Logistics in a +2°C world

A call for shippers and logistics service providers to accelerate efforts to strengthen the climate-resilience of global supply chains

Hamburg, May 2025

CLIMATE CENTER

Kühne Foundation and Kuehne Climate Center

The Kühne Foundation is a family-owned operational foundation and primarily implements its own projects and programs. It works in four main areas: logistics, medicine, culture, and climate. The Kuehne Climate Center, which started operations in 2023, develops and implements logistics-oriented solutions that reduce emissions, remove CO_2 from the atmosphere, and strengthen climate resilience to drive the transition to a just, low-carbon society, primarily in low- and middle-income regions.

Authors
Sophie t'Serstevens and Mark Major,
Kuehne Climate Center

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Foreword

Supply chains are disrupted everywhere, all the time. Wildfires, cyberattacks, floods, power blackouts, storms, strikes, tariffs—we can add a new event to the list every week. Add to the mix the growing geopolitical instability, and we have a perfect storm.

Since COVID, companies have shifted their attention to better protect themselves from future supply chain disruptions, and the topic has not gone away since.

Manufacturing companies and retailers—also called shippers or freight buyers—often resort to reconfiguring their global supply chains, for example, by keeping inventory buffers, nearshoring, and diversifying sources and manufacturing bases.

Logistics service providers (LSPs) have further refined their role as troubleshooters. They try to better anticipate disruptions anywhere in their logistics network, and respond swiftly by retiming deliveries, rerouting, or using backup suppliers. Technological innovations have also come to the rescue: Digital twins of global supply chains combined with analytical tools and artificial intelligence (AI) helps both shippers and LSPs to improve resilience, efficiency, and decision-making.

However, something important is being overlooked: these strategies only work around the problem. Solving the problem entails investing in making logistics infrastructure, operations, and the workforce more resilient from the outset.

There are three reasons to do things differently. 1) Current strategies are insufficient to face extreme climate change, now and in the decades ahead. 2) They ignore our dependence on various materials and products from few locations—think about coffee, cocoa or copper. And 3) we're aggravating the loss of livelihoods of local communities, the financial burden of companies, and the cost of living for consumers.

This white paper builds the business case to take supply chain resilience to that next level, and calls on shippers and LSPs to act now, as it is in their economic interest too.

This is also where Life-Links comes in. As a global nongovernmental organization (NGO) co-founded with the Kuehne Climate Center, we aim to build truly resilient supply chains, with a focus on the logistics links that connect producers with consumers. By uniting shippers, LSPs, and other stakeholders to co-invest in concrete solutions that keep our supply chains "alive," we improve resilience and can reduce emissions too.

Together we can build resilient supply chains for good.

Sophie Punte
Co-founder and CEO, Life-Links
Founder and Board member,
Smart Freight Centre

Executive summary

Climate change poses a growing threat to logistics systems worldwide. Shifting weather patterns and more frequent extreme events are damaging **logistics infrastructure**. By 2035, the average listed infrastructure and transportation company is projected to incur annual fixed asset losses of USD 50–53 million due to climate hazards—equivalent to about 7% of earnings.

While images of destroyed infrastructure—such as washed-out roads or collapsed warehouses—often dominate the narrative, the impacts of climate change on logistics systems extend well beyond physical losses. Climate hazards can interrupt infrastructure services, whether through direct damage or temporary shutdowns, and significantly disrupt **logistics operations**. For example, storms can force port closures for several days, resulting in vessel backlogs and cascading impacts throughout supply chains. Even preventive measures in response to unusual weather—such as weight restrictions on aircraft or reduced train speeds during extreme heat—can cause delays and operational inefficiencies.

Beyond infrastructure and operations, the **logistics workforce**—much of it working outdoors—is also exposed to climate hazards. Extreme weather events pose growing risks to workers' health and safety. High temperatures, for example, put workers at risk of heat exhaustion and heatstroke.

These risks present rising operational, financial, and reputational challenges for both **shippers and logistics service providers (LSPs)**—who are responsible for defining and fulfilling freight service requirements. For shippers, climate disruptions and inefficiencies can lead to stockouts, production shutdowns, lost sales, and reduced customer trust. For LSPs, the impacts can include damage to assets, increased operational costs, and reputational harm. Small and medium-sized LSPs are particularly vulnerable, facing potentially existential threats from localized extreme events. While both shippers and LSPs stand to incur losses, the effects also ripple across supply chains, ultimately influencing product availability and consumer prices.

Despite the increasing risks, efforts to **adapt to climate change and build resilience** in the logistics sector remain inadequate—namely among shippers and LSPs. Shippers often overlook the logistics dimension in their adaptation strategies, typically focusing more on sourcing and production. LSPs tend to rely on conventional contingency and business continuity planning, operating under the assumption that risks will remain within historical boundaries. A more transformational approach is needed.

This paper calls on shippers and LSPs to step up adaptation efforts and help strengthen the climate-resilience of supply chains. These efforts should focus on three key areas of investment:

— **Conducting climate risk assessments** across supply chains and logistics networks to identify key vulnerabilities in infrastructure, operations, and workforce. A forward-looking approach—leveraging climate projections and advanced analytics—is essential. Embedding these assessments within the companies' broader risk management framework ensures they are addressed alongside other risks.

- **Investing in best-in-class operational resilience** by strengthening planning and response capabilities to proactively anticipate and manage climate hazards. This includes "generic" resilience best practices, such as integrating scenario planning into core processes, deploying tools for enhanced network visibility, subscribing to early warning systems, and maintaining up-to-date emergency response protocols.
- **Strengthening the physical resilience of critical infrastructure**. For self-owned infrastructure, climate-proofing measures can be integrated directly into companies' master plans; for third-party infrastructure, collaboration with assets owners—either directly or via industry associations—to share practical insights and develop business cases for adaptation investments is the way to go.

Shippers and LSPs manage day-to-day logistics and connect the dots across complex networks. They hold both operational and economic levers to drive change. Climate adaptation is not only essential to sustaining their business and gaining competitive advantage—it is also critical to ensuring reliable supply chains for society at large.

Adaptation needs to happen alongside decarbonization and responses to other systemic changes. Done well, these efforts can reinforce each other and help create more sustainable, future-ready logistics systems. Delaying action will only increase costs for both businesses and society.

Content

1 Introduction

Logistics systems enable the movement of goods and related information from producers to consumers, forward and reverse, within and across countries and continents.[1] They include infrastructure and assets, regulations, processes and tools, and of course companies and people. They support trade and ensure the timely delivery of essential items—from food and medicine to construction materials and spare parts. Efficient logistics systems underpin economic stability, social well-being, and the functioning of modern society.

Climate change presents significant and growing risks for logistics systems worldwide. Shifting weather patterns and more frequent extreme events—such as storms, floods, and heatwaves—damage logistics infrastructure and disrupt operations. Studies estimate that 27% of road and rail infrastructure, globally, is exposed to at least one natural hazard [2] and 86% of ports to more than three.[3] Although comprehensive data for inland waterways is lacking, recent droughts in the Panama Canal (2023–2024), the Rhine (2022), and the Yangtze (2022) highlight their growing exposure too. Warehouses are also at risk: a study in the UK found them to be among the most climate-vulnerable types of commercial buildings.[4]

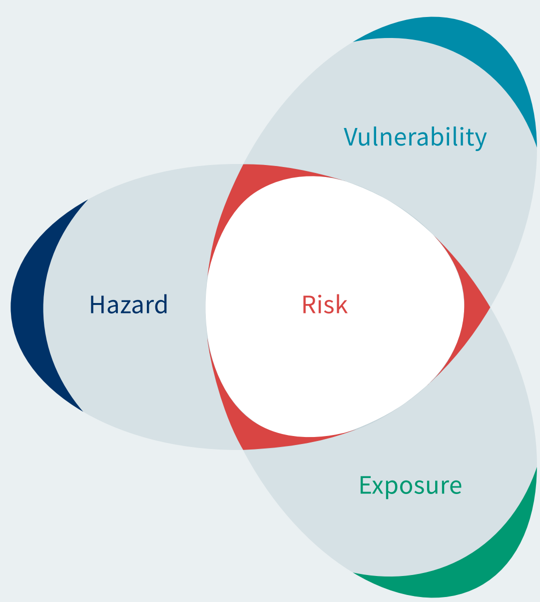
Logistics systems have several inherent vulnerabilities. Many critical assets, including ports, airports, and railways, are in low-lying areas that are particularly prone to flooding. The linear

Box 1. **Some definitions**[6]

A climate risk arises from the interactions between hazards, exposure, and vulnerability.

- **A hazard** is the potential occurrence of a physical event or trend that may cause harm to societies and ecosystems.
- **Exposure** is the presence of people, species, infrastructure, and other valuable assets in places that could be adversely affected by a hazard.
- **Vulnerability** is the propensity or predisposition to be adversely affected by a hazard.

Adaptation means reducing climate risks by addressing exposure and vulnerability.



nature of logistics networks means that damage to a single point—like a bridge or road segment—could cause cascading disruptions across the entire system. Additionally, because much of the logistics work occurs outdoors, operations are directly exposed to weather conditions.

In response to growing climate risks, the logistics sector must build resilience and adapt. While often used interchangeably, adaptation refers to the *process* of driving change to reduce the harm caused by climate hazards, whereas resilience is the *ability* to withstand and recover from these hazards [5] (see Box 1 for additional information).

Climate adaptation in the logistics sector requires greater attention

A review of over 8.000 articles and papers published in specialized logistics journals and media between 2015 and 2023 revealed that less than 1% explicitly address climate adaptation. This suggests a gap in research and awareness in the sector about the topic. A parallel review of publicly available corporate documents from 10 major logistics service providers (LSPs) and shippers showed a similar pattern: while climate mitigation efforts were often described in detail, adaptation received little to no attention. Among the shippers analyzed, none addressed logistics within their adaptation strategies. When LSPs mentioned adaptation, the focus was largely on acute hazards while chronic or slow-onset events were rarely considered. Only two companies viewed climate change as an immediate threat.

There has been some focus on adapting major infrastructure, particularly where owners, operators, and investors have a clear interest and financial incentives to act. Yet even with these efforts, the risks remain considerable: at current trajectories, the average listed infrastructure and transportation company is expected to face fixed asset losses from climate hazards of USD 50–53 million per year by 2035, equivalent to about 7% of their earnings.[7] These losses are expected to rise to USD 66–85 million annually by 2055.

At the national policy level, only 43% of Nationally Determined Contributions (NDCs)—plans for reducing emissions and adapting to climate change—include transport-related adaptation measures, [8] and fewer than 6% specify measurable targets. [9] This limits the policy momentum needed to drive systemic change.

The sector can build on its resilience capabilities

This does not mean that the issue of logistics adaptation is ignored. Resilience has long been a core focus in logistics, and natural hazards are frequently considered in enterprise risk management and business continuity planning. Disruption management is, in many ways, a defining responsibility of logistics professionals. However, the scale and frequency of climate disruptions are growing rapidly, and current efforts are inadequate. Many companies continue to prioritize cost-efficiency and delivery speed, assuming logistics disruptions will remain within the boundaries of previous experiences—an increasingly risky bet.

The challenge lies not only in giving resilience the extra attention it deserves, but also in addressing it with the necessary scope. Many companies adopt a narrow view of climate risks, focusing primarily on their direct operations and failing to take a broader supply chain perspective. [10] For those with supply chains extending into low- and middle-income countries, this neglects regions where logistics systems are particularly vulnerable to climate hazards, largely due to the prevalence of small and informal LSPs who lack the necessary resources to build climate resilience.

Shippers and LSPs are key to driving change

Shippers and LSPs are central to driving change. Shippers define freight service requirements and LSPs fulfill them. Together, they hold important operational and economic levers to build more climate-resilient logistics systems. They can strengthen resilience within their own supply chains and networks, where they have control. They can also influence sector-level discussions by sharing practical insights with infrastructure owners, government bodies, and the wider ecosystem, and help shape the business case for adaptation projects.

Shippers and LSPs also stand to lose significantly. For shippers, climate disruptions can translate into stockouts, production shutdowns, lost sales, and reduced customer trust. For LSPs, they can damage assets, increase operational costs, and pose reputational risks.

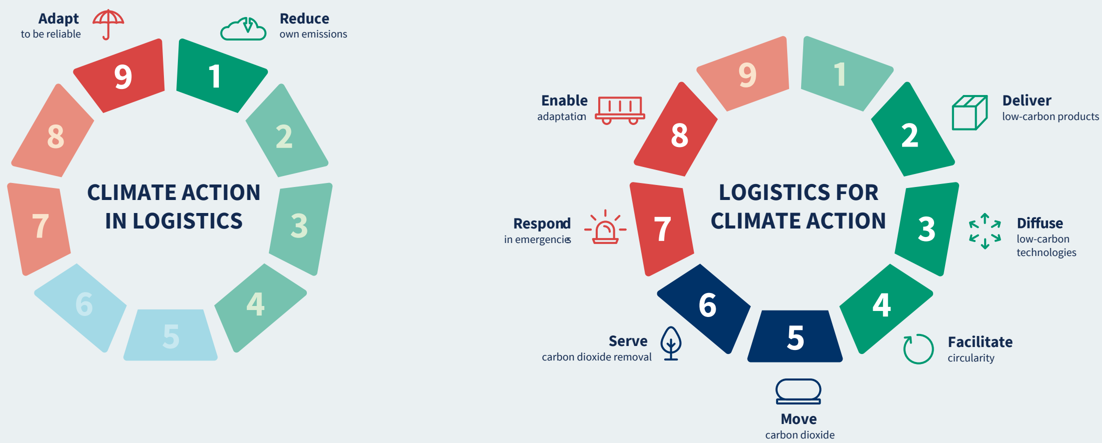
This paper therefore is directed at shippers and LSPs. It aims to raise awareness of how climate change threatens logistics systems—focusing on physical climate risks and their direct impacts expected over the next 15–20 years—and serves as a call to action for shippers and LSPs to strengthen their resilience efforts and advance climate adaptation in logistics, both as a climate imperative and a business necessity. It is structured as follows:

- Chapter 1 explores the climate risks facing logistics systems, focusing on infrastructure, operations, and workforce.
- Chapter 2 presents solutions to build resilience and adapt to these risks.
- Chapter 3 outlines key actions for shippers and LSPs to drive change.

As global temperatures continue to rise—potentially reaching 2°C as early as 2040—climate risks will intensify. Rapid transformation will be essential to ensure logistics systems remain reliable and able to support a low-carbon society (see Box 2).

Figure 1: The nine contributions of logistics to a low-carbon society

Source: KCC



Box 2. **The multiple contributions of logistics to a low-carbon society**

Logistics systems are key to the successful transition to a low-carbon society: they must reduce their own emissions and adapt to climate change (climate action in logistics), while also enabling broader societal transformations (logistics for climate action) (see Figure 1).

Climate action in logistics requires the provision of climate-compatible services to reduce (1) logistics emissions (by relying on different modes, different fuels, different business models etc.) and to **adapt** (9) logistics infrastructure and operations to function reliably and efficiently in a changing climate.

Logistics for climate action involves meeting the new needs of other parts of the economy that are also undergoing profound transformations toward a low-carbon future. Logistics needs to **deliver** (2) new flows of low-carbon products (like green steel or wood for construction) and **diffuse** (3) the low-carbon technologies (like solar panels or batteries) that will be required at scale.

Logistics also has a key role to **facilitate** (4) the circular economy that can reduce material use. Carbon dioxide removal (CDR) will be needed at scale to stabilize the climate, and logistics will need to **move** (5) carbon dioxide for storage and use. Logistics will also need to **serve** (6) the needs of the growing CDR industry, for example moving minerals for enhanced rock weathering that increases carbon sequestration and quality of agricultural land.

However quickly society adapts to climate change, there will be an increase in emergencies caused by extreme weather events. Logistics must be able to **respond** (7) to these emergencies. Finally, logistics needs to **enable** (8) the adaptation of all other sectors of the economy such as the construction of sea defenses or relocation of facilities.

While this paper focuses on adapting logistics systems, it is important to recognize that this task must be pursued alongside the eight other key contributions to the climate transition, while also responding to broader societal shifts such as demographic change and evolving global trade dynamics.

1 The diagnosis – How climate hazards affect logistics systems

The world could reach 2°C by 2040

Since 1970, the world has warmed at an unprecedented rate, faster than for any other 50-year period over at least the last 2,000 years.[11] The years from 2015 to 2024 were the warmest 10 years on record, and in 2024, the global average temperature exceeded 1.5°C above pre-industrial levels for the first time.12

With global temperatures increasing by more than 0.2°C per decade, Copernicus, the EU's Earth observation program, estimates **that exceeding the Paris Agreement's 1.5°C target is highly likely within the 2030s**.[12] This aligns with the Intergovernmental Panel on Climate Change (IPCC) projections (see Box 3), which suggest that surpassing 1.5°C is *more likely than not* to *very likely* in the near term (2021–2040) across a range of emissions scenarios, from very low to very high[11] (see Table 1).

Table 1: Changes in global surface temperature for selected 20-year time periods for very low, intermediate, and very high emissions scenarios

IPCC emissions scenario	Expected warming for 2021-2040	Expected warming for 2041-2060	Expected warming for 2081-2100
Very low	1.5°C	1.6°C	1.4°C
Intermediate	1.5°C	2.0°C	2.7°C
Very high	1.6°C	2.4°C	4.4°C

Source: IPCC AR6 WGI, SPM

Looking ahead to the target of limiting warming to well below 2°C, the IPCC estimates that exceeding 2°C during the mid-term period (2041–2060) is *more likely than not* to *very likely* under intermediate to very high greenhouse gas emissions scenarios[11] (see Table 1). **Recent research further indicates a high probability of reaching 2°C by 2040** (or earlier) in nearly all regions of the world,[13] suggesting the world may be on a faster trajectory toward this concerning milestone.

Box 3. **About the Intergovernmental Panel on Climate Change (IPCC)**

The IPCC is the United Nations (UN) body responsible for assessing climate science. It synthesizes research to reflect the global scientific consensus on climate change. The IPCC does not conduct its own research but rigorously reviews existing studies and provides policymakers with science-based insights that shape global climate action.

Gradual climate shifts are underway

With every additional increment of global warming, changes in the climate system will become more pronounced. **Temperatures** will rise across the globe, with greater warming over land than oceans, particularly in certain regions. **Precipitation** will also increase globally, though some regions will experience decreases. Precipitation will become more variable too, both seasonally and annually. Changes in **soil moisture** will largely follow changes in precipitation and may further exacerbate temperature increases locally. **Oceans** will continue to warm and expand, contributing to **sea level rise. Land ice** (like glaciers and ice sheets) and **sea ice** will melt, with the melting of land ice further contributing to sea level rise. **Permafrost thaw** will accelerate.[10]

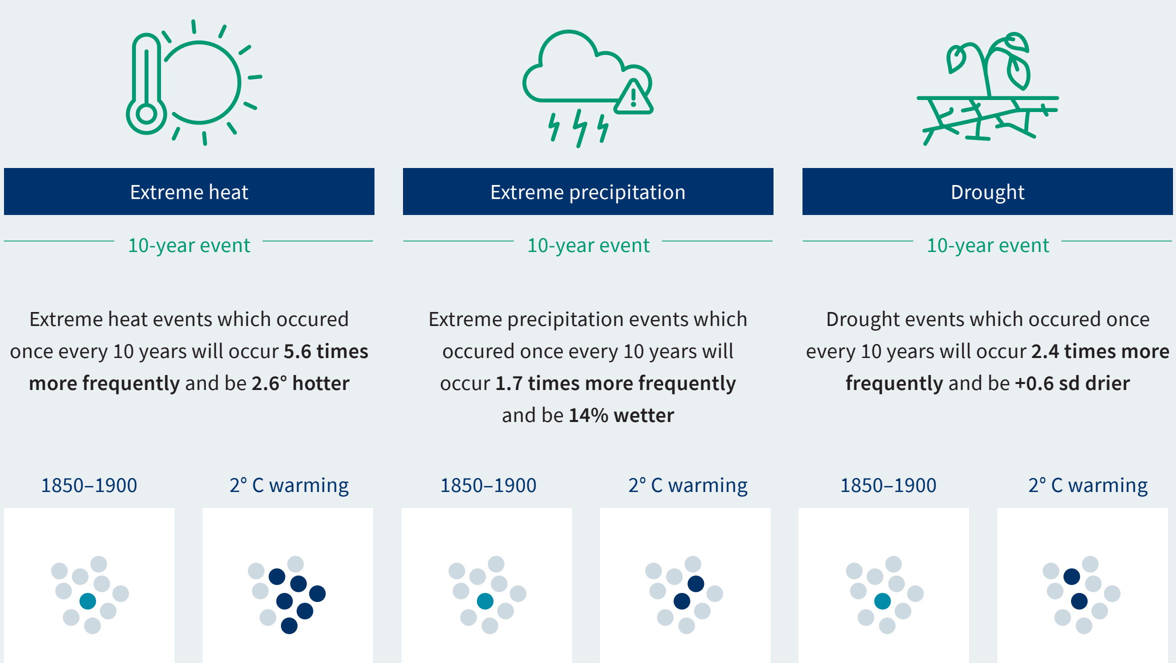
These are just some of the gradual processes driven by global warming. However, it is now clear that many of the impacts caused by climate change will result from sudden and acute shocks, namely with extreme weather events. [14]

Extreme weather events are increasing in intensity and frequency

Climate change has already increased the intensity and frequency of **extreme heat and precipitation events** at global scale and in most regions of the world. With every additional increment of global warming, the intensity and frequency of these extremes will increase further. The same trend applies to **droughts, floods,** and **cyclones**. [11]

The IPCC provides **quantitative projections of such extreme events under a 2°C warming scenario.** For example, extreme heat events which occurred only once per decade at pre-industrial times are expected to be 5.6 times more frequent and 2.6°C hotter on average. [11] Figure 2 also illustrates similar data points for extreme precipitation and drought events.

Figure 2: Projected changes in the intensity and frequency of extreme heat events, extreme precipitation events, and droughts



sd = standard deviations

Source: IPCC AR6 WGI, SPM

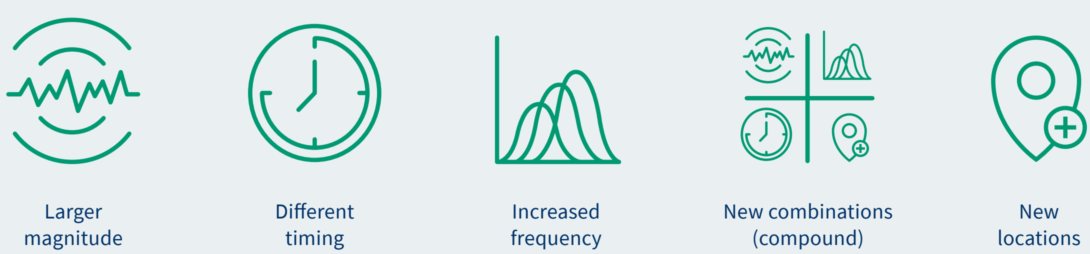
The frequency of **extreme sea level events** will also increase due to the combined effects of sea level rise and storm surges, leading to greater coastal flooding and erosion in low-lying areas. The IPCC projects that extreme sea level events, which historically occurred once per century, will happen at least annually at over half of all tide gauge locations by 2100. [11]

Beyond their increasing **intensity and frequency**, extreme events will also shift in **timing and location** and emerge in seasons and regions where they were never previously recorded. Additionally, climate change will drive **compound extreme events**, where multiple extreme conditions occur simultaneously. For example, the combination of heat, drought, and high winds escalates wildfire risk, while coastal flooding may result from the interplay of storm surges and extreme rainfall. [15]

Both gradual shifts and extreme events threaten logistics systems

To frame risk and impact assessments, the IPCC identified 35 **climatic impact-drivers (CIDs)**—climate-related conditions that influence natural and human systems. These include long-term averages (e.g., mean temperature and precipitation), common events (e.g., frost and thaw), and extreme events (e.g., coastal flooding and cyclones). The CIDs are grouped into seven intuitive categories: **heat and cold, wet and dry, wind, snow and ice, coastal, open ocean**, and a seventh category **"other"** for drivers that do not fit elsewhere. [16]

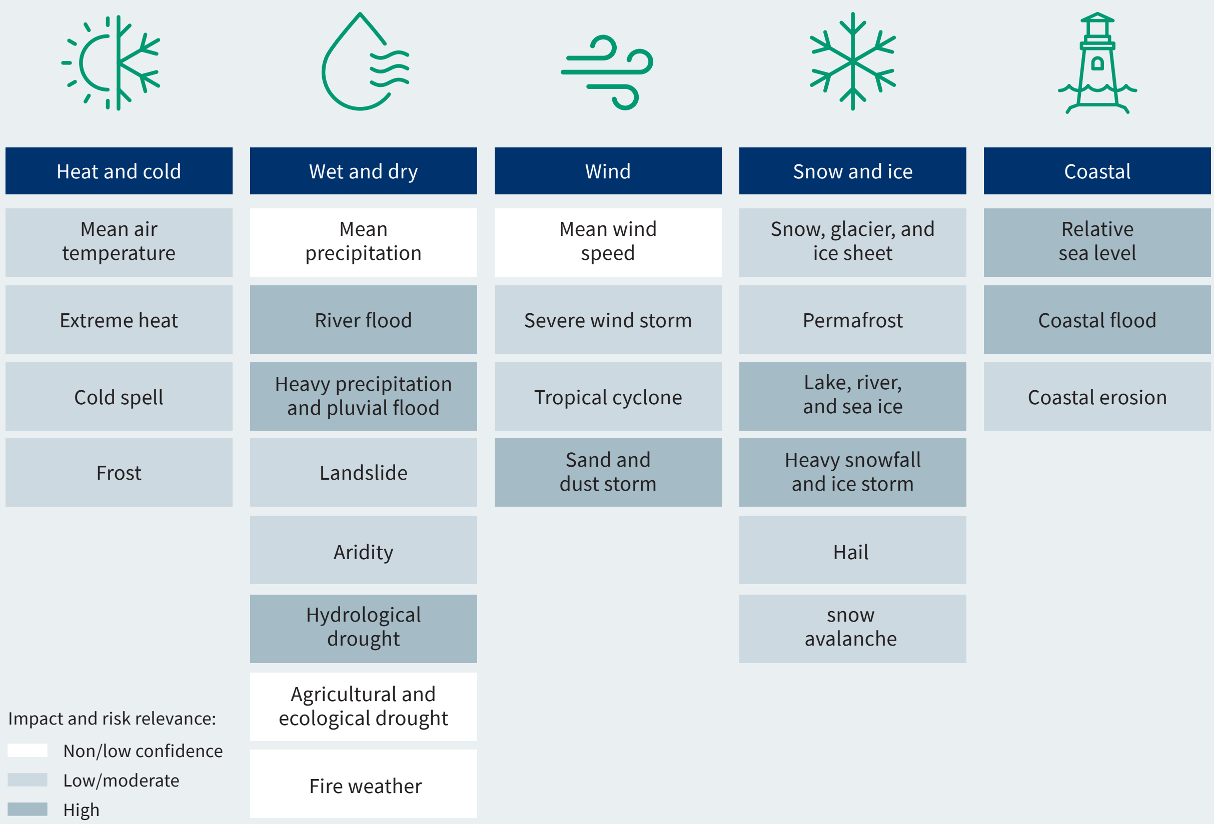
The IPCC analyzed how these drivers affect land and water transport (see Figure 3). While logistics systems encompass more than just land and water transport, the assessment illustrates the wide range of climate hazards they face.



Extreme events will not only be unprecedented in their frequency and intensity, but also in their timing, location, and the combination of these dimensions.

Source: IPCC AR6 WGI, Chapter 11

Figure 3: Relevant climatic impact-drivers for land and water transport



Source: IPCC AR6 WGI, Chapter 12

The following paragraphs explore how climate hazards affect logistics systems, with a focus on **infrastructure, operations, and workforce**—the key elements exposed. While risks to infrastructure receive some attention, particularly from investors, operators, and insurers, the risks to operations and workforce fall outside the spotlight. This paper does not attempt to catalogue every potential risk—such a list would be too extensive—but rather to present a broad overview that highlights the scope, significance, and urgency of the challenges climate change poses to logistics systems.

Although the focus here is on direct physical risks, climate change can also indirectly disrupt logistics systems by exacerbating social and geopolitical tensions, including factors like cost-of-living crises, political instability, and conflicts. These and other indirect risks such as pandemics and large-scale migration fall outside the scope of this paper but further underscore the need to strengthen resilience across logistics systems.

A. Logistics infrastructure

When assessing the risks of climate change on logistics systems, infrastructure damage is often the first concern. Images of destroyed assets, like roads and ports, leave a lasting impression, and extensive research highlights the risks posed by extreme weather events. Heat and cold, wet and dry, wind, snow and ice, and coastal CID categories are all relevant to logistics infrastructure risks.

Heat and cold. Extreme heat can warp and accelerate the degradation of roads and airport runways. It can also expand and deform rail tracks, thereby increasing the risk of derailments. On the other side, extreme cold and changes in freeze—thaw cycles cause roads, airport runways, and railways to deteriorate.

Wet and dry. Changes in rainfall patterns are expected to affect embankments and earthworks, like road and rail beds, through erosion and landslides for example. This can cause significant damage to roads and railways. Additionally, heavy precipitation leading to higher river flows will increase the risk of bridge scour and compromise bridge integrity.

Wind. Bridges can be vulnerable to severe winds, which may cause structural damage and, in extreme cases, when wind speeds exceed design thresholds, lead to collapse. Warehouses and other storage facilities are also at risk, as high winds may tear off roofs or destabilize structures.

In certain contexts, wind also causes gravel loss from infrastructure, such as roads, leading to accelerated deterioration and premature failure.

Snow and ice. While snow and ice conditions are expected to decline overall, they will start occurring in unexpected places. This can pose risks to infrastructure unprepared for such conditions. Heavy snow accumulation can overload the roofs of warehouses and other structures, potentially leading to collapse.

Coastal. Coastal flooding, driven by rising sea levels and storm surges, can severely damage seaports as well as coastal roads, bridges, and railways. Repeated saltwater inundation also accelerates corrosion and may undercut coastal roads, bridges, and railways.

The direct impacts of these risks are clear: **higher repair and maintenance costs** for damaged infrastructure, along with **potential financial losses** in cases where the infrastructure is beyond repair. While shippers and LSPs typically do not bear these costs—since they own little infrastructure—they still experience the consequences through **disruptions and inefficiencies**, discussed in the following section.

In July 2021, extreme rainfall triggered flooding in western Germany, which caused extensive damage to roads and railways, with repair costs estimated at EUR 2 billion. Over 130 km of motorways were closed, some for months, and 62 of 112 bridges in the hardest-hit area were destroyed, with only half restored within a month. The German railway network also suffered significant damage, with 600 km of tracks destroyed. While some repairs were completed within months, the most severely affected sections were expected to take until 2025 to fully restore. [17] Although the specific cost of this disruption has not been published, annual transport disruptions caused by extreme weather across the European Union are estimated at EUR 2.5 billion. [18]

B. Logistics operations

The climate risks to infrastructure as previously described have cascading impacts on logistics operations. Damage to infrastructure and increased repair and maintenance work can render certain segments or nodes across a logistics network inaccessible, causing short- or long-term disruptions and inefficiencies. While the examples covered previously focus on core logistics infrastructure, climate hazards can also affect supporting systems such as energy grids and telecommunications networks, causing further disruptions and inefficiencies.

Not all operational disruptions stem from physical damage of infrastructure. The heat and cold, wet and dry, wind, snow and ice, and coastal CIDs can also directly affect logistics operations—even when infrastructure remains intact.

Heat and cold. Extreme heat can require slowing trains to prevent derailments, suspending crane operations at ports to avoid overheating and technical failures, and imposing weight restrictions on planes due to reduced lift. Prolonged exposure to high temperatures can damage temperature-sensitive inventories and cargo when adequate cooling is not in place. Higher temperatures will also increase the need for cooling, requiring more refrigeration and longer running times.

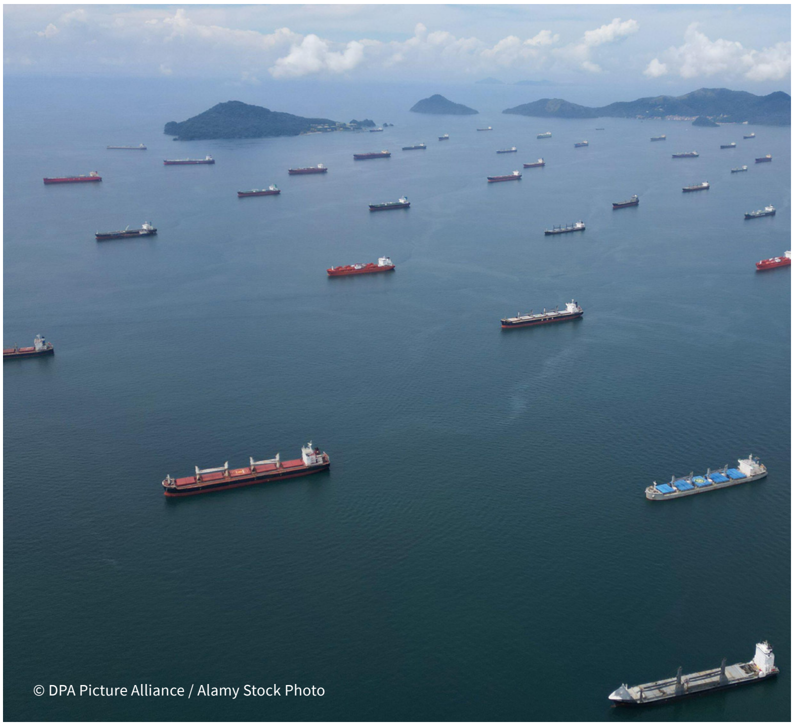
Wet and dry. Heavy precipitation can flood roads and railways, making them temporarily impassable. It can also inundate warehouses and port terminals, causing damage to inventories and cargo as well as operational shutdowns. It can raise the water levels of inland waterways beyond navigable limits. Conversely, droughts can result in critically low water levels, leading to restrictions on navigation services.

Wind. Crosswinds can delay takeoff and landing, while severe winds can ground aircraft entirely. In seaports, high winds can force crane operations to halt for safety reasons. On roads, they can make driving hazardous, especially for high-sided vehicles, and lead to temporary route closures.

Snow and ice. A decline in snow and ice may bring some benefits, such as longer shipping seasons in northern latitudes and the potential opening of Arctic sea routes. However, snow and ice will continue to affect logistics operations—especially in areas unaccustomed to such conditions. Accumulation can temporarily close airports and roads or delay activities at warehouses. Additionally, reduced glacier and snowmelt may increase the frequency of low-water events, limiting the navigability of certain inland waterways.

Coastal. Coastal flooding and storm surges can inundate seaports and force temporary port closures. They can also render coastal roads and railways inaccessible.

These operational disruptions and inefficiencies imply real business consequences for shippers and LSPs. For LSPs, they can **increase operational costs and delay deliveries**. While temporary capacity shortages might allow some providers to raise prices in times of disruption, these short-term gains are unsustainable as shippers grow more demanding and risk sensitive. For shippers, disruptions can translate into **stockouts, production shutdowns, and lost sales**. Unprepared shippers and LSPs may both also suffer **brand degradation** and lose their position within their respective markets compared to more resilient competitors.



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Severe droughts in Panama—driven by a combination of El Niño and climate change—made 2023 the second driest year on record, leading to historically low water levels in Gatun Lake, the Panama Canal's main water source. In response, the Panama Canal Authority restricted ship traffic in July 2023, creating a bottleneck and causing major disruptions to global shipping. These restrictions remained in place for a year and vessel transits dropped by 29% over fiscal year 2024. [19] Rerouting ships away from the canal is estimated to raise total ocean transport costs for affected trade by 5% and slow journeys by 20%. [20]

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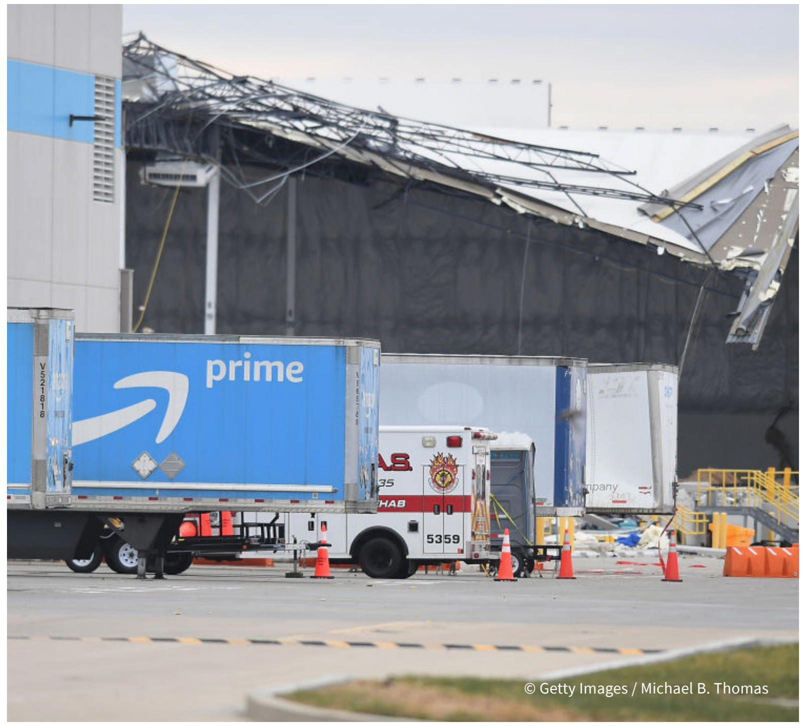
In Uganda's Mount Elgon region, damage to transport infrastructure, such as roads and bridges, is common during the rainy season. This risk has increased due to higher rainfall and flash floods observed over the last 10 to 15 years. Even when infrastructure remains intact, many roads—mostly unpaved—become impassable during and following periods of heavy rainfall. These conditions reduce access to markets, deteriorate the quality of produce transported (notably the region's renowned coffee), and raise transportation costs. High poverty levels limit communities' ability to adapt. As a result, exporters face reduced availability of high-quality coffee, and supply volatility may ultimately lead to higher prices for consumers. [21]

A distribution center in Illinois, USA, was severely damaged by a tornado in December 2021, resulting in the collapse of a wall and part of the roof. Six warehouse workers tragically lost their lives in the event. [22]



C. Logistics workforce

Climate change also carries risks for the logistics workforce, which is largely exposed to outdoor conditions. While most literature focuses on the impact of heat and heatwaves, which falls under the heat and cold CID category, other CID categories can also pose significant challenges.

Heat and cold. High temperatures put workers at risk of heat exhaustion and heatstroke. They can also cause fatigue and increase the likelihood of errors—some of which may lead to injury or even death. In the logistics sector, truck drivers, dock workers, and warehouse staff are among the most vulnerable to these heat-related dangers.

Other CIDs. More frequent storms and floodings increase accident risks for truck drivers. Extreme weather may also compromise warehousestructures, posing injury risks to workers. At sea, seafarers face various safety hazards during severe weather, including ship motion and exposure to the elements while working on open decks.

These hazards not only pose serious threats to worker health and safety but also carry operational and business consequences. Injuries or unsafe conditions can lead to slower workflows, increased error rates, and in some cases, full operational shutdowns. For LSPs, this means **lost productivity, potential delays, and rising costs** linked to worker protection, insurance, or incident recovery. For shippers, this implies **reduced service quality**, which in turn can affect their operations and **market position**.

As logistics roles are already physically demanding and often viewed as unattractive—especially in areas like long-haul trucking and port operations—climate impacts may deepen existing **labor shortages**.

2 Building resilience – Cost-effective solutions are within reach

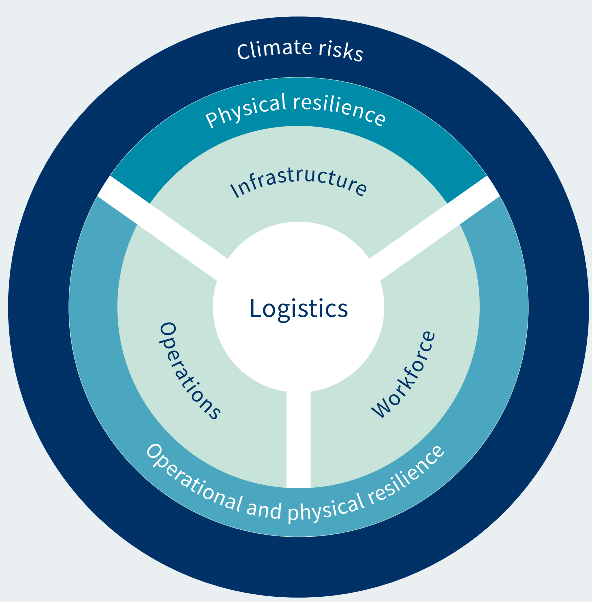
A wide range of solutions can strengthen resilience and enable adaptation

While climate risks are numerous, so are the solutions. A range of practical measures can help build resilience—and safeguard logistics infrastructure, operations, and workforce.

A. Logistics infrastructure

Infrastructure can be strengthened to withstand shifting weather patterns and extreme events through a range of engineering measures—such as reinforcing foundations, adding design redundancies, using appropriate materials, and installing protective systems. Regular inspections and maintenance also help preserve its integrity. Additionally, infrastructure can be relocated from high-risk areas or, ideally, not built in such zones at all. In essence, these measures help build **physical resilience** (see Figure 4).

Figure 4: Physical and operational resilience to protect logistics infrastructure, operations, and workforce



Network Rail, which owns and operates the majority of the UK's railway network, employs a range of measures to prevent rail buckling during high temperatures. Each winter, teams assess track stability and reinforce weak sections ahead of the summer. In areas with short rails bolted together, small gaps are left between sections to accommodate thermal expansion. When necessary, certain rails are painted white to reduce heat absorption, keeping them 5°C to 10°C cooler than if untreated. Additionally, temperature sensors installed on the tracks monitor heat levels in real time and enable proactive action. [23]

© Network Rail

Heat and cold. Improved bitumen can withstand higher temperatures and reduce the risk of road degradation. Rail tracks can be painted white to minimize heat absorption and the associated risk of buckling. Regular inspections of road- and railbeds can help drive early maintenance actions and prevent serious freeze-thaw damage.

Wet and dry. Embankments and earth-works can be stabilized with vegetation to reduce the risk of erosion and landslides. Bridges can be inspected after floods, and in cases of scour, necessary reinforcement work (e.g., with riprap) can be initiated to maintain structural integrity.

Wind. The design thresholds of bridges can be reassessed to withstand higher wind speeds. Warehouses, cargo terminals and other logistics facilities can be strengthened, in terms of materials and structure, to improve storm resistance. Regular inspection and maintenance work also play a role.

Snow and ice. The roofs of logistics facilities can be reinforced to withstand increased snow loads, namely with design adjustments such as steeper pitches and more resistant materials. Pre-winter inspections to identify issues early or snow removal plans can also help reduce the risk of roof collapse or structural damage due to snow accumulation.

Coastal. Coastal infrastructure can be protected through nature-based solutions like mangroves, or engineered defenses like dikes and levees. Specialized coatings help prevent corrosion from repeated saltwater exposure. In some cases, moving infrastructure to less exposed areas may be the most viable long-term option.

B. Logistics operations

Physical resilience is not only about preventing infrastructure damage, but also about ensuring the continuity of infrastructure services under hazardous conditions—thereby protecting logistics operations. At the network level, physical resilience implies sufficient redundancy (e.g., alternative routes) to maintain functionality if one part of the system is disrupted.

In addition to physical resilience, **operational resilience** (see Figure 4) plays a crucial role in protecting operations. Operational resilience focuses on the "soft" capabilities—people, processes, and systems—that enable companies to anticipate and effectively respond to disruptions.

Heat and cold. To avoid weight restrictions on very hot days, heavier flights can be rescheduled to cooler times, such as early morning or late evening. Runways can also be extended where feasible. Cranes can be upgraded with enhanced cooling systems and heat-resistant components to maintain functionality in high temperatures. Likewise, logistics facilities can be equipped with temperature-control systems to protect inventory from heat damage.

Wet and dry. Infrastructure such as roads, railways, airports, and warehouses relies on effective drainage systems to stay functional during rainfall. Upgrades that improve runoff management and increase water storage capacity can significantly reduce the risk of flooding. For new developments, avoiding construction in flood-prone areas is a way to eliminate the need for such upgrades altogether.

In developing regions and remote areas—where infrastructure is limited and network redundancy low—local storage solutions may offer workarounds when roads become impassable due to heavy rain.

Wind. Process changes, airspace redesign or, in extreme cases, changing runway orientation can all help tackle crosswinds at airports. Extra lashings can help prevent cargo falling overboard in heavy seas.

Snow and ice. Snow fences and windbreaks help prevent snow drifting onto roads and rail lines. Snow-clearing equipment can get runways open again after snowstorms. Winter tires and snow chains, as well as driver training, can keep road vehicles moving in snowy and icy conditions. Dynamic routing and scheduling enable real-time adjustments to freight routes to avoid disrupted segments.

Coastal. Several measures can protect seaport operations against coastal flooding. These include upgrading drainage systems, elevating critical infrastructure, designing ground-level areas to accommodate flooding, and relocating inventories to higher floors to prevent damage.

2 Building resilience – Cost-effective solutions are within reach

In March 2024, a snowstorm in Nevada, USA, led to the closure of a major pass, disrupting Walmart's distribution operations. In response, Walmart leveraged predictive analytics and artificial intelligence, utilizing a digital twin of its supply chain network to simulate scenarios and reroute deliveries. The system identified 85 alternative stores and four distribution centers across Nevada, California, and Oregon to fulfill the disrupted workload. This example illustrates the critical role technology is playing in enhancing climate adaptation in the logistics sector. [24]

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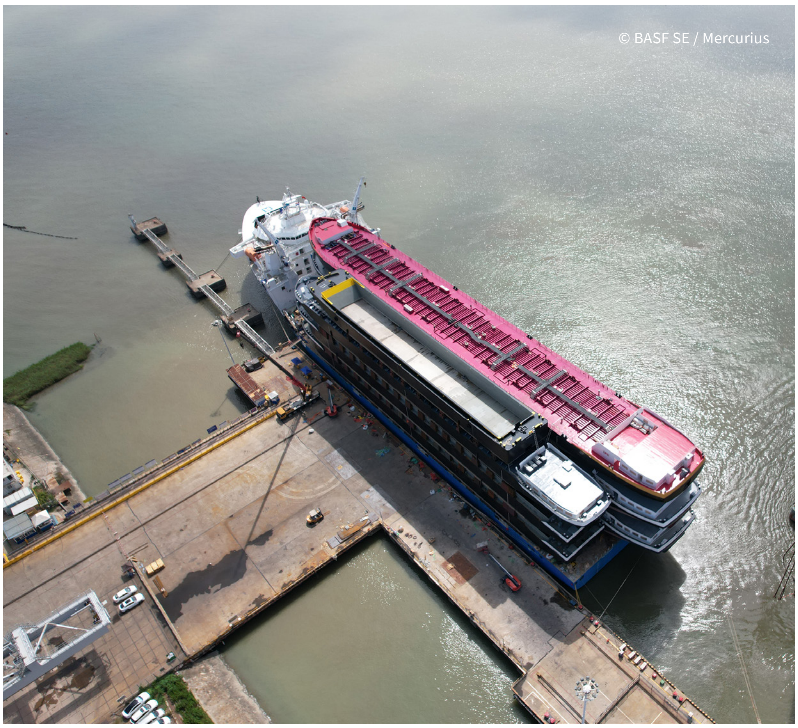
In Uganda's Mount Elgon region, intense rains often make roads impassable, delaying coffee transport and increasing the risk of mold and quality loss. To adapt, a local exporter uses sealed fermentation drums that allow cherries to begin processing safely on-site. Once roads are passable, the drums are transported by motorcycle down the mountain. This approach preserves quality and ensures continuity despite frequent weather-related disruptions.

© Mountain Harvest / Jjumba Martin



BASF and Stolt Tankers have jointly developed a new chemical tanker specifically designed to operate during extreme low water conditions—a growing challenge on Germany's Rhine, as seen during major disruptions in 2018 and 2022. This vessel represents a concrete step in a broader adaptation effort.[25] The Central Commission for the Navigation of the Rhine has laid out a comprehensive strategy to strengthen the resilience of inland waterway transport. Key measures include the deployment of low-draught and retrofitted vessels, enhanced digital forecasting tools, targeted infrastructure upgrades, and operational adjustments by shippers.[26]

C. Logistics workforce

Workforce safety and productivity in the face of climate hazards can be supported through a range of measures falling under **physical and operational resilience** (see Figure 4).

Heat and cold. To mitigate the risks of extreme heat for workers, a straightforward yet effective measure is installing air conditioning in trucks, crane cabins, and warehouses. For outdoor staff, shift schedules can be adjusted to reduce exposure during peak heat, and trainings can be provided to manage high-temperature conditions safely. Ports and dry ports in wealthier countries are also adopting autonomous vehicles and cranes, which reduces human exposure where working conditions are suboptimal.

Other CIDs. Staff protection during extreme weather events should include early warning systems, clear safety protocols, and a robust communication network to ensure rapid response and coordination.

Adaptation measures are often cost effective

Studies on the cost of climate adaptation have primarily focused on developing contexts. The World Bank, for example, assessed the cost of climate-proofing infrastructure in low- and middle-income countries. It estimated that these measures add approximately **3% to total infrastructure investment costs**. The results show strong cost-effectiveness: in 96% of the scenarios studied, the **cost-benefit ratio was greater than 1**; in 77%, it exceeded 2; and in over 55%, it was greater than 4. [18]

Although these findings are not universally applicable, they indicate that targeted adaptation—especially for infrastructure with high exposure or vulnerability—can offer significant **value for money**.

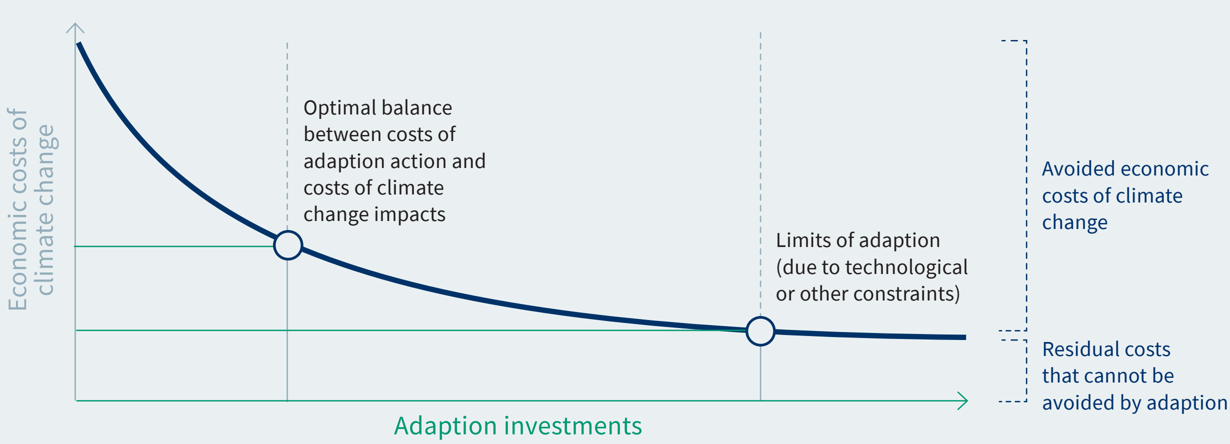
Importantly, these studies focus on physical resilience. Measures related to operational resilience are often assumed to be less costly, though their actual costs and benefits vary depending on the context.

Adaptation reduces but does not eliminate all risks

In general, investments in climate adaptation can significantly reduce financial losses from climate hazards, with larger investments typically resulting in greater savings (see Figure 5). However, there are **economic limits to adaptation**—these occur when the cost of implementing adaptation measures exceeds the value of the losses they prevent. In some cases, it may be too expensive to adapt to certain risks, or adaptation may only become cost-effective once higher levels of global warming have been reached.

Additionally, adaptation cannot eliminate all climate-related losses. Some **residual impacts** will remain unavoidable, especially from unprecedented and uncontrollable events like megafires or powerful hurricanes, which may exceed the capacity of even the most robust adaptation efforts. In such cases, climate insurance plays an important role, especially for smaller or more geographically focused companies.

Figure 5: Link between adaptation investments and the economic costs of climate change



Source: European Environment Agency

3 The way forward – What can shippers and LSPs do?

Multiple stakeholders play a role in logistics adaptation

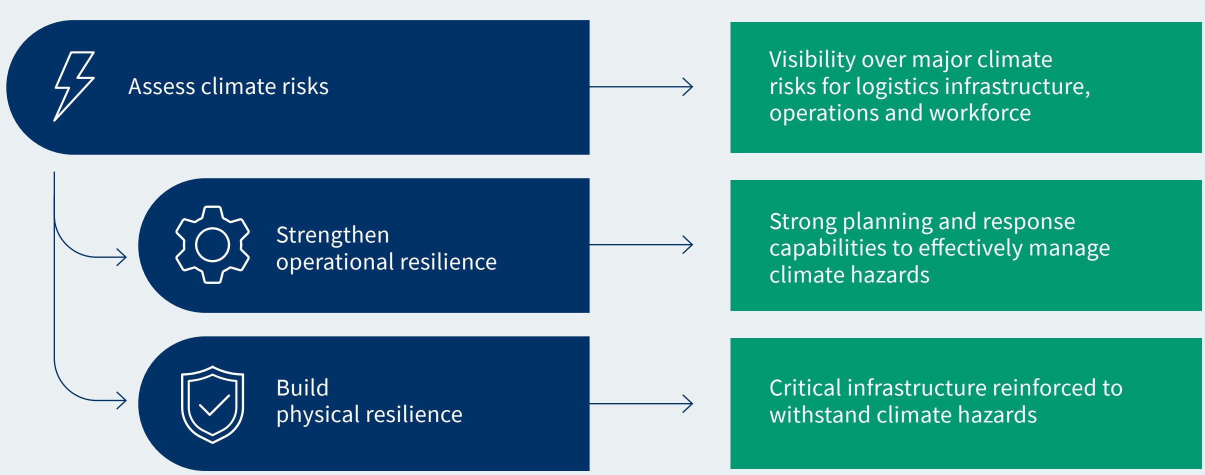
Adapting the logistics sector to a warming world requires efforts from multiple stakeholders. At the core are three groups: **shippers**, who need to move goods; **LSPs**, who manage the movement of goods and related activities; and **logistics infrastructure owners** who operate major assets like roads and ports. These roles are not mutually exclusive, as some shippers manage logistics in-house, and both shippers and LSPs may also own logistics infrastructure such as warehouses or port terminals.

Beyond these core players, a broader ecosystem contributes to climate adaptation. **Governmental and intergovernmental entities** shape the enabling environment through policies, standards, and public funding. **Financial institutions and insurers** enable investment and manage risks. **Industry associations** support collective action and amplify voices. **Construction and engineering firms** build and retrofit resilient infrastructure. **Technology providers** offer tools and expertise. **Academic and research organizations** generate insights and drive innovation.

This paper focuses on the role of shippers and LSPs. While the scale and uncertainty of climate adaptation can be overwhelming, there are several no-regret actions they can take to protect their logistics operations—and the infrastructure and workforce that sustain them. These actions are organized around three strategic pillars: assessing climate risks, strengthening operational resilience, and building physical resilience (see Figure 6).

The following paragraphs outline what they entail. Given that companies vary in needs and maturity, the information presented can serve as a practical checklist to support their logistics adaptation efforts.

Figure 6: Three strategic pillars for shippers and LSPs to drive climate-resilient logistics



Effective adaptation begins with climate risks assessments

Building operational and physical resilience and adapting to a warmer world starts with assessing risks. This involves identifying key **climate hazards**, understanding how these hazards are likely to evolve over time, and analyzing their potential impact on logistics **infrastructure, operations, and workforce**—across the supply chains and logistics networks of shippers and LSPs. Given that historical data alone is no longer a reliable predictor of future risks, shippers and LSPs must adopt a forward-looking approach, using climate projections and advanced analytics tools. External service providers can support these assessments by offering data, modeling capabilities, and specialized expertise

Collecting hazard data alone is not enough—shippers and LSPs must also assess their exposure and vulnerability. An **exposure** analysis should identify which logistics elements (e.g., a warehouse and its staff, a road) are in high-risk areas and thus exposed to climate hazards. A **vulnerability** analysis should evaluate how susceptible these exposed elements are to being disrupted or damaged. For example, a road in a flood-prone area may have high exposure to flooding, but its vulnerability depends on factors such as drainage capacity and network redundancy.

Initially, it may be useful for companies to conduct these assessments separately from broader risk management processes. However, to build long-term resilience, it is essential to embed climate risk assessments into the company's overall **risk management framework**. This integration ensures that climate risks are considered alongside other operational and strategic risks.

Where feasible, shippers and LSPs should collaborate in assessing climate risks. Just as many LSPs already provide greenhouse gas emissions data to their customers, they can also offer valuable visibility into climate risks. With their expertise and on-the-ground experience, LSPs are well positioned to conduct network-wide assessment and support their broader customer base. By integrating climate risk assessments into their **service offerings**, LSPs not only support their clients' adaptation efforts but also create opportunities to differentiate themselves in the market.

Shippers and LSPs should focus on building operational resilience

To effectively manage climate hazards, shippers and LSPs must cultivate best-in-class **operational resilience**, which includes both strong **planning and response capabilities**. Much of this builds on established resilience best practices that apply broadly—whether the disruption stems from climate hazards, geopolitical conflict, or other external shocks.

Operational resilience requires planning. Informed by climate risk assessments, shippers and LSPs can define potential disruption scenarios and feed these into supply chain planning. Scenario planning helps companies understand their response capacity and evaluate tactical and strategic contingency measures—such as relying on alternative routes and transport modes. For shippers, this might also involve fulfilling orders from different distribution centers, maintaining buffer stock, and diversifying suppliers. Simulations of climate disruptions and stress tests can help assess measures put in place and resilience more generally.

Operational resilience also demands strong response capabilities. Real-time network visibility, early warning mechanisms, and emergency protocols are essential for swift and effective action during climate disruptions. Companies should also establish dedicated crisis management teams or "war rooms" to lead response efforts and organize regular trainings and exercises to ensure readiness.

Shippers and LSPs should collaborate closely where appropriate, as **coordinated efforts** can greatly enhance resilience. Joint scenario planning and the development of contingency measures for example could enable both parties to align their responses and reduce vulnerabilities.

All these elements of operational resilience should be captured in comprehensive **business continuity plans**.

Operational resilience should be complemented by physical resilience

When climate risk assessments reveal that critical logistics infrastructure is vulnerable—with potential consequences such as physical damage, operational disruptions, or risks to workforce safety—action must be taken not only to strengthen operational resilience but also to harden infrastructure and build **physical resilience**. This includes reinforcing and upgrading existing assets, designing new infrastructure to withstand climate hazards, and establishing robust inspection and maintenance protocols.

If shippers or LSPs own the at-risk infrastructure—such as a distribution center—they should work closely with engineering experts to identify and implement appropriate hardening measures. These upgrades should be integrated into the **facility's master plans** and supported by a strong business case. Where practical, companies should also evaluate options to **relocate** vulnerable assets or introduce **redundancy** into their distribution networks. In addition, maintenance processes should include routine inspections, for example annual condition surveys and post-event assessments, to detect potential issues or vulnerabilities early.

When critical logistics infrastructure—such as port terminals, roads, or bridges—is not owned by shippers or LSPs, active collaboration with infrastructure owners, governmental entities, and ecosystem players becomes essential.

This engagement can take the form of direct dialogue, such as bilateral discussions, or **collective action through industry associations** and trade bodies. Shippers and LSPs can contribute by sharing operational data and risk insights, helping infrastructure owners better understand vulnerabilities and strengthen the business case for investments. Where scale and influence permit, they can also participate in **public–private partnerships** to co-develop solutions and co-invest in hardening at-risk infrastructure.

Box 4. **Special considerations for developing contexts**

Low- and middle-income countries often face greater exposure and vulnerability to climate risks than higher-income ones. Global shippers and LSPs with operations in these regions must understand and integrate these realities in their adaptation efforts.

First, this means adapting their strategies to local contexts. This includes understanding regional vulnerabilities and engaging local actors—such as smaller transport operators and community organizations—especially where informal logistics networks are key. Second, there is a need for knowledge sharing. Shippers and LSPs with operations in or partnerships across developing regions should actively disseminate best practices, tools, and data to local counterparts. This can include sharing methodologies for climate risk assessments and contingency planning, fore example. Third, where possible, shippers and LSPs should support or co-invest in climate-resilient infrastructure upgrades or new developments. Collaboration with multilateral development banks, donor agencies, and public-private partnerships can help fund and deliver projects such as climate-proofed warehouses and renewable-powered cold chains.

Conclusion

Climate hazards—including changes in weather patterns and extreme weather events—are affecting logistics systems in many ways. While impacts vary by context, they typically affect one or more of three core components: infrastructure, operations, and workforce.

To effectively manage the risks associated with climate hazards—growing as the world warms—resilience must be embedded in logistics systems. Physical resilience implies hardening infrastructure and protecting the operations and workforce that depend on it.Operational resilience refers to the soft capabilities needed to anticipate and respond to climate hazards, primarily aimed at safeguarding operations and workforce. Both dimensions are essential, and while the cost-benefit of specific measures may vary, evidence shows that targeted investments often yield positive returns.

Shippers and LSPs run logistics activities day-to-day; they connect networks and support the industries and systems that power today's society. As such, they are both directly impacted in case of hazards and crucial to driving change within the sector. However, adaptation efforts remain limited across both groups. While some shippers have begun developing climate adaptation strategies, these often prioritize production, with little attention given to logistics. On the LSP side, efforts are primarily focused on traditional contingency planning, with a lack of transformative thinking.

Shippers and LSPs must accelerate their adaptation efforts. Several no-regret actions can be taken to protect logistics operations, as well as the infrastructure and workforce that support them. These actions are centered around three strategic pillars: First, assessing climate risks across supply chains and logistics networks, considering hazards, exposure, and vulnerabilities. Second, fostering best-in-class operational resilience, which primarily requires robust planning and response capabilities. Third, enhancing physical resilience, either by directly addressing self-owned infrastructure or by collaborating with infrastructure owners and operators.

While shippers and LSPs have a commercial interest in adapting to climate risks, there is also a broader societal interest in ensuring that logistics systems remain resilient. Logistics systems are the backbone of trade and economic activity; they enable the movement of goods that fuel businesses and supply essential products to consumers. They are also crucial for local communities whose livelihoods depend on them. Repeated disruptions or permanent failure of logistics can have severe consequences for the surrounding communities as traffic is lost and activities move away. As such, logistics professionals have a responsibility to raise the importance of adaptation with customers, service providers, insurers, and governmental entities to drive change.

One of the challenges facing the logistics sector is that climate adaptation must occur alongside decarbonization and the rapid development of new capabilities in response to other major shifts—such as geopolitical instability, emerging technologies, and demographic changes. Balancing these demands is not easy, but they should not be viewed as competing priorities. In fact, adaptation and decarbonization are often mutually reinforcing [27], helping to create more efficient, resilient, and future-ready logistics systems.

The time to act is now. Delaying adaptation will only increase the risks and costs for businesses, supply chains, and society at large.

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