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Big Data-Driven Approaches to Geopolitical Risk and MNC De-risking Strategies

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ABSTRACT

The transition to a multipolar world has intensified geopolitical risks, challenging multinational companies (MNCs) to protect and adapt their global value chains (GVCs). These risks—ranging from resource scarcity and energy insecurity to techno-nationalism, cyber threats, and disrupted transport corridors—have prompted a shift toward proactive de-risking strategies. This study investigates how Big Data Analytics (BDA) supports such strategies, enabling MNCs to enhance visibility, resilience, and strategic agility. Using a conceptual-analytical method, the research first classifies geopolitical risks into three core categories: resource access disruptions, technological isolation, and transportation vulnerabilities. These risks are mapped to specific GVC activities to identify critical points of exposure. The analysis then explores the role of BDA in mitigating these risks, focusing on three core capabilities: real-time decision-making, predictive analytics, and scenario modelling. Key BDA-enabled strategies are identified across four domains: supplier and market diversification, dynamic risk assessment and contingency planning, real-time visibility, and local adaptation. Tools such as Resilinc, FourKites, Riskmethods, and digital twins are examined to demonstrate their relevance to specific geopolitical threats. The findings show that while BDA is commonly applied for efficiency and forecasting, its potential as a strategic enabler for geopolitical risk mitigation remains underutilised. By aligning BDA functionalities with core MNC de-risking strategies, this study offers a practical framework for integrating digital solutions into GVC risk management. It also highlights how the convergence of BDA with other Industry 4.0 technologies—such as IoT, blockchain, and GIS—can further enhance resilience. The results contribute to both academic discourse and managerial practice by demonstrating that BDA is not merely a supportive tool, but a central component of strategic planning in an increasingly unstable global environment.

1. Introduction

The emergence of a multipolar world order has brought about a wave of geopolitical disruptions that profoundly affect global economic stability. Armed conflicts, sanctions regimes, contested trade

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routes, and strategic rivalries—ranging from the Russia–Ukraine war and Middle East instability to Indo-Pacific tensions—have exposed the fragility of global value chains (GVCs). For multinational companies (MNCs), these shocks have translated into restricted access to energy and raw materials, regulatory unpredictability, transport disruptions, and escalating compliance risks.

In response, MNCs are reshaping their operational strategies by diversifying suppliers and markets, localizing production, reinforcing contingency plans, and investing in greater transparency and real-time oversight. Yet many of these strategies remain ad hoc or reactive without systematic, data-driven support.

Industry 4.0 technologies—and especially Big Data Analytics (BDA)—offer significant, underexplored potential to move beyond reactive risk mitigation. BDA enables MNCs to assess vulnerabilities, forecast disruptions, simulate geopolitical scenarios, and enhance supply chain resilience through predictive and real-time insights. Despite this potential, current research offers limited understanding of how BDA tools are applied in practice to support strategic risk management in geopolitically unstable environments.

This study addresses that gap by examining how BDA solutions strengthen MNC strategies to mitigate geopolitical risks and enhance resilience in global operations. The analysis focuses on two core contributions:

Exploring BDA applications for enhancing resilience in global value chains, and
Using BDA to improve strategic risk mitigation strategies in MNCs.

Both contributions are operationalized by identifying key categories of geopolitical risk—such as sanctions, trade fragmentation, and regional instability—and matching them with appropriate BDA-based tools and approaches [1]. This mapping provides a structured understanding of how data-driven technologies can be systematically integrated into corporate strategies to navigate today's volatile global landscape.

2. Material and Method

This research adopts a conceptual-analytical approach to explore how BDA can support multinational companies (MNCs) in mitigating geopolitical risks across global value chains (GVCs). The study relies on qualitative analysis of secondary sources, including academic literature, policy papers, institutional reports, and real-world examples related to supply chain risk, Industry 4.0 technologies, and international economic disruptions.

The analytical framework is built in two steps. First, the study classifies geopolitical risks based on established theoretical perspectives on GVC disruptions. While prior scholarship has emphasised the productivity and efficiency benefits of GVCs [2-4], this research focuses on vulnerabilities exposed by recent geopolitical developments. These risks are defined as any disruption to the flow of information, goods, or services across borders [5], and are grouped into three main categories [1]:

i. Resource supply risks, which include constraints in accessing energy and raw materials due to conflicts, sanctions, or political instability. For example, post-2014 sanctions against Russia and the escalation of the Ukraine war in 2022 led to reconfigured trade flows and energy supply shortages, especially in Europe's aluminium, steel, and chemical sectors [6]. Additional disruptions include the 2023 military coup in Niger, which impacted France's uranium supply, and OPEC producers' refusal to stabilise oil prices during the Ukraine conflict.
ii. Technological risks, which encompass both innovation-related challenges [7, 8] and the effects of techno-nationalism, export restrictions, and cyber threats. Contemporary examples include the U.S. CHIPS and Science Act, the EU's identification of high-risk

technological domains, and sanctions impacting firms exporting technology to Russia [9]. Cyberattacks—including politically motivated ransomware or espionage—target critical nodes in global supply chains, adding a new layer of geopolitical vulnerability.

iii. Transportation risks, driven by physical and political disruption of key trade routes. The war in Ukraine, for instance, has severely impacted Black Sea transport, especially grain exports via Odesa. Likewise, Houthi rebel attacks in the Red Sea have forced rerouting of shipping around the Cape of Good Hope, increasing costs and delivery times. These disruptions, including blockages of the Suez Canal, have led to a measurable decline in global trade volume [10-12].

These risks are mapped onto GVC activities—ranging from inbound logistics and operations to outbound logistics, marketing, and services—to identify where vulnerabilities most acutely arise (Figure 1). This mapping draws from foundational value chain concepts [12] and supports the alignment of BDA-based tools with specific risk categories.

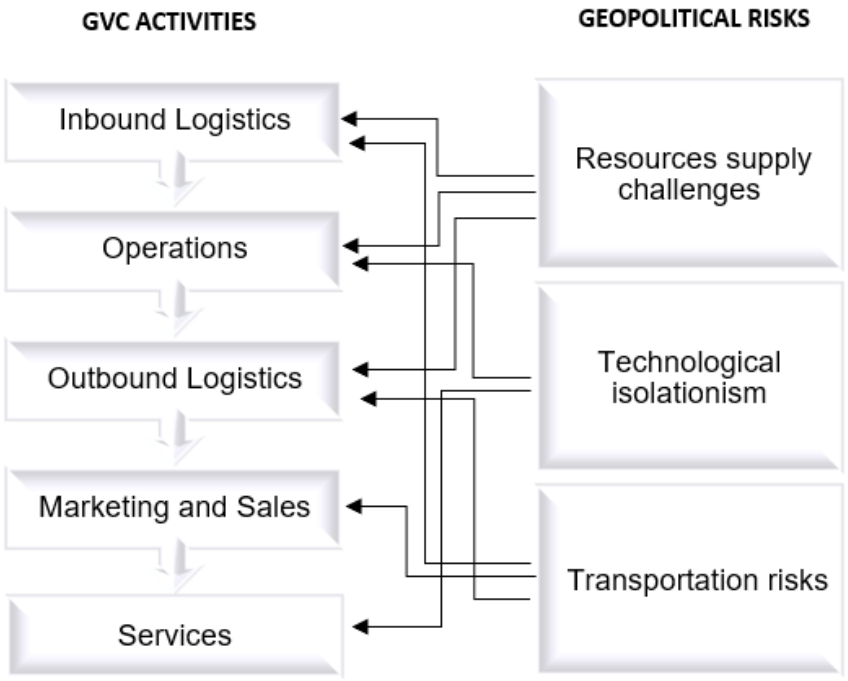

Fig. 1. Geopolitical Risk Exposure in Activities within Global Value Chains

The study applies thematic synthesis to match each risk category with specific BDA capabilities. Rather than seeking generalizability through statistical modelling, this step focuses on functional insight—understanding how BDA tools such as predictive analytics, digital twins, and real-time monitoring can be deployed to anticipate, model, and respond to risk in a dynamic geopolitical context.

The analysis identifies how BDA-enabled tools can be used not only to address risks reactively, but also to enhance MNC de-risking strategies more systematically. These include supplier and market diversification, contingency planning, transparency improvement, and local operational adaptation. By aligning BDA functionalities with strategic business responses, the study builds a framework that positions BDA as a central enabler of long-term resilience in volatile global environments.

3. Results and Discussion

3.1 Exploring BDA Applications for Enhancing Resilience in Global Value Chains

In an era of mounting geopolitical uncertainty, BDA has emerged as a critical enabler of resilience across GVCs. Broadly defined, Big Data encompasses large, fast-moving, and diverse datasets that exceed the processing capacity of traditional data systems. The value of Big Data lies not only in the "5Vs"—Volume, Velocity, Variety, Veracity, and Value—but also in its capacity to support real-time and predictive decision-making across complex international operations.

BDA refers to the extraction of actionable insights from massive, often unstructured, datasets using advanced analytical tools. These include predictive models, data mining techniques, machine learning algorithms, and real-time monitoring systems [13]. Initially applied to optimise operations and enhance customer engagement, BDA is increasingly being used for strategic risk management and supply chain resilience—particularly in the context of global disruptions.

Why Prioritize BDA in Geopolitical Risk Contexts? Among the various technologies of the Fourth Industrial Revolution (4IR), BDA is uniquely positioned to address geopolitical risk in GVCs due to three core capabilities:

i. Real-Time Decision-Making: BDA enables fast, informed decisions in dynamic environments. Tools such as *FourKites*, *Project44*, and *IBM QRadar* offer real-time visibility, tracking disruptions and cyber threats as they unfold.
ii. Predictive Analytics: By forecasting disruptions and demand shifts, BDA allows companies to anticipate and mitigate risks [14-16]. Platforms like *RapidMiner*, *SAS*, and *Tableau* are essential for early-warning systems.
iii. Interoperability with Other 4IR Technologies: BDA synergizes with IoT, AI, and blockchain to improve decision support. For example, *Provenance* leverages blockchain to enhance traceability, while *Uptake* integrates IoT with analytics for asset performance optimization [17, 18].

In the context of geopolitical instability, BDA strengthens value chains by supporting the following strategic functions:

i. Comprehensive Risk Assessment: Platforms like *Riskmethods*, *Interos*, and *Resilience360* continuously assess supplier exposure, geopolitical threats, and regulatory shifts.
ii. Scenario Planning and Simulation: Tools such as *AnyLogic* and *Simio* simulate possible geopolitical disruptions, allowing firms to develop data-driven contingency plans.
iii. Logistics and Process Optimisation: Solutions like *Kinaxis RapidResponse* and *Blue Yonder* enhance supply chain responsiveness, reducing costs and improving delivery efficiency.
iv. Supply Chain Diversification: Tools such as *Resilinc*, *Zycus*, and *Jaggaer* help identify alternative suppliers and markets less exposed to sanctions or conflict zones.
v. Transparency and Traceability: Through real-time data integration, BDA platforms increase end-to-end visibility, facilitating faster reaction to transport disruptions or compliance issues.

3.1.1 Harnessing BDA for Resource Risk Management in GVCs

In addressing uncertainties related to resource and energy supply—such as high energy costs, resource scarcity, and political instability affecting availability—technologies under the 4.0 IR umbrella have not fully enabled Western companies' GVCs to overcome new challenges or to seize spectacular opportunities. However, BDA and BDA-based solutions, particularly when integrated with the IoT and other digital technologies, can be crucial in addressing resource risks within GVCs.

The primary resource risks—price volatility, sectoral sanctions, and disrupted production/export capabilities—can be managed more effectively through the following ways.

Real-time Monitoring can support GVC in condition of price volatility. IoT sensors can track real-time data on resource availability, quality, and demand across different stages of the supply chain. BDA processes this data to detect early signs of price volatility, enabling companies to react swiftly. In regular conditions BDA is useful for predictive analytics, due to it can leverage large datasets (historical prices, weather patterns, economic indicators) to predict future price movements. But, in contemporary very frequent and various geopolitical turbulences, these possibilities of BDA can hardly provide valid information.

Regarding the risk of sectoral sanctions, BDA provides valuable capabilities for scenario planning. By analysing data on trade flows, political developments, and historical sanctions, BDA can simulate the potential impact of sanctions on different sectors. This helps companies to develop effective contingency plans and identify alternative suppliers or markets.

Additionally, BDA supports supply chain diversification by enabling firms to identify and evaluate new suppliers across various regions. This approach reduces dependency on any single country or sector that might be vulnerable to sanctions.

Furthermore, the combination of IoT and BDA facilitates real-time monitoring. This integration ensures that companies can continuously track transactions, manage supplier relationships, and oversee trade routes, thus maintaining compliance with international sanctions. For the risk of disrupted energy production and/or export BDA offer solutions for improving supply chain visibility. IoT devices can be deployed throughout the supply chain to provide real-time data on production processes, inventory levels, and logistics. BDA can analyse this data to predict and mitigate disruptions before they affect the supply chain. BDA, when combined with blockchain technology, can enhance transparency and traceability within the supply chain. This is particularly important in managing resource risks, as it ensures data integrity and provides a secure record of all transactions and resource movements.

One of success example give a global industrial conglomerate Siemens which has integrated IoT and BDA into its manufacturing processes to improve energy efficiency and predictive maintenance. By using IoT sensors across its production lines, Siemens collects real-time data on energy usage, equipment performance, and maintenance needs [19-21]. BDA is then applied to this data to predict when and where maintenance will be required, preventing downtime and optimizing energy consumption.

3.1.2 Mitigating Technological Risks in GVCs Through Big Data Analytics

BDA and BDA-based solutions can be instrumental in addressing and mitigating technological risks that arise from contemporary geopolitical landscapes, particularly in the context of techno-nationalism, economic sanctions and politically motivated cyberattacks.

To manage dependencies of U.S. and China, and its growing techno-protectionism and associated risks, MNCs need to adjust their global strategies, reconfigure supply chains, bolster resilience, and practice effective corporate diplomacy.

BDA can help firms develop comprehensive risk-assessment models that assess the likelihood and impact of violating sanctions in technology sector. These models can integrate data from various sources, including geopolitical developments, trade patterns, and historical enforcement actions, to provide a comprehensive view of the risks associated with specific transactions or partnerships. Also, by optimisation of value chain performance and market trends, BDA helps companies manage their

reliance on both the U.S. and China, as well as other key players. Another important BDA capability in this kind of risk is identification of alternative suppliers, that is supply chain diversification.

Similar to the case of resource supply requirements, BDA can help companies in supply chain diversification, in the way to not rely on single supplier of high technology and high-tech components.

Regarding cybersecurity as unique risk in the group of technological risks, BDA can support GVCs by real-time monitoring, predictive analytics and integration with ML and data mining. Real-time monitoring as one of the main advantages of BDA, can be integrated into cybersecurity systems to analyse vast amounts of data from network traffic, user behaviour, and threat intelligence feeds in real time. Machine learning algorithms can identify patterns and anomalies that indicate potential cyberattacks, enabling organizations to respond quickly to threats.

Predictive Analytics for Cybersecurity: BDA can be used to predict future cyber threats by analysing trends in cyberattack patterns, geopolitical tensions, and intelligence reports.

Besides, BDA uses machine learning algorithms and data mining techniques to analyse vast amounts of network traffic data and identify unusual patterns or behaviours that may indicate a cyberattack. By continuously monitoring for anomalies, businesses can detect threats earlier and respond more effectively. BDA platforms, such as Splunk and IBM QRadar, enable real-time monitoring of cybersecurity across the entire GVC. QRadar is adopted by a diverse range of organizations, including major financial institutions, healthcare providers, technology companies, government agencies, retailers, and energy firms. According to IBM [19], Pakistan Askari Bank significantly improved its security posture using QRadar. The system reduced the number of daily security incidents from approximately 700 to fewer than 20 by cutting down false positives. Additionally, automated response features decreased the average remediation time for cyberattacks from 30 minutes to just 5 minutes.

3.1.3 Big Data Analytics for Managing Transportation Risks in GVCs

BDA and BDA-related technologies, such as IoT, AI, and predictive modelling, can play a significant role in mitigating transportation risks in GVCs, particularly when dealing with dangerous transportation routes and fluctuating transportation costs due to geopolitical turmoil. BDA can process vast amounts of real-time data from various sources, including transportation logs and geopolitical events, to identify patterns and predict potential risks. BPA applications can be seen in procurement processes, manufacturing shop floors, routing optimisation, real-time traffic operation monitoring and proactive safety management [13]. This data can be used to identify potential hazards, such as political unrest, military conflicts, or natural disasters, that might affect specific routes.

Predictive Route Planning capability of BDA relate to the likelihood of roadblocks, protests, or military activity that could impact the movement of goods. This helps companies make informed decisions about the most cost-effective transportation routes, reducing the likelihood of encountering dangerous situations or incurring high costs.

In terms of transportation costs, Scenario Planning through BDA proves to be highly beneficial. It can simulate various geopolitical scenarios, such as the imposition of new sanctions or the closure of key trade routes, and assess their impact on transportation costs. Companies can use these insights to plan for contingencies, such as stockpiling goods, renegotiating contracts, or adjusting pricing strategies.

IoT devices provide real-time tracking and monitoring of shipments. It allows companies to respond quickly to potential risks or delays, optimizing routes and schedules to avoid dangerous

areas. Although this will not reduce transport costs, it is a significant help to save transported goods and vehicles. Integration of BDA and IoT with GIS can strength the ability to manage transportation challenges effectively.

One of the most compelling examples of advanced technological integration is Maersk Line, a prominent Danish international container shipping company and the second largest globally. Maersk leverages a spectrum of cutting-edge technologies including IoT, data analytics, AI and machine learning, digital twin, and even augmented reality (AR) [20].

The findings on how BDA can support the management of geopolitical risks are illustrated in Figure 2.

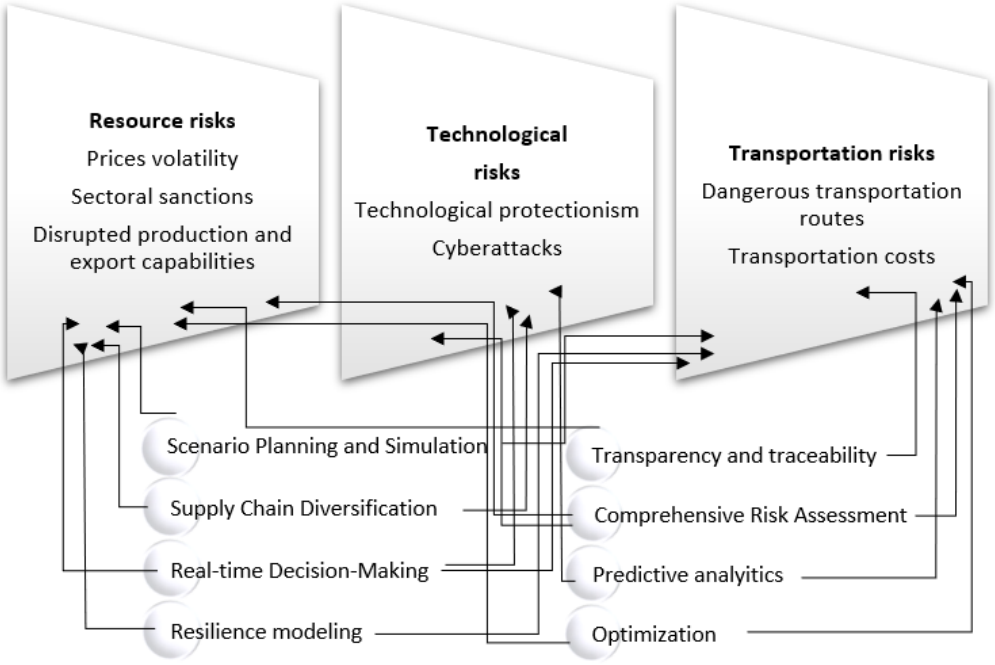

Fig. 2. Possibilities of BDA in Managing Geopolitical Risks

3.2 Using BDA to Enhance De-risking Strategies in MNCs

3.2.1 BDA and the Diversification of Suppliers and Markets

Diversification of suppliers and markets is a key strategy for mitigating geopolitical risks, and ~~Big Data Analytics (~~BDA~~)~~ plays an instrumental role in implementing this approach. In an era where global value chains are increasingly vulnerable to geopolitical shocks, BDA and BDA-powered tools enable multinational corporations (MNCs) to make informed, data-driven decisions that reduce exposure and enhance operational resilience.

BDA facilitates the identification and evaluation of alternative suppliers by processing large volumes of data related to supplier performance, geopolitical stability, and market conditions. Platforms such as Riskmethods and Resilinc apply BDA techniques to assess supplier vulnerabilities and monitor geopolitical developments in real time, thereby enabling companies to diversify their supply base and reduce overdependence on a single region or partner.

Similarly, BDA supports market diversification by analysing regional economic indicators, trade patterns, and political risk factors. Market intelligence platforms such as Crunchbase, Euromonitor International, and Gartner offer granular insights into emerging market opportunities. These insights

empower MNCs to enter new markets with greater confidence, reduce exposure to high-risk regions, and align diversification efforts with long-term strategic goals.

3.2.2 BDA for Risk Assessment and Contingency Planning

Effective risk assessment and contingency planning in today's volatile geopolitical landscape requires advanced tools that go beyond traditional frameworks. BDA significantly enhances this process by providing dynamic, predictive, and scenario-based insights.

Real-time analytics platforms—integrating IoT data, market feeds, and social media inputs—allow companies to continuously monitor both internal operations and external environments. These platforms deliver early warnings about disruptions, political unrest, or economic instability, supporting rapid decision-making and crisis response [22].

Integrated risk management platforms with BDA capabilities combine historical data with real-time inputs and predictive modelling to create detailed risk profiles. These tools simulate a range of geopolitical scenarios, identify systemic vulnerabilities, and recommend adaptive strategies, thereby enabling robust contingency planning.

Advanced analytics—including machine learning and data mining—reveal hidden patterns and correlations, offering proactive insights into risk trajectories. For example, companies can model likely outcomes of supply chain disruptions stemming from specific geopolitical events and design targeted mitigation strategies.

Digital twins, or virtual replicas of supply chain networks, further augment contingency planning by enabling scenario testing in a risk-free digital environment. Supported by BDA, AI, and ML, digital twins help firms simulate the impact of disruptions and evaluate the effectiveness of alternative strategies [23].

Across these tools, the common denominator is the use of BDA to transform vast, heterogeneous data sets into actionable intelligence—streamlining both risk detection and response mechanisms.

3.2.3 Enhancing Visibility and Transparency Using BDA During Geopolitical Turmoil

During times of geopolitical instability, supply chain visibility becomes critical. BDA enhances transparency across global operations, allowing MNCs to respond more effectively to shocks and maintain business continuity.

Platforms such as Project44 and FourKites enable real-time tracking of logistics and inventory flows. In crisis situations, these tools provide live updates on shipment routes, delays, and inventory shortages, allowing businesses to proactively adjust procurement and distribution plans.

Other platforms, such as IBM Watson Analytics, integrate data from diverse sources to provide a comprehensive operational overview. During geopolitical disruptions, such platforms help businesses visualise the full scope of risks and make evidence-based decisions regarding sourcing, manufacturing, and market engagement.

3.2.4 Local Adaptation Supported by BDA

In addition to supporting global risk strategies, BDA also strengthens local adaptation. All aforementioned platforms provide regionalised insights that help firms tailor operations to specific local conditions—whether it involves adjusting logistics routes, sourcing domestically, or navigating local regulatory shifts.

By enabling granular, context-specific decision-making, BDA empowers MNCs to increase their adaptive capacity and operational agility in both stable and crisis-prone environments (Figure 3).

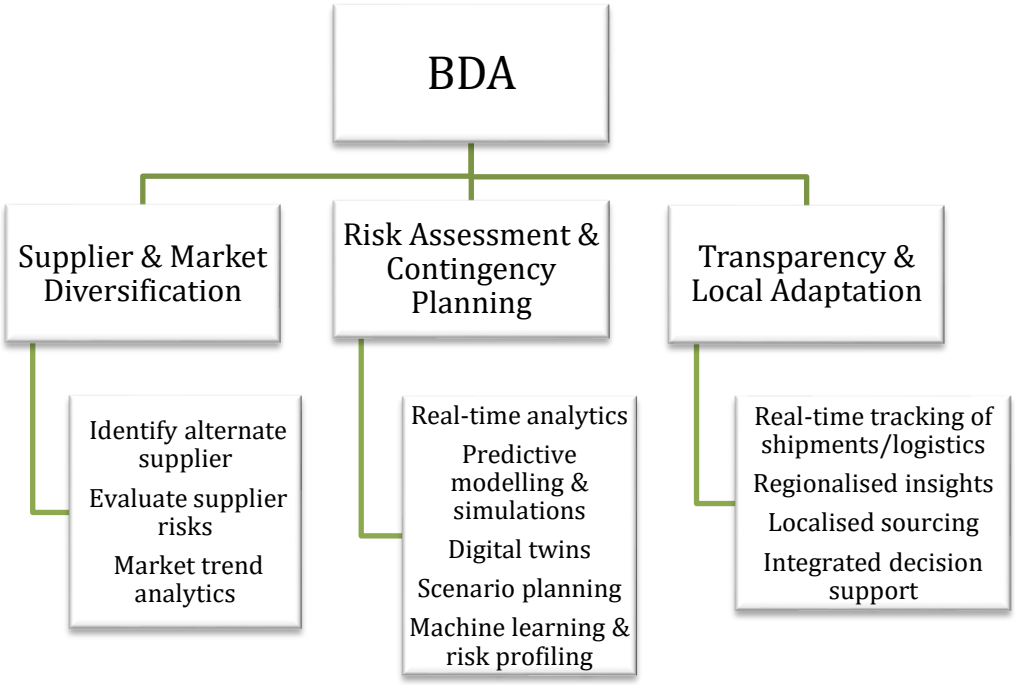

Fig. 3. BDA-Supported Strategic Risk Management Framework for MNCs under Geopolitical Uncertainty

4. Conclusions

The shift to a multipolar global order has introduced new layers of geopolitical risk, including resource volatility, technological fragmentation, and insecure transport corridors. These developments have significantly disrupted the structure and functioning of GVCs, compelling MNCs to adopt more sophisticated de-risking strategies.

This study demonstrates that BDA plays a pivotal role in supporting such strategies by enhancing visibility, adaptability, and strategic foresight across supply chains. Key findings include BDA's capacity to support real-time decision-making amid price fluctuations and regulatory changes, and its application in scenario planning to navigate sectoral sanctions, transportation disruptions, and techno-nationalist policies. Furthermore, BDA tools such as predictive analytics, risk assessment platforms, and digital twins enable MNCs to simulate geopolitical scenarios, model contingency plans, and optimize logistics under uncertainty.

The integration of BDA with complementary 4IR technologies—such as IoT, blockchain, and GIS—further strengthens MNCs' ability to monitor risks, diversify suppliers and markets, and improve local responsiveness. By systematically matching BDA capabilities to specific categories of geopolitical risk, this research offers a functional roadmap for embedding data-driven resilience into MNC strategic planning. As geopolitical complexity deepens, BDA emerges not only as a tactical tool but as a foundational pillar for long-term de-risking and global operational stability.

This research highlights the critical role that BDA and BDA-based tools play in enhancing the resilience of GVCs against geopolitical risks. By matching specific BDA capabilities with the various types of geopolitical risks, the study provides valuable guidelines for GVC management. It also suggests future adaptations of software solutions to better equip MNCs in dealing with the unpredictable and complex nature of geopolitically-driven business risks. The integration of BDA with other 4IR technologies offers a comprehensive approach to managing resource, technological, and

transportation risks, ensuring that GVCs remain robust and adaptable in an increasingly volatile global environment.

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Conflicts of Interest
The authors declare no conflicts of interest.

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