated measurement framework. Third, the Global Management Pathway Model should be tested using quantitative approaches that connect CE adoption levels, risk management practices, and innovation intensity with resilience outcomes across sectors.

In conclusion, the circular economy, when integrated with resilience and innovation, offers a promising pathway for managing global volatility. Yet turning this potential into practice requires addressing the evidence gaps, refining measurement tools, and adapting the model to diverse regional realities. This challenge is particularly urgent in countries such as Romania, where aligning CE ambitions with resilience and competitiveness could transform geopolitical risk into an opportunity for long-term strategic renewal.

REFERENCES

Bednarski, L., Roscoe, S., Blome, C. & Schlepper, M. C. (2023). Geopolitical disruptions in global supply chains: A state-of-the-art literature review. *Production Planning & Control*, *1–27*. https://doi.org/10.1080/09537287.2023.2286283

Dong, F., Zhao, X., Mangla, S. K. & Song, M. (2025). Enhanced supply chain resilience under geopolitical risks: The role of artificial intelligence. *Transportation Research Part E: Logistics and Transportation Review*, *202*, 104300. https://doi.org/10.1016/j.tre.2025.104300

Figge, F., Thorpe, A. S. & Gutberlet, M. (2023). Definitions of the circular economy: Circularity matters. *Ecological Economics*, *208*, 107823. https://doi.org/10.1016/j.ecolecon.2023.107823

Glencross, A. (2024). The geopolitics of supply chains: EU efforts to ensure security of supply. *Global Policy*, *15*(4), 729–739. https://doi.org/10.1111/1758-5899.13388

Incekara, R. & Incekara, B. (2024). Effects of economic and geopolitical risks on the supply chain: An econometric analysis. *Pressacademia, 2*. https://doi.org/10.17261/Pressacademia.2024.1938

Kirchherr, J., Reike, D. & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling, 127*, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005

Kirchherr, J., Yang, N.-H. N., Schulze-Spüntrup, F., Heerink, M. J. & Hartley, K. (2023). Conceptualizing the circular economy (revisited): An analysis of 221 definitions. Resources, *Conservation and Recycling*, *194*, 107001. https://doi.org/10.1016/j.resconrec.2023.107001

Lazard. (2024, August 20). *The geopolitics of supply chains* (Research brief). Retrieved September 2, 2025, from https://www.lazard.com/media/d4dnwbvc/the-geopolitics-of-supply-chains.pdf

Liu, Y., He, B., Hildebrandt, M., Buchner, M., Inzko, D., Wernert, R., Weigel, E., Beyer, D., Berbalk, M. & Tresp, V. (2023). A knowledge graph perspective on supply chain resilience *(No. arXiv:2305.08506v1). arXiv*. https://doi.org/10.48550/arXiv.2305.08506

López, C., Morales-Contreras, M. F., Langella, I. M. & Alonso-Monge, J. (2025). Modeling supply chain disruptions due to geopolitical reasons: A systematic literature review. *Transportation Research Part E: Logistics and Transportation Review, 202*, 104290. https://doi.org/10.1016/j.tre.2025.104290

Luo, W., Kang, S. & Di, Q. (2025). Global Supply Chain Reallocation and Shift under Triple Crises: A U.S.-China Perspective. *(No. arXiv:2508.06828v1). arXiv*. https://doi.org/10.48550/arXiv.2508.06828

Mirzaee, H., Samarghandi, H. & Willoughby, K. (2023). On designing a resilient green supply chain to mitigate ripple effect: A two-stage stochastic optimization model *(No. arXiv:2303.01729). arXiv*. https://doi.org/10.48550/arXiv.2303.01729

OECD. (2025). OECD supply chain resilience review: Navigating risks. *OECD Publishing*. https://doi.org/10.1787/94e3a8ea-en

Pellegrino, R. & Gaudenzi, B. (2025). Supply chain resilience as a viable way to cope with disruptions: an empirical analysis of Italian firms. *Rev Manag Sci*. https://doi.org/10.1007/s11846-025-00911-z

Xiong, W., Wu, D. D. & Yeung, J. H. Y. (2025). Semiconductor supply chain resilience and disruption: Insights, mitigation, and future directions. *International Journal of Production Research, 63*(9), 3442–3465. https://doi.org/10.1080/00207543.2024.2387074