

Marija Matotek Anđelić⁵¹

Technical College of Applied Sciences in Zrenjanin, Zrenjanin/Serbia

Dušan Regodić⁵²

MB University, Belgrade/Serbia

Biljana Maljugin⁵³

Technical Faculty "Mihajlo Pupin" Zrenjanin, University of Novi Sad, Zrenjanin/Serbia

THE INFLUENCE OF CLIMATE CHANGE CHALLENGES ON SUPPLY CHAIN FLEXIBILITY

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Abstract:

Climate change poses an increasing global risk to the sustainability and competitiveness of organizations, disrupting the stability of their supply chains. These changes, such as rising global temperatures, extreme weather events, and natural disasters, can significantly impact physical infrastructure, resource availability, and human mobility. Climate risks often have a cascading effect, impacting primary, secondary, and tertiary actors within supply chains. This paper explores the multidimensional impact of climate-related risks on supply chain stability, resilience, and performance. Additionally, it proposes strategies, technological, and organizational measures to mitigate these risks, thereby contributing to long-term sustainability and operational continuity.

Keywords: Climate Change, Supply Chain Management, Risk, Resilience, Sustainability, Supply Chain Disruption, Climate Risk Mitigation

Introduction

Climate change remains a significant global risk, with "climate action failure" identified as one of the most impactful risks in the Global Risks Perception Survey (GRPS) [1]. Two-thirds of global economic activity is directly or indirectly influenced by weather conditions, exposing businesses to increasing climate-related risks. Climate change and supply chains mutually influence each other, with natural disasters exacerbating risks, while supply chains contribute to greenhouse gas emissions [2]. Current climate models predict ongoing disruptions to global supply chains due to extreme weather events such as storms, droughts, and heatwaves [3]. This makes building climate-resilient supply chains essential, as they are vulnerable to unpredictable weather events, global

⁵¹ matotek@gmail.com, ORCID: 0009-0007-0878-3133

⁵² dusanregodic5@gmail.com, ORCID: 0000-0001-6951-880X

⁵³ biljanamaljugic28@gmail.com, ORCID: 0009-0008-3326-7146

interconnectedness, and challenges in stakeholder engagement. Extreme weather events often lead to transportation disruptions, facility damage, supply shortages, and increased costs.

This paper aims to explore the impact of climate change on supply chain stability and proposes strategies to mitigate these risks, enhancing resilience and long-term sustainability within supply networks.

Defining climate risk categories

Establishing definitions is critical to any in-depth venture, and understanding the different types of climate risk is essential. Climate risk comprises two types of risk: physical and transition [4].

Physical risks arise from the physical climate (and weather) effects of a changing climate. Physical risks are classified as:

- Chronic, or longer-term shifts in climate patterns, such as sea level rise, average temperature increases over decades, glacier melting, and glacier recession
- Acute, or event-driven shifts such as cyclones, hurricanes, floods, and wildfires

Transition risks arise from the economic transformation and dislocation needed to drastically reduce, and eventually eliminate, net greenhouse gas (*GHG*) emissions and reach net-zero. Many countries have set this goal for themselves to reach by 2050. Transition risks are classified in four broad categories:

- Policy and legal risks. These risks arise from changes in government policies, regulations, and mandates on existing products and services and from reporting obligations, such as carbon pricing.
- Technology risks. These risks emerge when existing technologies become unsustainable or obsolete or when there is a demand for lower-emission products to replace existing ones.
- Market risks. These risks occur when there is a significant shift in consumer preference, such as electric vehicles or solar panels over fossil fuel-driven energy.
- Reputation risks. These risks stem from stigmatization of a sector (such as fossil fuel) and from customer perceptions that the organization is not doing enough to lower its carbon emissions and address associated negative impacts.

These four categories of risks transform into financial risks that include credit, market, operational, underwriting, and liquidity risks. This movement occurs through various macro- and microeconomic channels, including property damage, business disruption, capital depreciation, loss of income, and productivity degradation.

Research&Results

The Allianz Risk Barometer is a yearly survey by Allianz, with the latest 2024 report including 3,069 respondents from 92 countries. The survey covers a wide range of participants, including Allianz clients (large global companies), brokers, industry associations, risk consultants, underwriters, senior managers, claims professionals, and other experts in risk management [5]. The three main actions that companies are taking to mitigate the direct impact of climate change are: 1) Adapting or increasing insurance protection (incl. alternative risk transfer); 2) Adopting carbon-reducing business models (e.g., recycling and reducing waste, encouraging sustainable travel, developing more sustainable supply chains); and 3) Creating contingency plans for climate-related eventualities (e.g., response and recovery, assessing critical systems and resources). Many companies are investing in clean technologies to reduce emissions.

Building resilience goes beyond simply meeting regulatory requirements and reporting risks; it involves taking proactive steps to safeguard business assets, staff, and operations. Companies can implement resilience strategies in three main areas. Physical actions involve protecting infrastructure and assets from climate-related risks through measures like flood barriers, sea walls, and flood-resistant building materials. Nature-based solutions focus on restoring or conserving natural ecosystems to mitigate climate risks, such as using green spaces to cool the environment or unpaved areas to slow stormwater flow. Behavioral changes are also essential for effective resilience, including developing and rehearsing emergency response plans, training staff on handling extreme weather events, and educating local communities on sustainable practices.

According to the World Economic Forum's Global Risks Report, threats to the environment dominate the list for the third year in a row – both in terms of impact and likelihood. "Of all the risks, the world has most clearly entered a disaster in relation to the environment," the report

warns [6]. This report offers a unique perspective on the threats facing our world, by looking at not only those risks that are most likely, but also those that would have the biggest impact.

The report's findings are based on the annual Global Risks Perception Survey, which asks the Forum's network of business, government, civil society and thought leaders to gauge the risks facing our world.

Table 1: Top 10 business risks ranked by likelihood and by impact

Top 10 Risks by Likelihood	Top 10 Risks by Impact
1. Extreme weather events	1. Weapons of mass destruction
2. Failure of climate-change mitigation and adaptation	2. Failure of climate-change mitigation and adaptation
3. Major natural disasters	3. Extreme weather events
4. Massive incident of data theft	4. Water crisis
5. Large-scale cyberattacks	5. Major natural disasters
6. Man-made environmental damage and disasters	6. Mayor biodiversity loss and ecosystem collapse
7. Large-scale involuntary migration	7. Large-scale cyberattacks
8. Mayor biodiversity loss and ecosystem collapse	8. Brakedown of critical information infrastructure and networks
9. Water crisis	9. Man-made environmental damage and disasters
10. Asset bubbles in a mayor economy	10. Rapid and massive spread of infectious diseases

Source: Global Risk Report

The tables highlight that extreme weather events and climate-change-related risks rank high both in likelihood and impact. These risks are closely interconnected, with extreme weather events exacerbating ecological disasters, and the failure to mitigate climate change increasing supply chain vulnerabilities. Addressing these risks requires proactive adaptation and resilience strategies to ensure long-term stability.

Today, a billion-dollar extreme weather event occurs every three weeks. Four decades ago, one occurred every four months [7]. These extreme weather events can take many forms, from floods to hurricanes

to droughts. Yet, a consistent factor for all is that each makes global supply chains less reliable.

Droughts and flooding in key regions in 2023 have had a significant impact on global supply chains. Water level reductions in critical waterways have disrupted the flow of goods, while extreme flooding has caused facility damage and forced plant closures, further impacting production and supply chain operations [8],[9].

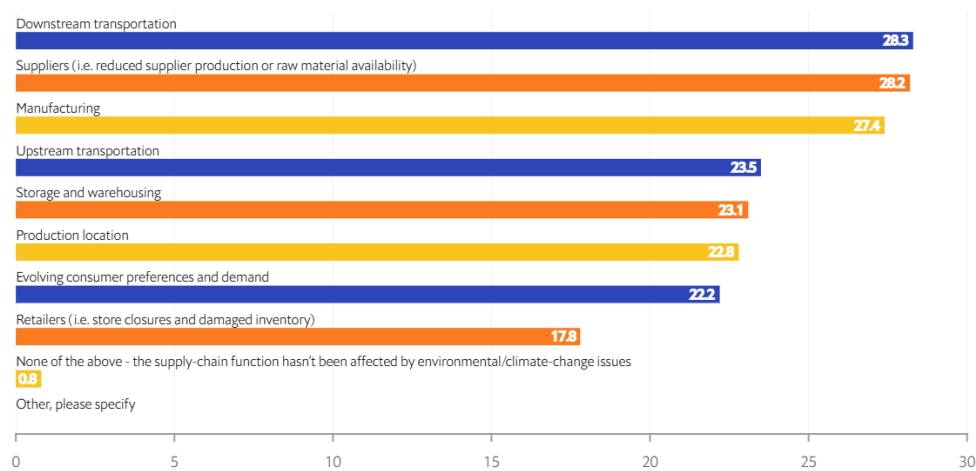


Figure 1. Part of the supply chain most impacted by climate change [10]

Source: Economist Impact

Extreme weather disruptions are expected to continue as a major risk in 2024, leading to longer delivery times, higher costs, and reduced output. The economic impact of climate change on global trade is estimated at US\$81bn, potentially rising to US\$122bn when considering related industrial and consumption activity [11]. Floods, storms, drought, and fires are all climate hazards that have already disrupted supply chains in recent years, halting production and resulting in lost revenues and profits. Drought can also impact supply chains. As climate change makes extreme weather more frequent and/or severe, it increases the annual probability of events that are more intense than manufacturing assets are constructed to withstand, and supply chain disruptions become more common.

Climate change is an external factor of the system, and its consequences directly or indirectly affect several SC performance measures such as availability of raw materials, productivity, delivery performance, order-

fulfilment rate and customer satisfaction (Figure 2). Besides the impact of climate change on physical flows in SC networks, it also leads to some economic impact for SC stakeholders.

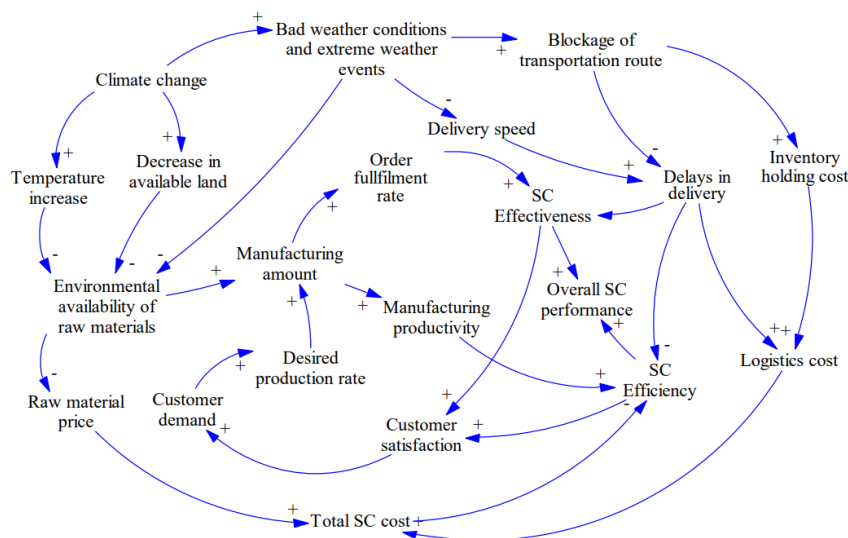


Figure 2. Causal loop diagram [12]

Source: Merve, E.K. et al. (2020) "Modelling the impact of climate change risk on SC"

Challenges

Global economic production is heavily reliant on interconnected supply chains, which contribute nearly \$20 trillion to global trade [13]. These supply chains, optimized for efficiency, are increasingly disrupted by climate change, leading to delays, higher costs, and shortages. As climate-related risks grow, businesses face financial pressures, including managing transition risks and regulatory compliance costs. Physical damage and operational disruptions are key concerns due to their potential impact on profitability. Environmental issues like extreme temperatures, water scarcity, and biodiversity loss further exacerbate risks [5],[14].

To address these challenges, companies can implement both technical and operational strategies. Technological solutions include the use of AI and IoT for risk monitoring, renewable energy for improved energy efficiency, and nature-based solutions like ecosystem restoration. Operationally, diversifying supply chains and production locations,

adopting sustainable models, and training employees for climate-related crises are critical. Additionally, resource-saving strategies, such as water recycling and waste reduction, enhance resilience and contribute to sustainability. Managing climate change transition risks, such as decarbonization, is also crucial as regulations and reporting requirements rise [5].

Conclusion

In the short-term, diversification of supply chains will be crucial if companies want to increase resilience against extreme weather events. Focusing production or transportation within a single region or country will leave companies without adequate protection. Diversifying locations and suppliers will help ensure that companies have the necessary redundancy capabilities to withstand disruptions caused by climate change. Effective monitoring of extreme weather events is also a necessity. Technology is pivotal to this. The Internet of Things, where connected devices are able to communicate through sensors and software, can help increase resilience through monitoring. Next-generation artificial intelligence can also be used for predictive modelling and real-time monitoring, allowing companies to get valuable insights into their supply chain and identify potential risks in advance.

Surveys found that 98% of companies are using artificial intelligence (AI) in at least one supply-chain activity, such as forecasting demand or optimising inventories. Their ability to harness the benefits of AI needs to be broadened to enhance their ability to monitor and predict extreme weather patterns. The cost of not accounting for the impact of extreme weather is consequential for businesses. The first stage is to make it a more central part of supply-chain strategies. This may prompt a redesign of supply-chain networks and greater use of advanced technologies. Doing so would benefit businesses' short-term and long-term resilience.

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