

Life-Links for Resilient Supply Chains and Logistics

**Framework for
collaborative action**



October 2025

Contents

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About Life-Links

Life-Links is a global non-profit based in the Netherlands, co-founded in 2024 by the Kuehne Climate Center and CEO Sophie Punte. Its vision is that resilient supply chains can drive climate action and local sustainable development, benefiting communities, companies, countries, and consumers alike. Through its Life-Links Framework, supply chain actors are mobilized to co-develop and co-invest in solutions that make critical transport links more resilient, sustainable, and inclusive.

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Box 2: Multiple supply chains through port: Sophie Punte

Box 2: Critical materials supply chain: Unsplash / Ra Dragon

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Box 5: Case Study India: Unsplash / Gyan Shahane

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The Life-Links Framework contributes to global adaptation goals, most notably the **Sharm El-Sheikh Adaptation Agenda's** call for resilient transport infrastructure to climate hazards.

The **Race to Resilience** is a global campaign catalyzing action by non-state actors to build the resilience of 4 billion people from vulnerable communities to climate risks by 2030.

SAA

**SHARM
ADAPTATION
AGENDA**

**RACE TO
RESILIENCE**

Foreword and Introduction

Supply chains connect us all – communities, companies, countries, and consumers alike. In recent years, those connections have been tested by the COVID-19 pandemic, geopolitical tensions, and the accelerating impacts of climate change. When supply chains fail, everyone feels it – but the most vulnerable are hit first and hardest: farmers cut off from markets, workers losing income, households facing shortages. For many people, supply chains are true lifelines. Yet responses to these disruptions – by both governments and companies – are often reactive, local, and short-term, instead of strengthening supply chains for the benefit of all.

I asked myself: what if the supply chains that connect producers and consumers could become a driver for climate action and local sustainable development? Could we use the shared interest of companies, governments, and communities to keep supply chains moving – and turn that into coordinated action? And could we combine adaptation, mitigation, and finance to help deliver on the Paris Agreement? I took this idea to the Kuehne Climate Center, and together we created the **Life-Links vision: resilient supply chains for good.**

From the start, we focused on the **critical transport and logistics links** – such as roads, railways, ports, and corridors – because they are essential to supply chains and too often overlooked until disruption hits. I developed the Life-Links Framework as a clear step-by-step method, while in parallel, the Kuehne Climate Center applied it to avocado and coffee supply chains between Africa and Europe to ground the approach in real-world experience.

I knew that I could never develop the Framework on my own. Life-Links touches on many fields – from supply chain and disaster risk management to development

aid, sustainability and logistics. There were already many guidelines, tools, initiatives, and organizations working in these areas. So I set out to bring together experts with different backgrounds – from academia, business, development, and civil society – to form the **Life-Links Council** and help give the Framework shape and direction. With support from the Climate Champions and many others, we organized events at COP29, the International Transport Forum Summit, and London Climate Action Week to gather insights from as many stakeholders as possible.

The result is the **Life-Links Framework** – a practical approach to unite partners to co-develop and co-invest in measures that build resilience, while also contributing to emissions reduction and local sustainable development. Shared resilience creates value in multiple ways: by avoiding losses when disruptions occur, generating economic benefits through more stable trade and supply, protecting livelihoods and the natural resources they depend on, and delivering social and environmental co-benefits.

The Framework is structured into four parts:

- **Part A: Why Resilience** – explains the challenges of supply chain disruptions and climate change, the market barriers that make them hard to address, and the opportunity for change.
- **Part B: Life-Links Framework** – describes what the Framework is and how it contributes to the Paris Agreement and sustainability goals, what it builds on, its overall structure, and how to use it.
- **Part C: Life-Links Steps** – helps users select a supply chain and a critical transport link, and then follow three steps: risk assessment, selection of action measures, and coordinated implementation – to create value for all partners, illustrated with real-world examples.



- **Part D: Resources** – provides practical materials to support the implementation of the Life-Links steps, such as overviews of guidelines and tools, hazard types, and examples of metrics and measures that improve resilience.

The Framework is meant to be used **flexibly**, because every supply chain is different. I invite everyone with a stake in resilient supply chains and logistics – especially the companies that power them – to **apply the Life-Links Framework**, share what you learn, and help us continue building it with practical examples and experiences. The Framework will keep evolving through collaboration and learning.

In the end, building resilience is as much about strengthening roads and ports as it is about how people work together. It means balancing interests, building trust, and giving everyone a seat at the table so that solutions last. My hope is that Life-Links will help make that possible.

Sophie Punte
Co-founder & CEO, Life-Links

Why Resilience



The image features a large, stylized, orange letter 'A' in the background. A white line with three circular nodes winds through the center of the image. The background is a gradient of colors, transitioning from dark blue on the left to orange on the right, with a large brown circle in the center.

A Why Resilience

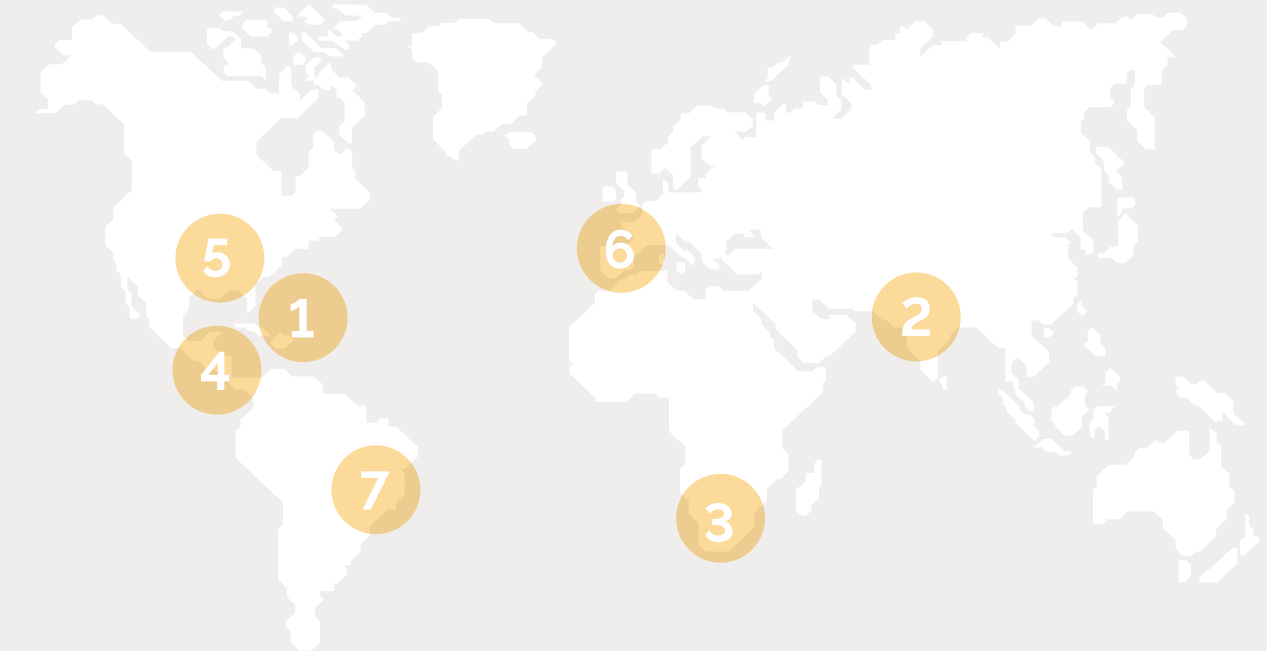
A-1. Supply Chains, Logistics, and the Climate Challenge

Supply chains are our lifelines. They have always underpinned societies - from ancient trade routes to today's global networks. Now they represent an even greater share of how the world works, with trade equaling 57% of the world's GDP.¹ When the weakest link in a supply chain breaks, everyone suffers – especially the most vulnerable. Wildfires, cyberattacks, floods, power blackouts, storms, strikes, tariffs – every week seems to add a new disruption to the list. Combined with growing geopolitical instability and the possibility of future pandemics, we face a perfect storm.

Climate change poses a growing threat to supply chains, through both acute hazards such as storms, floods, and heatwaves, as well as slow-onset chronic hazards like sea level rise and shifting weather patterns. Weather anomalies can disrupt supply chains, leading to inflationary pressures.² Moreover, climate change may exacerbate disruptions caused by other factors – geopolitical conflicts, pandemics, earthquakes, and accidents – and vice versa. The social, economic, and environmental impacts are vast and worsening as climate change intensifies.

Logistics infrastructure and operations are particularly vulnerable to climate hazards, and no supply chain can function without it. For example, 27% of global road and rail infrastructure is exposed to at least one natural hazard, and 86% of ports are exposed to more than three.^{3, 4, 5} Every USD 1 investment in adaptation measures can yield >USD 10 in benefits.⁶ Measures to climate-proof infrastructure add roughly 3% to total infrastructure investment costs in low- and middle-income countries, yet deliver a cost-benefit ratio greater than 1 in 96% of cases.⁷

Box 1: Climate impacts on supply chains are already being felt



Natural disasters caused an estimated USD320 billion in losses in 2024, with 93% resulting from extreme weather events and insurers covering around USD140 billion.⁹ By 2050, 4.4% GDP could be lost without adaptation, disproportionately affecting the Global South: South Asia is most exposed with 12% GDP at risk, and Subs-Saharan Africa is least prepared to face losses.¹⁰ Some examples are:

- 1 Dominica (2017):** damages from Hurricane Maria cost the Caribbean island 226% of GDP.¹¹
- 2 Pakistan (2022):** floods caused USD 30 billion or 10% GDP in damages.^{12, 13}

- 3 Durban Port, South Africa (2023):** bad weather, combined with lack of staffing and equipment, caused 18 days of berthing delay for 60+ container ships, while 68% of the country's GDP depends trade.^{14, 15}

- 4 Panama Canal (2024):** droughts, exacerbated by decades of deforestation, reduced daily traffic by nearly 40% and toll revenues by USD100 million per month, or about 1.5% GDP annually, with many ships diverting to longer ocean routes, which increases both costs and GHG emissions.^{16, 17}

- 5 U.S. (2024):** Hurricanes Helene and Milton cost the U.S. economy 50 billion dollars each, with almost half attributable to human-caused climate change, and leading to North Carolina mines that supply 80-90% of global high-quality quartz to close operations.^{18, 19, 20}

- 6 Valencia, Spain (2024):** combined rainfall and river flooding led to 232 deaths, significant infrastructure damage and economic losses of Euro 16.5 billion.²¹

- 7 Brazil (2024):** extreme flooding destroyed critical infrastructure that led to USD billion lost revenues and USD3.7 billion rebuilding costs.²²

Research suggests that in freight transport systems around two-thirds of resilience-enhancing measures can also cut greenhouse gas emissions.⁸

However, responses to supply chain disruptions by governments and companies tend to be reactive, localized, and isolated, driven by short-term interests. Avoiding and managing risks help reduce disruptions and its impacts, but they don't solve the core underlying issues. To truly improve resilience, we must structurally strengthen supply chains for the long-term benefit of all – communities, companies, countries, and consumers.

A-2. Market Failures at the Heart of the Challenge

Why are responses from companies and governments to supply chain disruptions often reactive and isolated? The answer lies in market failures.

Supply chains are complex, multifaceted, and fragmented, involving thousands of players, making them difficult for anyone to oversee, let alone control. Only one in three surveyed businesses have good visibility beyond their first-tier suppliers and associated risks. This lack of upstream and downstream visibility is a major barrier to addressing supply chain disruptions.²³ Companies may be discouraged from investing in logistics networks when competitors benefit without contributing, a classic free-rider problem. As a result:

- Manufacturers and retailers – also known as shippers or freight buyers – often respond by modifying their global supply chains. Strategies include keeping inventory buffers, nearshoring, regionalizing, or diversifying their sources, manufacturing bases, and logistics providers. Those investing in resilience or adaptation tend to focus on assets within their direct sphere of influence (e.g., factories or warehouses) rather than on logistics and transport infrastructure that connects their products to consumers. Likewise, many supply chain risk management tools used by corporations are 'location-focused,' overlooking the transport legs of the chain.
- Freight forwarders and logistics service providers (LSPs) have sharpened their tactical role as trouble-shooters. They work to anticipate disruptions anywhere in their networks and respond quickly by retiming deliveries, rerouting, switching modes, or using backup carriers. Technological innovations have also been widely adopted: digital twins of global supply chains, combined with predictive analytics and AI, are helping both shippers and LSPs improve resilience, efficiency, and decision-making. A further priority is improved coordination and information sharing, for example to facilitate container transfers through ports.

Yet something crucial is being overlooked: these strategies only work around the problem. Truly solving it requires investing upfront in making logistics infrastructure, operations, and the workforce more resilient.

Adaptation, supply chains and transport remain blind spots in the Paris Agreement and NDCs. Progress on implementing the agreement – including the goal on global

adaptation²⁴ – has been slow due to an overemphasis on mitigation, while the Global South continues to call for equal attention to finance and adaptation, combined with local development. Moreover, supply chains have long been overlooked across all aspects: mitigation, adaptation, and finance. While 81% of Nationally Determined Contributions (NDCs) include adaptation, of the 23 third-generation NDCs submitted by July 2025, only half include transport adaptation measures – and those often lack detail beyond a generic mention of adapting transport infrastructure to a changing climate.^{25, 26} A contributing factor is that costs and benefits from adaptation measures needed to build the investment case are poorly understood.⁶

Supply chains, logistics and adaptation are often short-comings in companies' climate efforts. 'Scope 3' greenhouse gas (GHG) emissions make up 75% of an average company's footprint, yet only 37% report on all scopes to the environmental disclosure platform CDP, and just 30% recognize upstream climate-related risks in their value chains.^{27, 28, 29} Few companies have incorporated supply chains into their climate adaptation strategies: while 21% of those assessed by Standard & Poor's already have adaptation plans, these tend to focus more on their own assets than on transport and logistics parts of their supply chains that usually are outsourced.³⁰

A short-term mindset dominates political and economic systems. Immediate concerns, such as strikes or inflation, take priority over long-term planning for impacts like coastal inundation or food system collapse. Similarly, after disasters, companies focus on getting back on their feet quickly, while governments prioritize immediate local emergency relief after storms or crop failures.

Both governments and companies struggle to allocate budgets for building long-term resilience, especially when it involves supporting other countries or deeper parts of a company's value chain. Deep uncertainty — not knowing how future scenarios will play out — further complicates decision-making.³¹ They and other actors also hesitate to invest independently due to the diversity of hazards and adaptation measures, the challenges of predicting extreme weather (location, frequency, intensity, and impact), and the uncertainty of when and to what extent benefits will materialize.

The connection between consumers and producers is also weak. Since COVID, almost half of consumers in both advanced and developing economies place importance on buying local from their own markets.³² However, consumers don't always know where their vegetables, clothes, or the critical materials in their mobile phones come from, weakening the link between them and producers. Labels on products can be inconsistent or misleading.³³ As a result, the damage that climate change or other disruptions inflict on local communities in poorer countries is less visible to consumers. Contributing to this disconnect is the fact that more than half of consumers everywhere are preoccupied with the rising cost of living, and for 81% of surveyed consumers price is the main consideration in purchase decisions.³⁴

Life-Links vision:
Resilient supply chains for good



What if...

- **we make supply chains**, that connect producers and consumers across the globe, **drivers of resilient climate action and local sustainable development**
- by building **innovative partnerships** that co-invest and collaborate on solutions...
- ...to make **critical logistics links** in shared supply chains **more resilient**, while reducing emissions and improving sustainability...
- ...benefiting **all stakeholders** from communities to companies, countries and consumers.

A-3. The Opportunity for Change

The opportunity for change forms the foundation of the Life-Links vision and theory of change, which sits at the nexus of supply chains, climate and sustainability, and logistics.

Supply chains and trade routes are in the limelight, creating an opening to align supply chain resilience with climate action.

Yet something crucial is being overlooked: these strategies only work around the problem. Truly solving it requires investing upfront in making logistics infrastructure, operations, and the workforce more resilient.

Climate policy frameworks and funding discussions are maturing, presenting a critical moment to embed supply chains – including transport and logistics – into climate resilience strategies. Pressure is mounting for integrating and balancing climate mitigation, adaptation, and finance, with strong pressure coming from the Global South.

- In 2022, the UNFCCC Parties launched the Sharm-El-Sheikh Adaptation Agenda, setting 30 global targets for 2030 across six systems (including infrastructure) to support the Race to Resilience's goal of improving resilience for 4 billion people.^{35, 36}
- At COP29, countries agreed on a new finance goal of \$300 billion, covering mitigation, adaptation, and loss and damage — a step forward, though the annual climate finance gap remains at USD 5.93 trillion.³⁷

- Notably, adaptation finance doubled between 2018 and 2022, underscoring a shift toward building resilience.³⁸

Supply chain cooperation can become a powerful lever for closing the investment gap, accelerating climate adaptation, and supporting a just transition — aligning political priorities with economic opportunity. With development cooperation retreating, policymakers are urging private sector to embrace the opportunity.

Societal support for climate action is stronger than ever, giving political and business leaders a mandate to act.

- Public demand for climate action is at an all-time high with 9 out of 10 people across 125 countries wanting stronger climate action.³⁹ 47% of surveyed global consumers buy sustainable products and 37% pay more for these.⁴⁰ Notably, fewer individuals feel personally responsible to act compared to a few years back, as they look at governments and companies to take the lead.⁴¹
- Experts across academia, business, government, the international community ranks climate risk and failure to adapt very highly, according to the WEF Global Risk Survey: when looking ten years ahead, the top 4 risks are all environment/climate related.⁴²
- Development agencies and funders are also shifting priorities, focusing more on climate adaptation, nature inclusion, human rights, and support for the Global South, complementing traditional mitigation and technology-driven 'breakthrough' agendas.

Business leaders are reframing supply chains as strategic, and ESG as resilience.

- Companies increasingly recognize the direct link between business continuity and resilience to supply chain disruptions – and the need to act. After COVID, 93% of 60 surveyed global supply chain leaders planned to increase resilience (44% even at the expense of short-term savings).⁴³ Out of 508 global CEOs last year, 78% intend to make supply chain changes in the next 3–5 years, citing disruptions mainly due to political uncertainty and trade wars as their top concern.⁴⁴ Of 109 surveyed organizations, 63% seek to understand their supply chain's exposure to weather-related events and natural disasters.⁴⁵ The opportunity lies in leveraging the supply chain focus to also improve resilience to impact from climate change—transport and logistics included.
- The business case for sustainability remains strong. Surveyed CEOs link climate action to higher profit margins and revenue growth.⁴⁶ More than half of surveyed business leaders state that sustainability actions helped drive supply chain resiliency.⁴⁷ Companies have to act to maintain access to resources – around 95% of surveyed businesses expect circularity to be important or extremely important three years from now.⁴⁸ What has changed is that ESG (strategies focused on Environmental sustainability, Social responsibility, and Governance practices) and climate issues have become increasingly politicized. Many businesses now prefer to frame their efforts around "resilience" – a politically neutral approach that situates these actions within a broader context of corporate value chains and risk management.⁴⁹

- Requirements from regulators, investors and customers are accelerating this shift. Companies must meet increasingly stringent supply chain-related requirements on climate, nature, and human rights under frameworks like the EU CSRD (disclosure), EU CSDDD, German Supply Chain Act, EU Deforestation Regulation (due diligence), EU CBAM (carbon border tax), and IFRS Sustainability Disclosure Standards.^{50, 51, 52, 53, 54} Regulations may be weakened, but the pressure stays.

The technology and tools are rapidly evolving, making it possible to strengthen supply chain and logistics resilience in a more pro-active and collaborative way, while supporting climate goals.

- Digital twins of global supply chains, combined with analytical tools and AI, help both shippers and logistics service providers (LSPs) increase supply chain visibility, improving resilience, efficiency, and decision-making.
- Multiple tool providers and platforms are available for companies and other supply chain users to tap into. For example, climate hazards can be connected to supplier locations and transport legs, allowing companies to identify high-risk nodes or links. Better data access and exchange would further enhance coordination and collaboration among different supply chain actors, fostering shared resilience.
- Climate modelling also allows countries and companies to look ahead to 2030, 2050, and beyond, making it easier to integrate future climate impacts into policies, planning and investment decisions.

Life-Links
framework

B Life-Links framework

B-1. Why this framework?

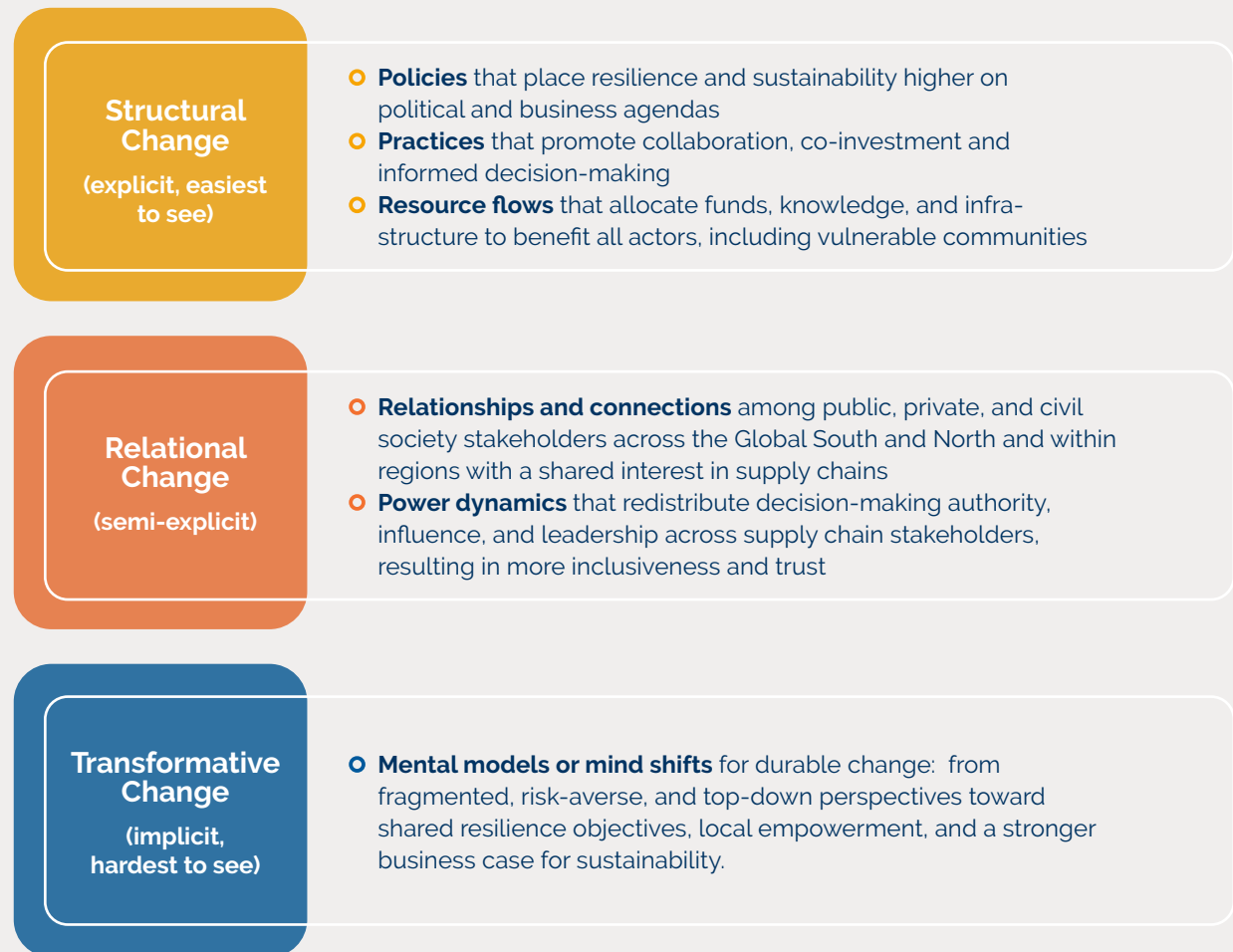
The **Life-Links Framework** provides a practical and forward-thinking way to tackle the urgent challenges of climate change by strengthening supply chains that people, companies, and economies rely on every day. Supply chains can be transformed from sources of vulnerability into drivers of collaborative climate action and local sustainable development – making them truly “**resilient supply chains for good.**”

Life-Links centers on vulnerable transport and logistics ‘links’ nodes/hubs and transport modes that connect them. Logistics links are critical parts of trade and supply chains connecting producers with consumers, but underrepresented in government NDCs and National Adaptation Plans (NAPs), corporate climate plans, and supply chain risk management tools and guidelines. Logistics system are looked at holistically and includes: network, infrastructure, operations and workforce, flows of goods, finance and information/data. The logistics system interacts with societal, regulatory, financial, physical and nature-based supporting systems.

→ *Part D-2: Logistics System and Supporting Systems*

Life-Links leverages shared interests in supply chains to build partnerships that enable collaborative action and co-investment that strengthens resilience for all stakeholders. By applying this framework together, partners can make decisions and investments that individual actors would not pursue alone, leading to greater collective impact. Because each partner contributes uniquely tailored measures focused on transport and logistics,

Figure 1: Systems change for resilient and sustainable supply chains and logistics ⁵⁷



collective resilience is strengthened. In parallel, partners can unlock opportunities for reducing greenhouse gas (GHG) emissions and advancing sustainability as a co-benefit.

Life-Links helps deliver on the Paris Agreement by:

- Bridging adaptation, mitigation, and finance at the intersection of the Paris Agreement – areas that have often been addressed separately.
- Filling a gap on transport by contributing to the Sharm El-Sheikh Adaptation Agenda outcome: Transport infrastructure is resilient to climate hazards through the adoption of new technology, design and materials.³⁵
- Connecting global policy objectives and NDCs and NAPs to private sector interests and local development needs and priorities
- Facilitating Global North–South cooperation based on a shared interest in trade, rather than risk pitting their interests against one another.
- Translating climate goals into real-economy outcomes: improved livelihoods, lower costs of living, economic growth, and business revenue.
- Positioning climate risks within the broader risk landscape faced by companies and countries, with a particular focus on vulnerabilities affecting supply chains.
- Connecting and contributing to on-the-ground implementation of three related global agendas, the Paris Agreement, the 2030 Sustainable Development Goals,⁵⁵ and the Sendai Framework for Disaster Risk Reduction 2015–2030.⁵⁶

➔ *Part D-3: Three Global Agendas and relevance to transport and logistics in global supply chains*

Ultimately, Life-Links aims to help bring about a systems change in supply chains and logistics, which requires working across multiple layers. In practice this means more than new policies or technical measures. To create resilient supply chains that last, we also need to rebalance power, nurture collaboration, and reshape the way people understand the problem itself. This is summarized in Figure 1, and with further details in Part D-5.⁵⁷

➔ *Part D-4: Mind Shifts that Enable Systems Change*

B-2. Building on Existing Guidelines and Tools

Approaches to assess supply chain risks and determine responses vary widely by stakeholder, often focusing on single actors or regions with fragmented objectives. Broadly speaking, two types of tools and guidelines are distinguished.

On the one hand, sophisticated commercial tools target mainly multinationals and combine predictive analytics and AI to manage their supply chains and risks, usually without considering other supply chain users or beneficiaries. Many of these focus on locations, while transport and logistics – the backbone of supply chains – are often overlooked.

On the other hand, multiple guidelines and tools by development agencies, insurers and other organizations focus on resilience of (national) infrastructure, such as roads or ports, climate risk assessment and management, disaster risk management, including overlaps. However,

these often omit supply chains and supply chain actors. This siloed approach leaves gaps, weakens resilience, and slows progress on climate and sustainability goals. A common framework would unite stakeholders, integrate transport and logistics, and enable coordinated action to build more resilient and sustainable supply chains.

➔ *Part D-5: Guidelines and Tools*

Figure 2: Focus of guidelines and tools

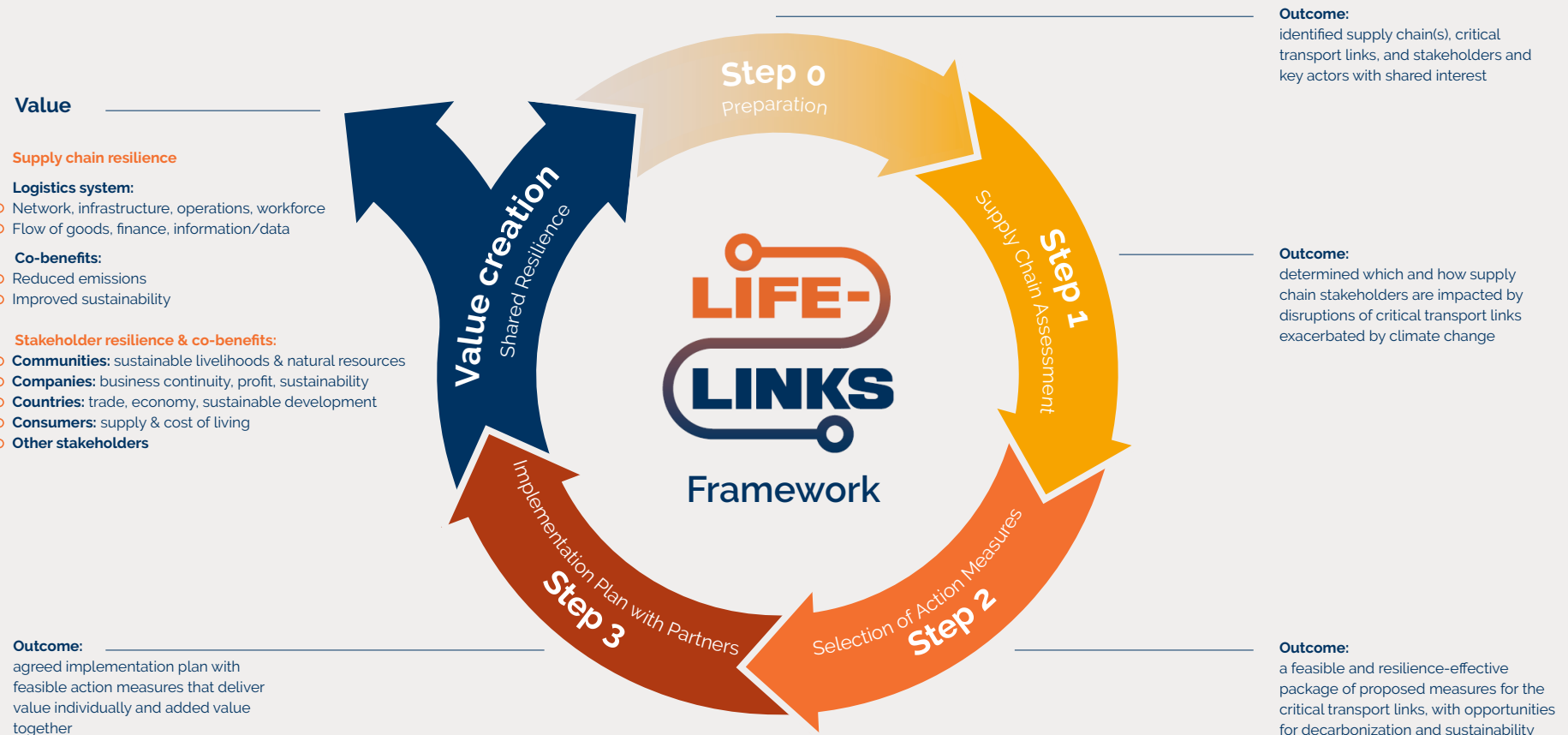


B-3. Framework Structure and How to use it

The framework starts with a preparation step, followed by a three-steps: assessing supply chains, selecting appropriate interventions, and agreeing on an implementing

plan with partners. Each step has its own outcome, cumulating to a shared resilience in supply chains that delivers real economy benefits.

Figure 3: Life-Links Framework overview



A Life-Links application can be initiated by any partner or stakeholder in the concerned supply chain, or by a supporting organization, who can then bring in other stakeholders.

Use Part C of the framework to go through each step (see Figure 4):

- Start with the **preparation step** to make sure the supply chain, actors and stakeholders and the value they are likely to expect from the project are clear.
- Next, go through the **three steps** one by one, which are broken up in sub-steps.
- The **value of the project** for different partners and stakeholders can be assessed after implementation, but is ideally determined at the start and validated as part of the feasibility analysis and the commitment to a package of actions.

Examples are used to give the step more practical meaning, drawing from pilot applications that are already underway in agricultural supply chains connecting East Africa to Europe led by the Kuehne Climate Center, along with other practical examples provided by Life-Links Council members and from guidelines and literature.

Resources in Part D can be used in support of the different steps, most importantly:

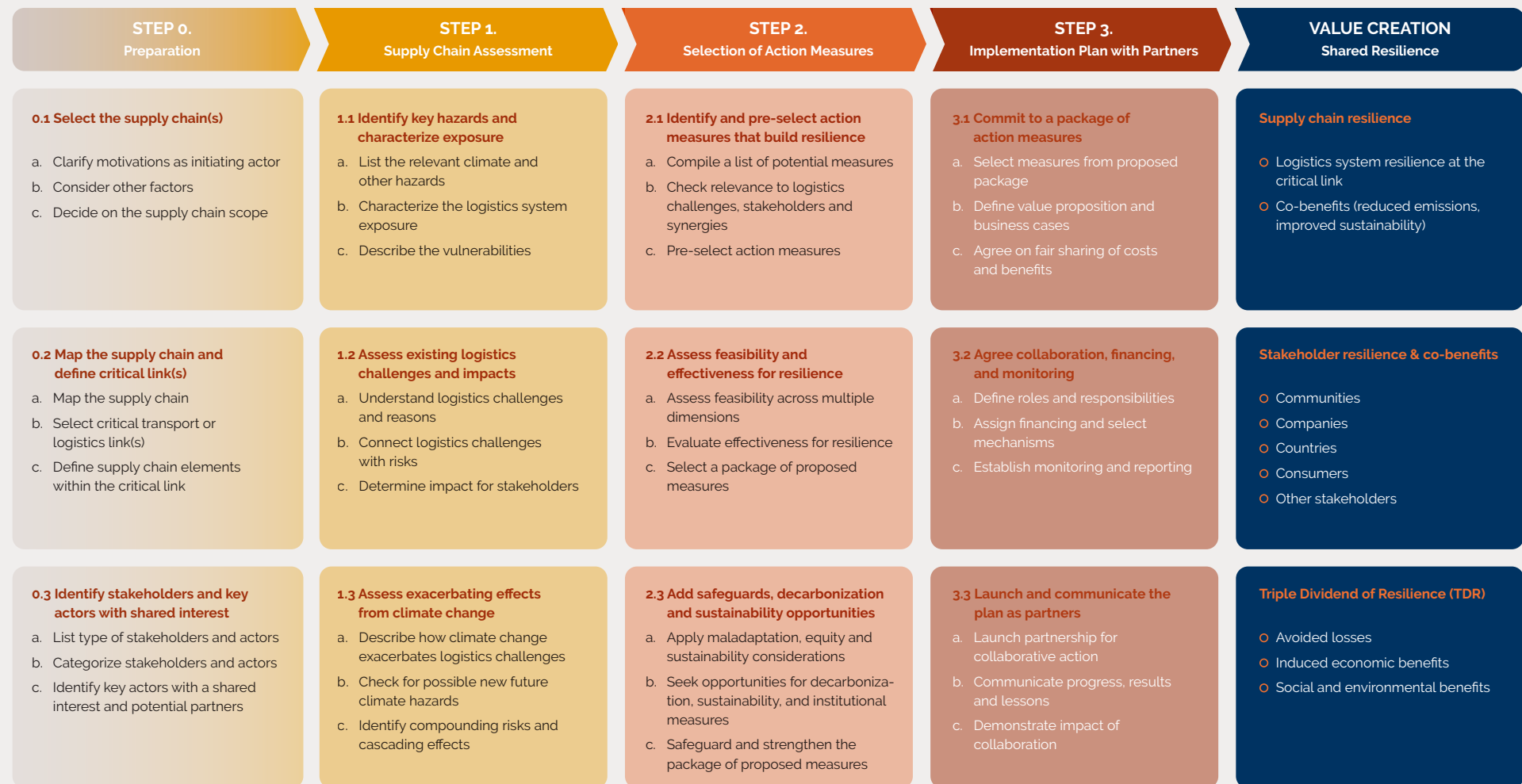
- Overview of the logistics system and supporting systems to put clear boundaries around the project while recognizing interdependencies between systems (D-2).
- List of tools and guidelines and what steps they can support (D-5).
- Lists of stakeholders and actors from a supply chain perspective to help identify stakeholders and key actors with shared interests (D-6).
- A categorization of hazards to supply chains and logistics along with examples, making a distinction between natural and human-made hazards, and identifying climate-related physical hazards (D-7).
- Examples of metrics and indicators for Life-Links steps and for resilience attributes at the transport, logistics or supply chain level (D-9).
- Action measures to improve resilience by strengthening existing routes and its transport modes and logistics hubs (D-10).
- Multi-stakeholder partnerships – risk and success factors (D11).

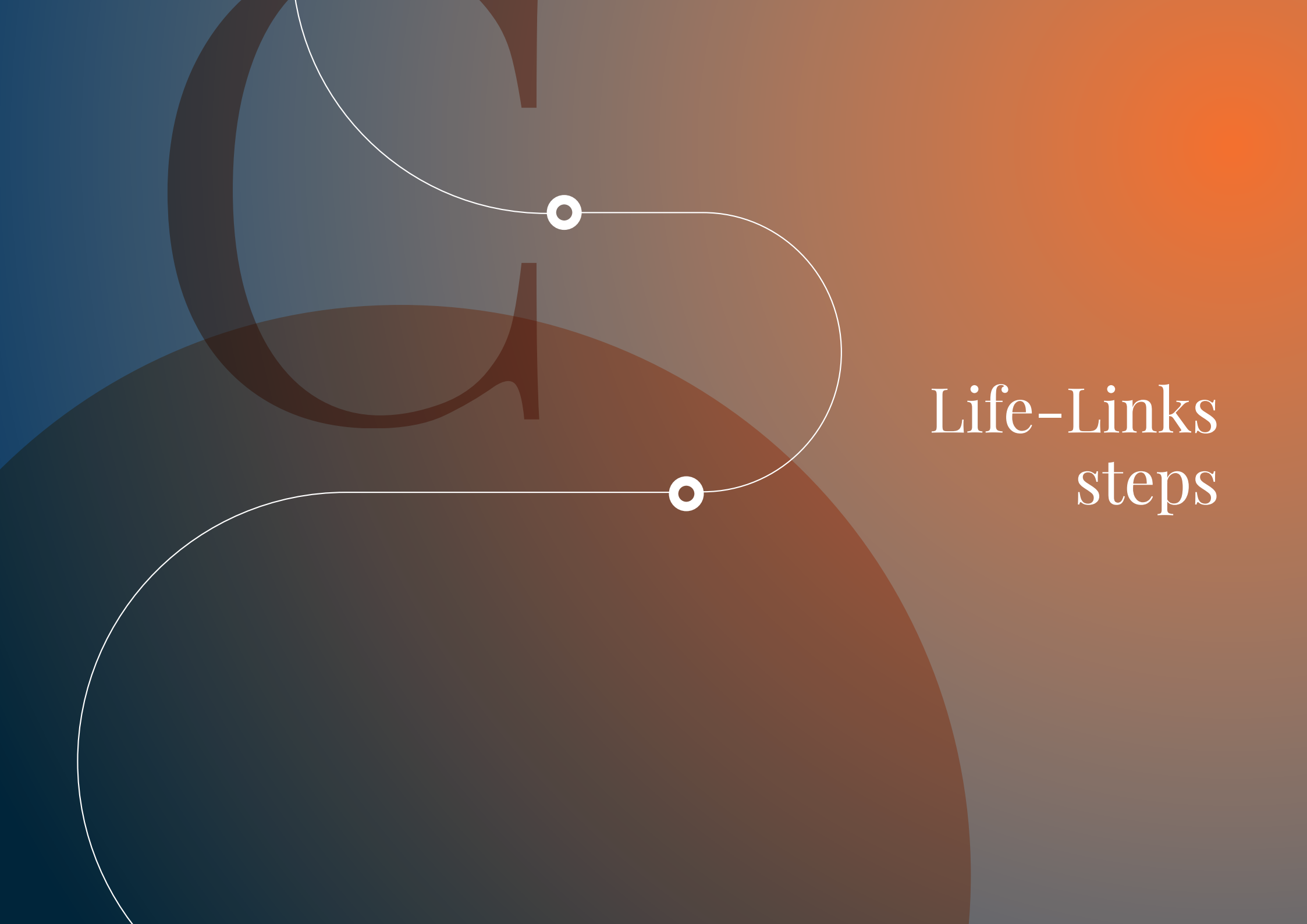
Finally, it is important to note that this is a meta-framework with the aim to enrich it with resources and practical cases over time. The emphasis now lies on **applications to real-world supply chains**, and use learnings to enrich the framework further. In time, the framework can be supplemented with playbooks for practical implementation to different geographies, sectors, products and stakeholders.

The **availability of resources and data** can also be a barrier to conducting a thorough assessment of supply chain risks and measures to build resilience, especially for segments in developing and emerging economies.

For these reasons, **the approach is flexible**: different actors taking the lead, different scopes, and different entry points are all possible. **What matters is creating value** through these partnerships of supply chain actors and stakeholders: enhanced resilience with tangible benefits for communities, companies, consumers and countries alike. Done is better than perfect – we have no time to lose.

Figure 4: Life-Links Framework steps



The background features a gradient from dark blue on the left to orange on the right. Overlaid on this are several large, semi-transparent circles in shades of blue, grey, and brown. A thin white line winds through the composition, starting from the top left, curving around a grey circle, then following a horizontal path between two white circular nodes, and finally curving down towards a larger brown circle at the bottom left.

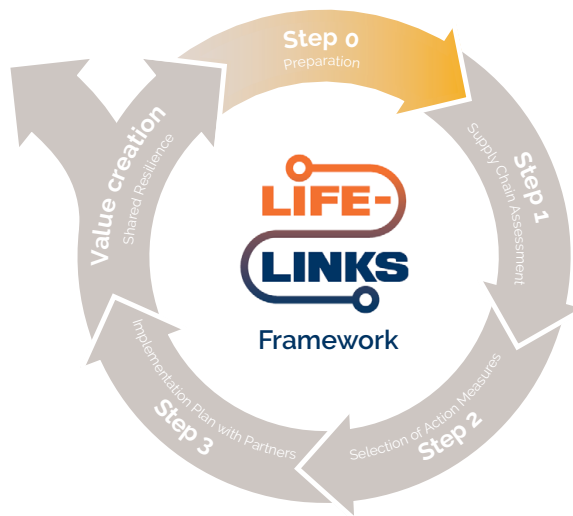
Life-Links steps

C Life-Links steps

Step 0: Preparation

Outcome: identified supply chain(s), critical transport link(s), stakeholders and key actors with shared interest

Step 0: Preparation



- 0.1 Select the supply chain(s)
- 0.2 Map the supply chain and define critical transport link(s)
- 0.3 Identify stakeholders and key actors with shared interest

The preparation phase is about selecting specific transport links within end-to-end supply chains. This allows greater focus on vulnerable links – ideally with high GHG reduction potential – and helps involve a broad range of stakeholders and actors. It can also serve as a continuation of the cycle after partners successfully implemented measures to improve resilience and sustainability.

0.1 Select the supply chain(s)

The process for selecting the supply chain for the Life-Links application is described below and illustrated with fictive examples in Box 2.

a. Clarify motivations as initiating actor

Clarify the motivation of the initiating actor of the Life-Links application, which may be one or several supply chain actors, such as companies, government agencies, foundations, insurers, or others. The motivation to pursue supply chain resilience is a key factor influencing the choice and scope of the supply chain. For example, a manufacturer's primary motivation may be to secure continued access to critical materials, a retailer may prioritize the sourcing of coffee, cocoa, or avocados that have sharply increased in price, while a foundation may focus on protecting the livelihoods of local communities.

b. Consider other factors

Consider additional factors when selecting a supply chain, such as

- Vulnerabilities and past disruptions with significant impacts.
- The type of goods, trade volumes, and economic value, while avoiding products that are environmentally or politically too sensitive.
- The dependence of local communities for their livelihoods.
- Exposure to regulatory requirements that are connected to supply chain visibility.
- Opportunities to leverage other developments, such as existing emissions accounting and decarbonization plans, initiatives and investments by other actors, and favourable policy environments.

For some stakeholders, the choice of supply chain is straightforward. For example, it is easier to select a supply chain involving a single material, commodity, or finished good. For others – particularly multinational companies with thousands of multi-tier supply chains – the process may require a more detailed preliminary assessment. In such cases, guidance may be needed to identify the most vital or promising supply chains, since not all can be subjected to the same level of scrutiny.

c. Decide on the supply chain scope

Decide on the supply chain scope by giving clarity on both the goods or products as well as the origin and destination. For example, a cocoa supply chain from Ghana in West Africa to Europe via the Port of Rotterdam. Supply chains within a country or continent could also be selected, for example, the wine supply chain from vineyards in Bordeaux, France to supermarkets in Germany, or the aerospace supply chain from Boeing's aircraft assembly plants in Washington to airlines operating out of Atlanta, Georgia.

Box 2: Fictive examples of supply chain selections



Coffee supply chain:

A coffee trader aims to improve the resilience of its supply chain from Colombia, Uganda, or Indonesia to Europe as part of broader efforts to secure a more consistent supply, given the climate sensitivity of coffee cultivation. While the trader already works with farmers to increase yields and use beans more resilient to higher temperatures and diseases, it has not yet addressed the first mile that connects farms to export hubs, which is vulnerable to delays and disruptions. An insurer is interested in the same sector because coffee production is concentrated in a few regions, and therefore disruptions can lead to large claims associated with business interruption, property loss, and liability. The Uganda–Europe supply chain for Arabica coffee is assessed first due to its trade volume, revenue importance, and the vulnerability of Arabica plantations to climate impact.



Consumer goods supply chains through a trade corridor:

Countries along the Middle Corridor (also known as the Trans-Caspian International Transport Route), which connects Asia to Europe, seek to enhance the resilience of this multimodal trade route for containerized manufactured and consumer goods, including electronics, garments, parts, and machinery. In addition to cross-border customs procedures, delays arising from the Caspian Sea ferry crossing and the associated rail systems are undermining the corridor's attractiveness. These delays are expected to be further exacerbated by climate-related hazards. Several mobile phone and laptop manufacturers, which already have plans to decarbonize their logistics operations, see an opportunity to integrate resilience and adaptation measures. The supply chains of these products are selected for assessment so that companies are involved from the start.



Textiles and apparel supply chain:

A charitable foundation active in the fashion sector has worked to improve climate resilience and reduce emissions at textile and apparel factories and workshops in Bangladesh. It is now exploring expansion into the transport and logistics segments of supply chains from Bangladesh to Europe and North America, particularly as climate change, geopolitical tensions, and other hazards increasingly disrupt supply chains and drive up costs, leading to reduced incomes for garment workers and for Bangladesh as a whole. The Bangladesh to UK supply chain is chosen because of collaboration opportunities under the UK Textiles Pact, a voluntary agreement with over 130 signatories focused on sustainable and circular supply chains.



Multiple supply chains through a port:

The Port of Santos in Brazil has completed a climate risk assessment conducted by the Brazilian government in collaboration with a development agency. To secure investments for a range of adaptation measures, it seeks to leverage support from companies involved in the export of goods such as soy products, coffee, sugar, orange juice, meats, and automotive parts, as well as the import of chemicals, machinery, electronics, wheat, and petroleum products. The soy product supply chain from Brazil to China is selected for primary analysis because soy products account for 20–30% of the port's export volume, with about 73% going to China.



Pharmaceutical supply chain:

Multiple producers of pharmaceutical ingredients and generic medicines are co-located in a designated Bulk Drug Park in the Indian state of Andhra Pradesh to boost self-sufficiency and expand exports. Realizing this potential requires investment in cold-chain systems and improved rail and road links to Visakhapatnam port, designed to withstand growing climate impacts. The Indian and state governments are engaging global pharmaceutical firms and development banks to attract long-term investment and expertise. The supply chain to the US was selected as the primary focus, as India aims to strengthen its role as a key supplier of pharmaceutical products to the United States as the world's largest pharmaceutical market, home to more multinationals, and governed by a unified regulatory framework.



Critical materials supply chains:

The European Union works to secure alternative sources of graphite for lithium-ion battery production as part of the Global Gateway. The Tanzanian government aims to strengthen road network resilience to safeguard household access to goods and the interests of international buyers using Tanzania and the Port of Dar es Salaam. All stakeholders depend on the same East African transport corridors. A European commodity trader and a Tanzanian firm have formed a joint venture to advance large-scale graphite production for use in electric vehicle batteries. A partnership between Tanzania and the EU will focus on developing resilient graphite supply chains to Europe, whose routes overlap with vital national supply chains in both countries.

0.2 Map the supply chain and define critical link(s)

a. Map the supply chain

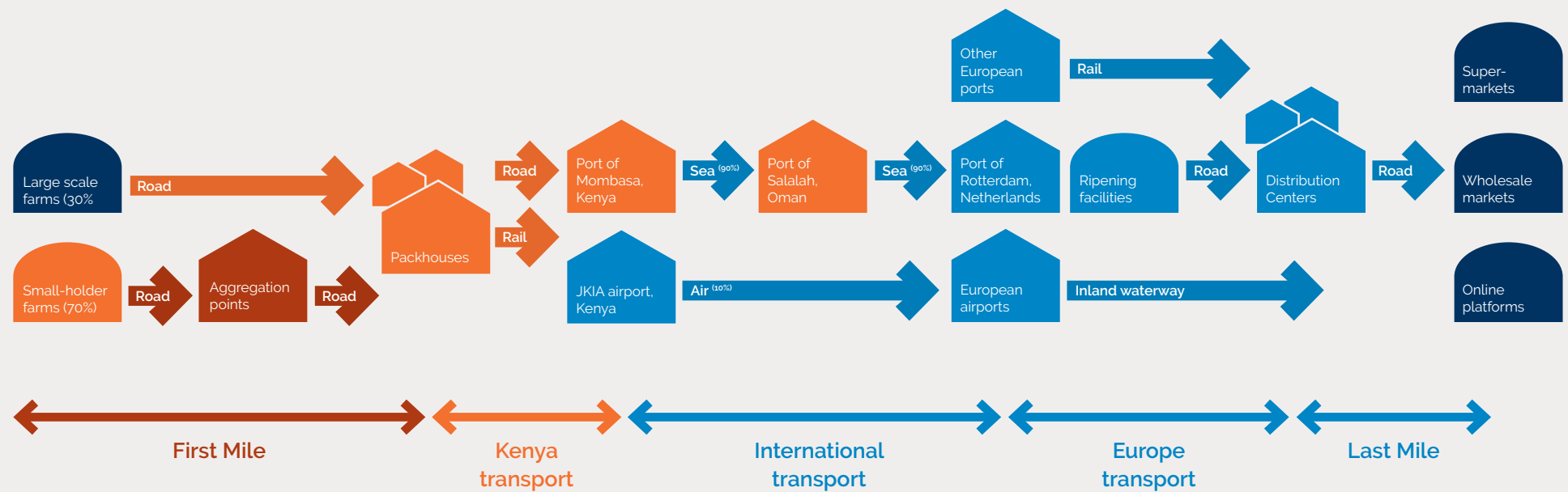
Map the chosen supply chain from origins to destinations, including supply chain nodes, transport modes and logistics hubs. As Life-Links focuses on transport and logistics, consistency with the GLEC Framework V3.1 and ISO 14083 is important, with further details on logistics hub types available from Fraunhofer.^{61, 62, 63}

Where possible, use supply chain management tools to produce detailed maps. A practical, less resource-intensive approach is to begin with a simplified map - such as the example below for an avocado supply chain - and develop details only for the critical transport link selected later. It is also useful to define segments as first mile, middle mile (potentially multiple in global supply chains), and last mile. Apply color-coding to qualitatively indicate disruption risk as low, medium or high.

Table 1: Nodes, modes and hubs that make up a supply chain

	Supply chain node	Transport mode	Logistics hub
Symbol			
Definition	A place where goods originate, are transformed, stored (long-term warehousing or stockholding), sold or consumed	The means of moving goods between nodes or hubs	A side where goods are consolidated, transshipped, stored (as part of a transport activity), or handled in the transport chain
Examples	○ Farm ○ Factory ○ Forest ○ Mine ○ Online platform ○ Supermarket / Shop ○ Wholesale market	○ Air ○ Cable Car ○ Inland waterway ○ Pipeline ○ Rail ○ Road ○ Sea	○ Packhouse ○ Warehouse ○ Distribution center ○ Rail terminal ○ Maritime port ○ Port terminal

Figure 5: Mapped supply chain for an avocado supply chain from Kenya to Europe



b. Select critical transport or logistics link(s)

A transport or logistics link is a transport segment of the logistics network that connects two points. It always includes at least one transport mode, and may also include a supply chain node or logistics hub when these are part of the same connection. Examples include a road corridor, a port with its inbound and outbound road and sea connections, or the first mile from farm to packhouse.

A 'critical link' is a logistics link in a supply chain that is at risk of disruption, with the risk exacerbated by climate change, and whose failure would have significant impacts on stakeholders whose prosperity depends on the supply chain. The choice for a critical link should not consider the transport or logistics system in isolation, but rather in the context of its importance to the supply chain – specifically, the type of goods being transported and their value to key actors and stakeholders.

Some examples of a critical link selection from a supply chain perspective, with consideration of GHG emissions reduction potential, are:

- Existing logistics vulnerabilities.** For example, the first mile of Kenya's avocado supply chain from smallholder farms to packhouses is a critical link because losses can reach 40% mainly due to logistics issues (storage, transport, packing). Rural areas often drive production, but weak logistics – marked by poor roads, aging fleets, informality, and weak regulation – lead to high transport costs, spoilage, losses, and food short-

tages. From a development perspective, the first mile is also a critical link because smallholder farmers, first-mile transporters (often informal or "popular" transport¹⁴⁴), cooperatives and their communities are the ones whose livelihoods are most affected by disruptions. Reducing food losses here also cuts a hidden source of GHG emissions in agriculture.

- High volume or value of goods and costs.** For example, the Port of Durban is Africa's biggest port, handles over 60% of South Africa's containerized cargo. It is also vulnerable to climate change and equipment breakdowns, resulting in berthing delays and reduced handling capacity in 2023 and 2024 and contributing to unreliable services and higher costs.^{64, 65} This directly impacts the profitability of maritime carriers and exporting companies and ultimately the country's economy. The vulnerability of global container shipping to wider risks adds to the importance of port resilience.⁶⁶ Reducing port congestion also lowers emissions from idling ships and trucks.
- Seasonal vulnerability.** For example, the 50-mile Georgetown-Vail stretch of the I-70 corridor through Colorado's Rocky Mountains in the United States is a critical link because avalanches and heavy snow regularly close the road, leaving few alternatives.⁶⁷ It is a major freight route between the Midwest and Western States and also supplies mountain tourism towns. Closures disrupt both interstate trade and local communities who depend on the corridor for jobs, services, and daily essentials.⁶⁸ Avoiding detours and idling during closures also reduces fuel use and emissions.

- Lack of alternative routes.** For example, Laos PDR's road segment in the North-South Economic Corridor between China and Southeast Asia is a critical link for agricultural and manufacturing supply chains. Alternative routes are scarce, railway infrastructure is limited, there are no seaports, and its road infrastructure is highly susceptible to climate hazards.⁶⁹ Disruptions are most felt most acutely by Lao communities, companies and the country's economy. Investments that improve efficiency can also reduce freight emissions over time.
- Regional economic life.** For example, the Gotthard Pass region in Switzerland is a critical link because tunnels and roads there carry large volumes of north-south European trade. The same routes also supply Alpine communities with food, fuel, and household essentials. Limited alternatives for crossing the Alps mean disruptions directly affect both European trade and local livelihoods.⁷⁰ Protecting this corridor also safeguards Europe's shift from road to lower-emission rail freight.
- Overlap between supply chains for consumers and buyers.** For example, Tanzania's transport routes for agricultural, processed food and manufactured products consumed by households show significant overlap with international buyers purchasing goods from or passing through Tanzania. Two segments of trunk roads of 181 km combined were selected as critical links based on the goods passing through and the impacts from disruption.⁷¹ Upgrading these trunk roads reduces congestion, cutting costs and emissions for multiple supply chains.

c. Define supply chain elements within the critical link

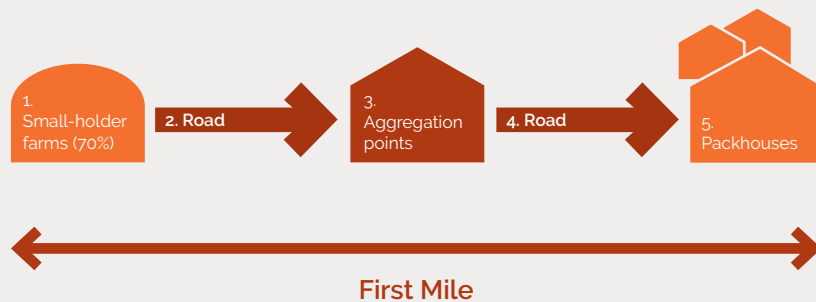
Take the supply chain map as a starting point to define supply chain elements for the critical link. A supply chain element (SCE) is the smallest building block in a supply chain, that ideally spans no more than

- One activity at a node.
- One transport mode movement between two points.
- One activity at a logistics hub.

When a supply chain element involves a transport or handling activity, it is also considered a Transport Chain Element (TCE) under ISO 14083 / GLEC Framework.

Depending on the desired level of detail, record descriptive attributes where applicable (e.g., port name or code, vehicle type, geographic locations of roads, facility type, assets used, and operating requirements such as bulk vs. liquid, temperature-controlled, or containerized).

Figure 6a: First mile 'critical link' for an avocado supply chain from Kenya to Europe



Supply chain elements (and if also a transport chain element):

1. Post-harvest storage at small-holder farms (not TCE)
2. Road freight to aggregation point (small vehicles) (TCE)
3. Aggregation point – sorting and consolidation (TCE)
4. Road freight to packhouse (small vehicles or medium trucks) (TCE)
5. Packhouse – cooling (TCE) and packing/branding for sale (not TCE)

Figure 6b: Port terminal operations 'critical link' for a soy products supply chain from Brazil to China



Supply chain elements (all are transport chain elements):

1. Road freight transport to port
2. Rail freight transport to port
3. Port terminal – truck gate operations
4. Port terminal – rail arrival operations
5. Port terminal – unloading into silos or conveyors
6. Port terminal – temporary storage / yard handling
7. Port terminal – vessel loading
8. Maritime transport to China

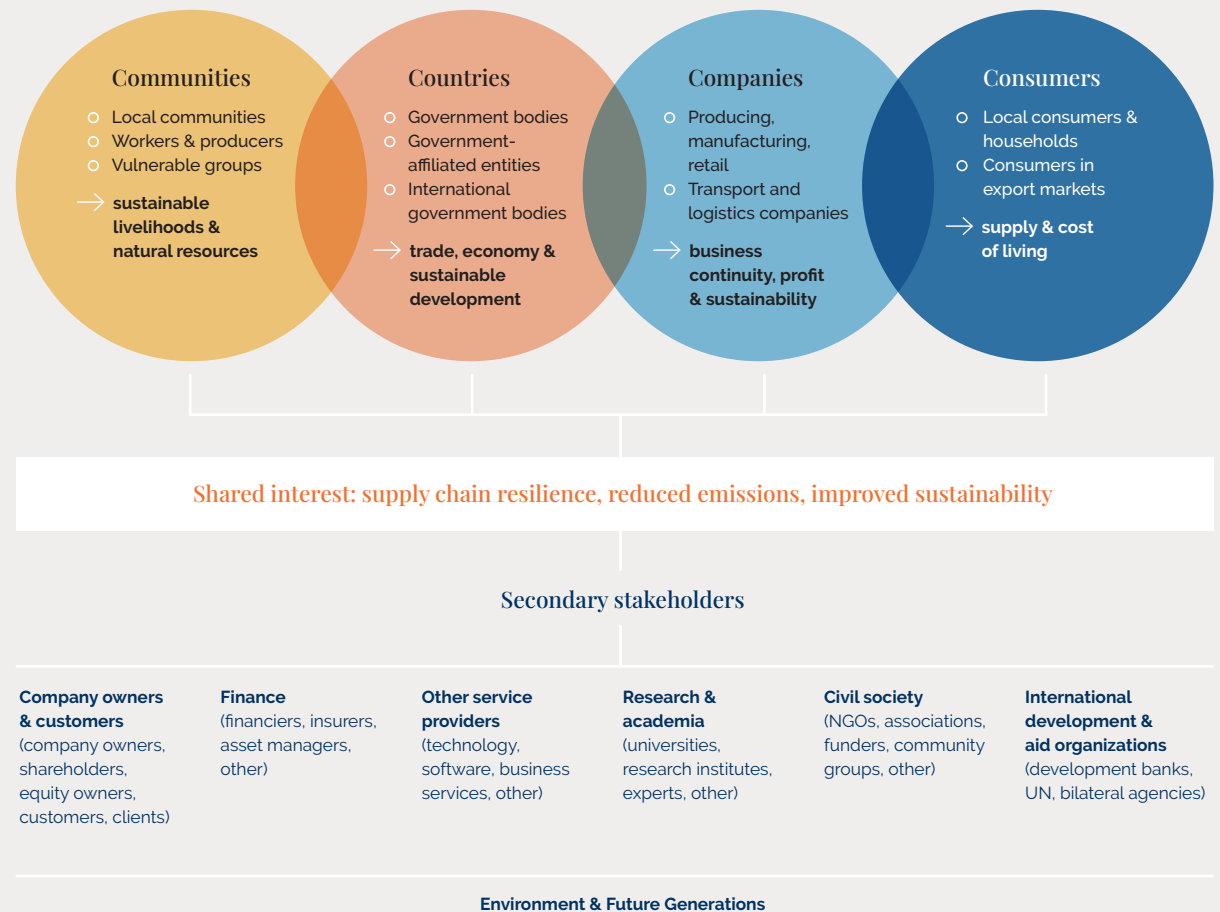
0.3 Identify stakeholders and key actors with shared interest

a. List the type of stakeholders and actors

List which type of stakeholders and actors are relevant to the supply chain. In the context of Life-Links a stakeholder has an interest in, can influence, or are affected by the outcome of the project, whereas actors may actively participate in the project and in making decisions. Primary stakeholders are communities, countries, companies and consumers, whereas secondary stakeholders work with, for, on behalf of primary stakeholders. The below figure and the resource in Part D can be used as a starting point, including alignment with the structure that EU directives (CSRD and CSDDD) expect companies to use when identifying stakeholders.

➔ *Part D-6: List of Stakeholders and Actors*

Figure 7: Supply chain stakeholders and actors and their interests



b. Categorize stakeholders and actors

Next, categorize and prioritize your stakeholders based on the critical link and the full supply chain. This should be done in a way that shows different levels of influence on the resilience of supply chains, while at the same time allowing for practical stakeholder engagement that is necessary for taking action.

c. Identify key actors with shared interest and potential partners

Finally, identify the key actors you will likely need to approach early and actively engage for the project to succeed. As part of this, determine their motivations and whether there is a shared interest in keeping the supply chain functioning. If key actors join as project partners, steps 1 to 3 can be carried out jointly, resulting in a shared implementation plan of feasible actions.

For example, if soybeans are selected as a supply chain going through the Port of Santos to export markets in China, then Chinese state-owned trading firms, feed manufacturers and processors are likely key actors. Will port resilience matter (enough) to them and are there transport links connected to the port that should be considered? In some cases the initiator of the project may wish to involve a trusted third party acting transparently to oversee the steps and manage the power imbalances along supply chains that often hinder cooperation.

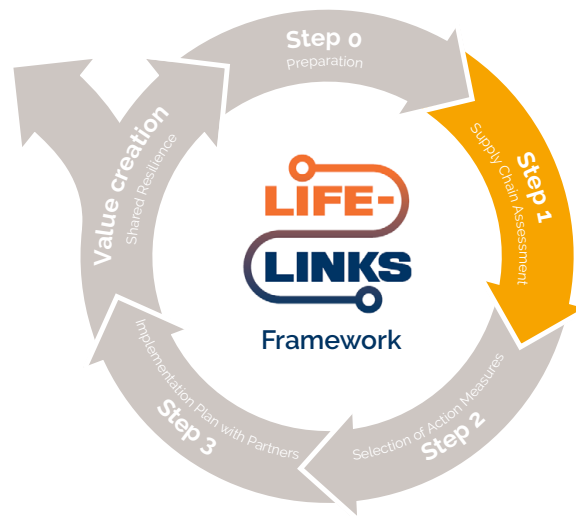
Table 2: Supply chain actors and stakeholders

Level	Description	Example for a port	Example for first mile avocados Kenya
1. Micro	Actors that are directly involved at the level of the critical link through ownership, oversight, operations, or direct work, and who play an active role in coping with disruptions and resilience measures	Port level: - Port authority - Regulatory agencies - Terminal operators	- Farmers and farmer cooperatives - Middlemen / aggregators - Exporters (buying at the farm) - Packhouse operators
2. Meso	Actors that depend on the link for freight flows and enable its functioning through transport, logistics and coordination, and who play an active role in coping with disruptions and resilience measures	Carriers: - Shipping lines - Rail carriers - Trucking companies - Logistics service providers (LSPs)	- Local transport operators - Service / solutions providers (e.g. cold storage rooms) - Exporters (buying from the middlemen)
3. Macro	Actors that are indirectly impacted by the supply chain performance and disruptions, and who have an influence in resilience at a supply chain or system level through freight demand, regulations, services or co-location	Customers and stakeholders: - Cargo owners - Logistics - Manufacturing - Industry - Energy - Fishery - Communities - Tourism	- Importers, their customers (wholesale & retail markets), and consumers - International logistics service providers (LSPs) - Trade associations (e.g. Kenya produce exporters, shippers and LSPs in Africa and Europe) - Government (e.g. Kenya Ministry of Agriculture, transport authorities) - Communities - Local and international NGOs - Development agencies
4. Meta	Actors who shape the long-term resilience through financing and risk valuation.	- Finance - Insurance	- Financiers - Insurers

Step 1: Supply Chain Assessment

Outcome: determined which and how supply chain stakeholders are impacted by disruptions of critical transport links exacerbated by climate change.

Step 1: Supply Chain Assessment



- 1.1 Identify key hazards and characterize exposure
- 1.2 Assess existing logistics challenges and impacts
- 1.3 Assess exacerbated effects from climate change

An assessment of risks and impacts of supply chain disruptions can be carried out in different ways, from qualitative to quantitative, and at varying levels of depth. The choice depends on the time, resources, and data available, which will naturally differ from one application to another.

If a decision is made to carry out a comprehensive climate risk assessment (CRA), then there are multiple guidelines available. In addition, the FAIR data guiding principles can support the assessment of supply chain risks and impacts, especially when data is obtained and integrated from multiple sets and sources and combined with AI.

➔ *Part D-2: Guidelines and Tools provides further resources on conducting climate risk assessment*

➔ *Part D-8: Fair Guiding Principles on Data*

The supply chain assessment approach described here is pragmatic working within the limits of time, resources, and data. The is done by:

- Taking a bottom-up perspective, starting with conversations with stakeholders, and it stays focused on the supply chain, looking closely at the challenges that disrupt logistics and drive up costs.
- Prioritizing to make it evident that costs and other impacts will rise in the future due to increasing climate change – companies and other stakeholders are far more likely to invest in solutions when they already see the price of today's logistics challenges and resulting disruptions.
- Making results relevant to stakeholders as gaining their support for collaborative actions to build resilience is essential. If stakeholders cannot see themselves in the

picture – or fail to grasp the projected negative impacts of climate change on their supply chain – securing their buy-in becomes a major challenge.

Box 3: Risk definitions expanded for logistics systems ^{4, 66}

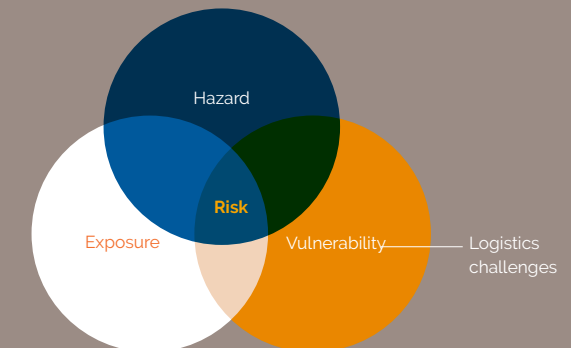
A risk results from dynamic interactions between hazards, exposure and vulnerability across the logistics system.

Hazard: potential occurrence of a physical event or trend that may cause harm to societies or ecosystems – or in logistics systems may harm infrastructure, operations, or the workforce.

Exposure: the presence of people, species, infrastructure, or other valuable assets in places and settings that could be adversely affected – or in logistics systems, the concentration of infrastructure, operations and workforce in hazard-prone areas.

Vulnerability: the propensity or predisposition to be adversely affected by a hazard – or in logistics systems, the susceptibility to disruption of networks, infrastructure, operations, workforce, and the flow of goods, finance and information/data.

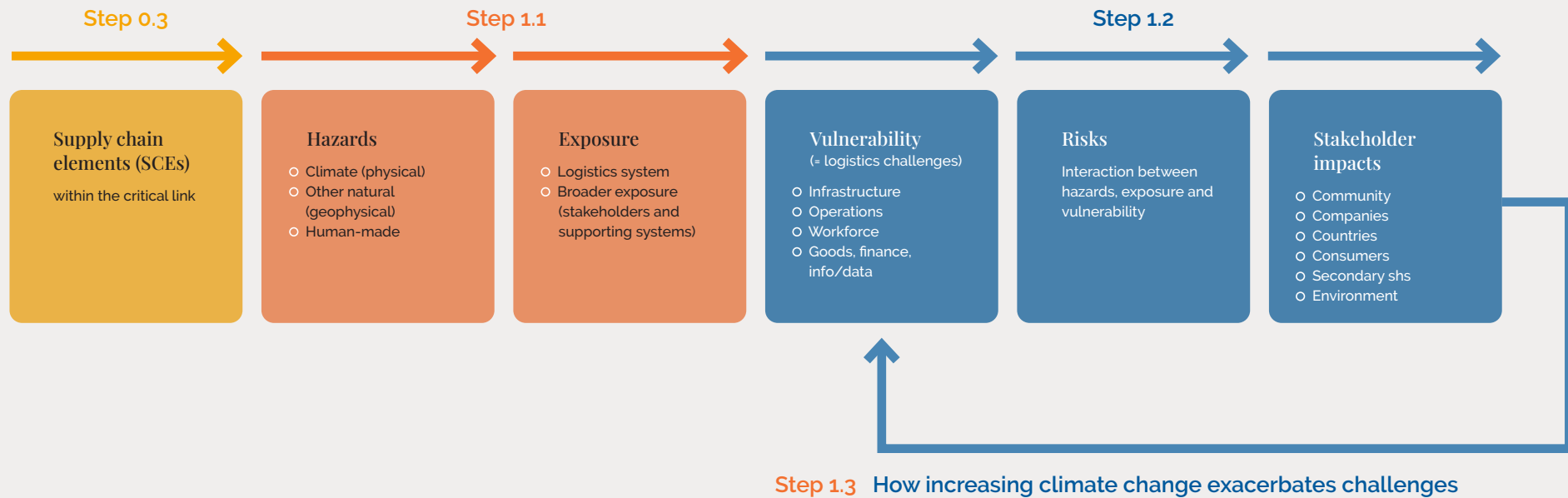
Logistics challenges: problems or inefficiencies that make it difficult to move, store, and handle goods efficiently within supply chains.



This step begins with a qualitative identification of key hazards to the critical link and a characterization of exposure, looking beyond climate hazards and the logistics system to place the assessment in a broader context. (sub-step 1.1). This is followed by a vulnerability assessment focused on existing logistics challenges,

and the resulting disruption risks and impacts (sub-step 1.2). Then it is assessed how climate change will make today's logistics vulnerabilities even worse (sub-step 1.3). For example, the lack of refrigeration generates food waste, and higher temperatures exacerbate this problem.

Figure 8: Supply chain assessment process



1.1 Identify hazards and characterize exposure

Begin with a qualitative determination of hazards and exposure to supply chain disruptions, extending beyond climate change. This ensures the assessment remains relevant to stakeholders, especially companies with broader supply chain risk management approaches.

a. List relevant climate and other hazards

Start by listing the climate hazards that currently apply to the transport/logistics SCEs that make up your critical link. For example, sea-level rise applies to a port but not to a packhouse located inland, whereas storms apply to both. List relevant other hazards, for example, earthquakes, political instability or a conflict. These may be important for the willingness to invest in strengthening the critical link within the existing supply chain, as many companies are rethinking their entire supply chain network.

Part D-7: Hazards to Supply Chains and Logistics

b. Characterize the logistics system exposure

Explain the exposure of the critical link SCEs including:

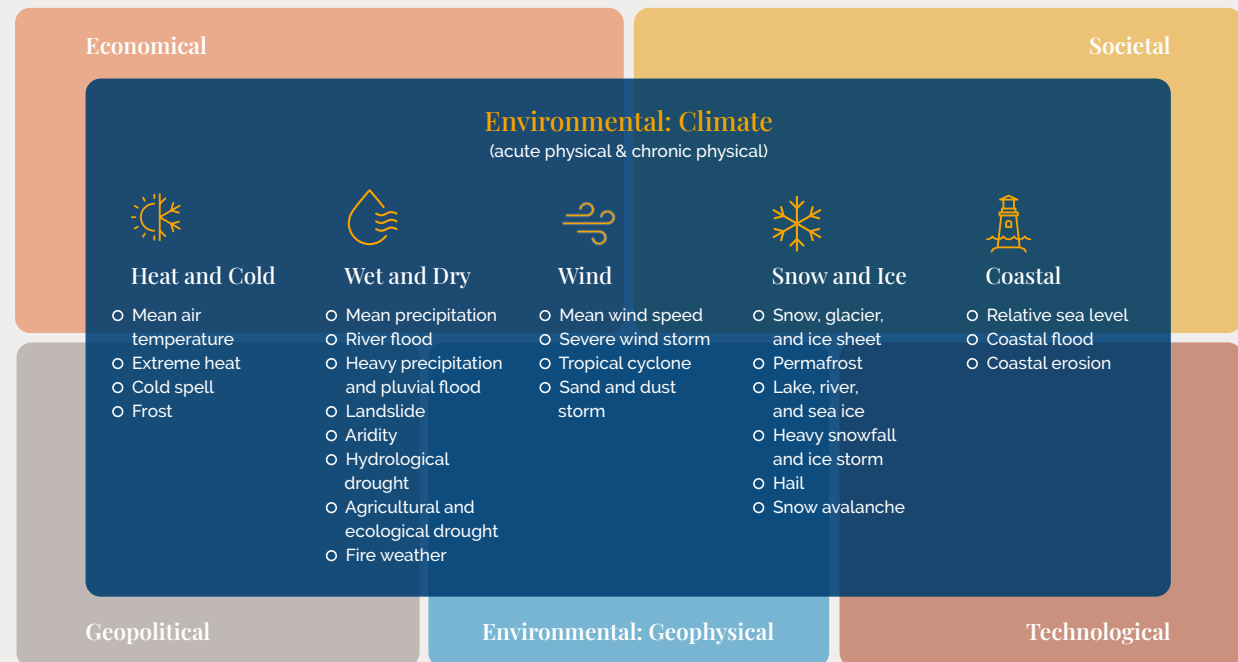
- Network (the spatial configuration of nodes, modes and hubs, and which the critical link is part of).
- Infrastructure or physical assets (transport infrastructure, logistics hubs, vehicles, equipment).
- Operations (management processes, systems, and governance structures).
- Workforce (own workforce, contractors, suppliers).
- Flow of goods, supported by related flows of finance and information/data.

c. Characterize the broader exposure

Characterize the broader exposure, which refers to the dependence of stakeholders (companies, countries, communities, consumers and secondary stakeholders) on logistics flows, making them vulnerable to disruption even

beyond the logistics system itself. For example, local communities living near a port are also exposed to storms or strikes that shut a port down. This also includes supporting systems (societal, legal, financial, physical, nature-based – see Part D-2).

Figure 9: Relevant climate hazards for land and water transport in the context of broader hazards⁵



1.2 Assess logistics vulnerabilities, risks and impacts

Once broad hazards and exposure have been determined, the next step is to zoom into the logistics system to assess vulnerabilities and identify risks and impacts.

One approach is to assess the vulnerability of transport modes and logistics hubs that make up the critical link, as show in Table 3. For example, an unpaved road or one

lacking drainage is more vulnerable, and poor maintenance further increases the risk. However, developing vulnerability relationships based on hazard intensity and exposure characteristics is challenging and often requires detailed site-specific information, which is frequently lacking.

A pragmatic solution is to use existing logistics challenges as the entry point. Logistics challenges are the problems or inefficiencies that make it difficult to move, store, and

handle goods efficiently through a supply chain. They can relate to infrastructure (e.g. unpaved roads, limited cold storage, inadequate vehicles), operations (e.g. inefficient collection, long lead times, packhouse bottlenecks), workforce (e.g. limited skills, long work hours, exposure to heat stress), flows (e.g. perishable goods with short shelf-life, broken cold chains, payment delays, data errors), or the external environment (e.g. certification requirements, customs procedures, market standards).

Table 3: Examples of vulnerabilities to climate hazards for different transport modes and logistics hubs⁵

Transport modes and logistics hubs	Infrastructure vulnerabilities	Operational vulnerabilities	Workforce vulnerabilities
Road	- Heat warps/asphalt - Freeze-thaw damage - Erosion, landslides, flooding - Coastal flooding/saltwater corrosion	- Flooded/iced roads impassable - Hazardous driving in storms/winds - Snow/ice closures	- Drivers face accident risks in storms/floods/snow - Long-haul drivers face heat-stress
Rail	- Heat deforms tracks (derailment risk) - Freeze-thaw weakens embankments - Erosion/landslides - Bridge scour - Coastal flooding undermines railways	- Flooding disrupts services - Trains slowed in heat - Snow/ice blocks tracks	Frostbite and hypothermia risks for workers de-icing lines or clearing snow
Inland waterway	Bridge scour from higher river flows	- Heavy rain raises levels beyond navigability - Drought/low water restricts navigation - Reduced snowmelt worsens low-water events	Fast currents and high water levels increase risk of collision or grounding
Sea	Melting sea ice alters routes, increases risk	- Severe storms/winds disrupt shipping - Snow/ice decline lengthens Arctic seasons but can still block routes	Seafarers exposed to storms, ship motion, and sea spray
Warehouse / Packhouse / Distribution center	- High winds tear off roofs/destabilize structures - Heavy snow overloads roofs	Flooding inundates warehouses/terminals, damaging goods and halting operations	- Heat stress in non-cooled spaces - Injuries if structures fail
Rail terminal	Flooding and freeze-thaw damage	Disruptions if tracks/handling areas are flooded or snow-covered	Wildfire smoke exposure for platform staff and yard workers
Marine port / terminal	- Sea level rise/storm surges damage ports - Saltwater accelerates corrosion	- High winds halt crane operations - Flooding/storm surge disrupts access	- Dock workers face heat illness - Exposure to storms/high winds/sea conditions

Focusing on logistics challenges makes vulnerabilities more tangible and enables an easier connection to risks and impacts that stakeholders can clearly recognize. It also helps them understand how climate change may exacerbate existing challenges. This is illustrated with the avocado application in Table 4.

a. Understand logistics challenges

Begin with the supply chain elements that make up your critical link as defined in Step 0. For these elements, identify the existing logistics challenges that affect the flow of goods transportation through the supply chain.

The most effective approach is to first consult stakeholders who have a direct role in the supply chain – such as farmers, cooperatives, shippers, logistics service providers (LSPs), associations, or non-governmental organizations (NGOs) – to understand the day-to-day challenges they face. This ensures that the type of goods being transported, as well as its stakeholders, are implicitly considered, both of which are key determinants of the impacts of transport disruptions (and subsequently the value created by addressing them). These stakeholders are also more likely to know what possible solutions exist or have been

attempted, with whom, and may later support the implementation of action measures.

It is important to note that only a combination of stakeholder perspectives can provide a true understanding of the underlying reasons behind certain challenges. These extend from the field to the final consumer. For example, a trader may describe delays at the first mile that affect the shelf life of avocados, while a European importer may add that inconsistent quality is exacerbated by different batches of avocados with varying remaining shelf lives being loaded into one container.

Table 4: Risks of supply chain disruptions exacerbated by climate change – example first mile for an avocado supply chain from Kenya to Europe

Supply chain elements	Hazards	Exposure	Vulnerability (= logistics challenges) and relevant SCEs	Risks	Impacts: stakeholder value	How climate exacerbates challenges
1. Storage at small-holder farms	Acute climate: ○ Heavy precipitation and pluvial floods	○ Goods (avocados)	Infrastructure	○ Food waste	Community: ○ Farmers, cooperatives: lower price, financial resilience	○ The higher the temperatures, the bigger the impact on shelf-life
2. Road freight to aggregation point (small vehicles)	○ Extreme heat	○ Farms	○ Unpaved roads (2)	○ Loss of product quality	○ Middle men: lower margins, financial resilience	○ Heavy rainfall makes rural roads from farms to aggregation points impassable and collection less predictable
3. Aggregation point - sorting and consolidation	Chronic climate: ○ Rising air temperature	○ Roads	○ Transport with open pick-ups and vans without AC (2,4)	○ Inefficient collection of goods	Companies: ○ Exporters: lower revenue from product sales & higher costs	○ Increased storms, floods and precipitation patterns makes disruptions of transport to pack-houses more frequent
4. Road freight to packhouse (small vehicles or medium trucks)	○ Changing precipitation patterns	○ Logistics hubs (aggregation points, packhouse)	○ Lack of cool/cold storage infrastructure (1,3)	○ Road impassability	○ Importers/retailers: lower quality products with potentially lower sales price	
5. Packhouse – cooling and packing/ branding for sale	Other hazards (optional, see Part D-8)	○ Vehicles	○ Limited capacity at pack-houses during peak season (5)	○ Transport delays	Country: tax/revenue, GDP, infrastructure repair costs	
		○ Workers	Operations	○ Long waiting times at packhouses	Consumers: higher prices, lower quality and/or reduced availability	
			○ Scattered farms, inefficient collection process (1)	○ Worker heat stress and safety incidents	Environment: GHGs associated with food waste and logistics delays	
			○ Inconsistent use of crates during transport (2,4)			
			○ Long transport lead times from Western counties to Nairobi packhouses (4)			
			Flows (goods)			
			○ Avocados have a limited (remaining) shelf-life or time-to-market (1–5)			
			○ Avocados are vulnerable to bruising, fungi, and heat (1–5)			

b. Connect logistics challenges with risks

Next, determine how these logistics challenges can lead to risks of disruption. For example, as shown in Table 5, unpaved roads are more susceptible to heavy rain and flooding, which can make roads impassable or delay transportation. Inconsistent use of crates may lead to bruising of avocados transported in open pick-up trucks along these roads. Since logistics challenges often connect to multiple risks, use a matrix to record and analyse these relationships.

c. Determine impacts for stakeholders

Make the connection between the risks from disruptions and the potential impacts on stakeholders – communities, companies, countries and consumers – especially on the (socio-)economic value that these supply chains bring. For example, farmers may get less income from avocados, while importers and retailers are faced with lower product volumes or quality, which may affect the price they can charge consumers. For example, household loss as % of income (due to increase in transport costs and due

to shortages).⁷ An expanded impact analysis could also include secondary stakeholders, such as insurers facing increased claims resulting from infrastructure failures.

The “environment” and future generations that depend on this, should be treated as a distinct stakeholder. For example, if avocados are discarded, the resulting food waste generates GHG emissions, which may need to be accounted for by companies sourcing avocados from this supply chain.

Table 5: Logistics challenges and their impact – example first mile for an avocado supply chain from Kenya to Europe

Vulnerabilities (= logistics challenges)	Risks						
	Food waste	Loss of product quality	Inefficient collection of goods	Road impassability	Transport delays	Long waiting times at packhouses	Worker heat stress and safety incidents
Avocados have a limited (remaining) shelf-life or time-to-market	X	X					
Avocados are vulnerable to bruising, fungi and heat	X	X					
Lack of cold storage infrastructure and broken cold chains	X	X					
Scattered farms, inefficient collection process	X		X		X		X
Unpaved roads		X		X	X		X
Transport with open pick-ups, vans, without AC	X	X					X
Inconsistent use of crates during transport		X	X				
Long transport lead times from Kenya Western counties to Nairobi packhouses	X		X		X		X
Limited capacity at packhouses during peak season	X		X		X	X	

Where possible, validate assumptions about how disruptions affect stakeholder value. This is critical for building cooperation on future solutions. For example, if most of the costs associated with losses are currently borne by farmers and first-mile operators, importers and retailers may not yet feel sufficient financial impact to do anything about it. Try to show if this could change over time, as has already been observed in coffee and cocoa supply chains due to climate change, reduced interest to become a coffee farmer, and other reasons.

➔ Part D-9: Examples of Metrics and Indicators

When assessing impacts on communities, it is essential to take a holistic view of their livelihoods, as these are ultimately what we aim to protect. Sustainable livelihoods are commonly defined through five types of capital that people draw upon to achieve their livelihood objectives, and which can be impacted by disruptions: ¹⁰²

- Physical capital: basic infrastructure (e.g., transport, shelter, water supply, energy, communications) and producer goods (e.g., tools, machinery).
- Financial capital: financial resources available to people, including stocks (e.g., savings, livestock) and regular inflows (e.g., remittances), which can support both consumption and production.
- Social capital: the social resources people can access (e.g., networks, connections, memberships, and relationships of trust, reciprocity, and exchange).

- Natural capital: natural resource stocks (e.g., land, water, forests, biodiversity) and the associated flows and services they provide (e.g., nutrient cycling, erosion protection).
- Human capital: the skills, knowledge, health, and capacity for labor that enable people to make use of the other four forms of capital.

1.3 Assess exacerbating effects from climate change

Finally, go back to revisiting the identified logistics challenges with a climate lens. The purpose is to understand how climate change could worsen current bottlenecks, create new hazards, or trigger complex chains of disruption across the logistics system. By looking at both direct and indirect impacts, this assessment helps ensure that resilience measures address not only today's challenges but also tomorrow's risks.

a. Describe how climate change exacerbates logistics challenges

Revisit your identified logistics challenges and assess whether climate change is likely to make them worse. For example, a road or railway that is currently only occasionally impassable due to rain may, with more frequent and severe rainfall, face regular disruptions. This could reduce profit margins for farmers, producers, or transporters to unsustainable levels or lead customers to stop ordering products due to higher prices.

b. Check for possible new future climate hazards

Also check for hazards that may emerge in the future. For example, a port that has not yet experienced flooding or extreme heat days may begin facing these risks within the next decade. Here is where risk assessment and climate modelling tools can come in handy to determine the extent of the risks (based on likelihood and severity) today and in the future. For example, a study of Brazilian coastal public ports made use of a risk index to classify risks from 1 (very low) to 5 (very high) for strong winds, storms and sea level rise.⁷² It is noted that most of these tools still lack the spatial granularity to assess at the level of a supply chain element.

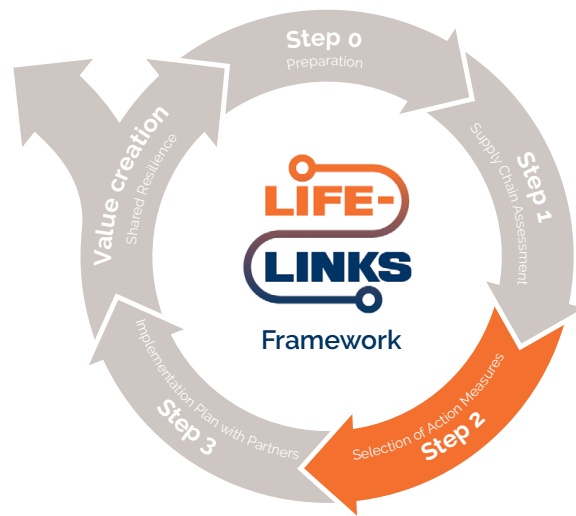
c. Identify compounding risks and cascading effects

Identify where multiple climate-related hazards may overlap or interact with existing logistics challenges. For example, prolonged drought may simultaneously reduce crop yields and restrict inland waterway transport, or heat waves may coincide with energy shortages that disrupt cold storage and refrigerated transport. Such interactions can create "knock-on" effects across the supply chain, multiplying risks beyond those of individual hazards.

Step 2. Selection of Action Measures

Outcome: a feasible and resilience-effective package of proposed measures for the critical transport links, with opportunities for decarbonization and sustainability

Step 2: Selection of Action Measures

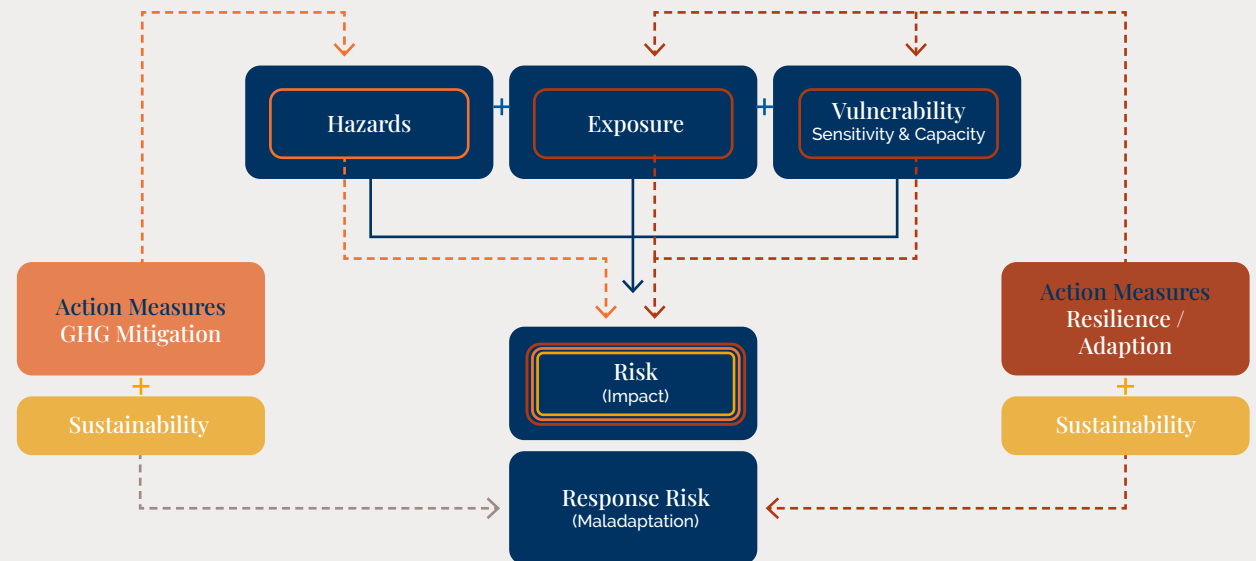


- 2.1 Identify and pre-select action measures that build resilience
- 2.2 Assess feasibility and effectiveness for resilience
- 2.3 Add safeguards, decarbonization and sustainability opportunities

Figure 10 shows the importance of an integrated approach to mitigation and adaptation. Resilience or adaptation measures reduce the exposure and/or vulnerability of the logistics system, whereas GHG mitigation measures

reduce the climate hazards or causes of climate change. Opportunities to improve sustainability can be combined with other measures, although this is not always easy in practice.

Figure 10: Action measures for enhanced resilience/adaptation, GHG mitigation, and sustainability



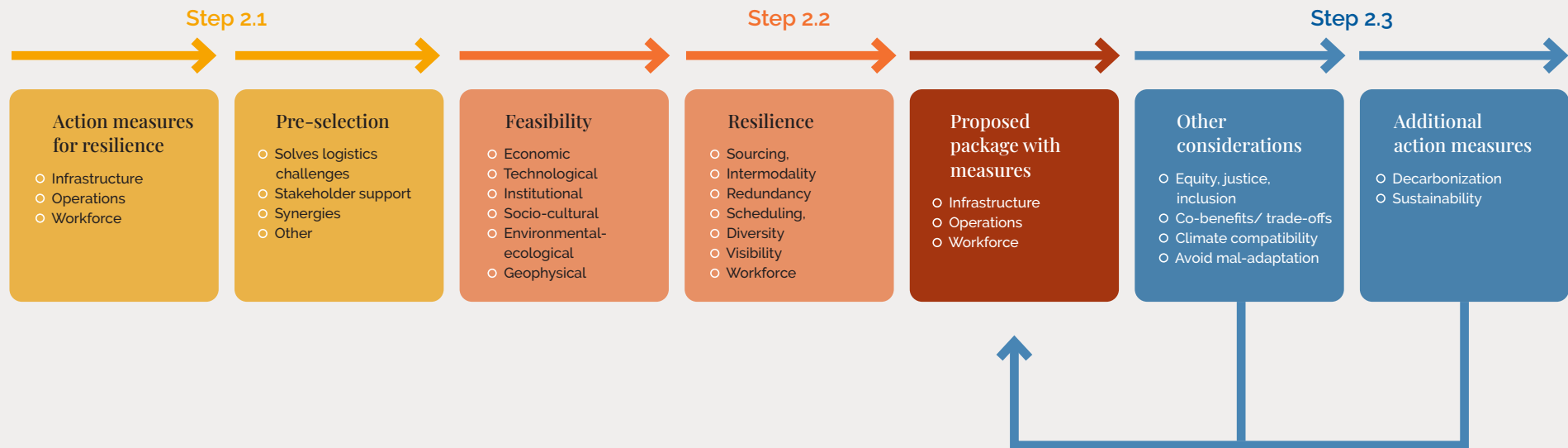
Based on ISO14091:2021⁷³ and compatible with IPCC.

The term "action measures" is used to distinguish it from disaster risk management "response measures"; and from GHG "mitigation measures". Action measures are broadly categorised as: Structural/physical (engineering/built environment; technological; eco-system based); Social (educational, operational, information-related, behavioural); Institutional (economic, regulation, policy & programmes)¹¹⁸

In this step, potential action measures are identified, screened, and analyzed in detail to create a feasible, resilience-effective, and future-proof package. The process begins with compiling and pre-selecting action measures aimed at improving resilience (sub-step 2.1). These are then assessed for feasibility and resilience effectiveness,

including checks for maladaptation risks (sub-step 2.2). Finally, the package is enhanced by applying considerations such as equity, justice, and inclusion, and by actively seeking additional opportunities for decarbonization and wider sustainability (sub-step 2.3).

Figure 11: Selection of action measures process



2.1 Identify and pre-select action measures that build resilience

Develop a long list of potential measures, screen them against logistics challenges and stakeholder benefits, note synergies, and make a pre-selection for further analysis. Table 6 shows examples of measures across three main strategies for dealing with risks in logistics systems:

- Avoid focuses on reducing exposure by redesigning supply chains to bypass hazards altogether.
- Manage involves accepting that hazards will occur and emphasizing the ability to prepare, respond, and recover. This approach aligns with the stages of disaster risk management: before (prevention and preparedness), during (response), and after (recovery).
- Strengthen seeks to address underlying vulnerabilities within the logistics system itself, improving resilience across existing routes and its transport modes and logistics hubs.

Life-Links prioritizes measures within the strengthen strategy. The focus lies on enhancing long-term, structural resilience by addressing the root causes of disruptions in logistics systems, rather than pursuing strategies of avoidance.

Resilience at the transport, logistics or supply chain level is characterized by nine attributes or aspects that these measures help improve (7-9 are newly added): ⁸

- 1. Sourcing:** average distance freight consignments move in a supply chain, SCE or trip, and how far and from where goods are procured.
- 2. Intermodality:** extent to which using different transport modes spreads disruption risk, and the ability to switch modes before or during disruptions.
- 3. Redundancy:** amount of spare capacity and inventory in the logistics system to buffer interruptions to the flow of goods.
- 4. Scheduling:** degree to which production and logistics processes are synchronized (e.g. just-in-time, replenishment) and flexibility in timing and coordination of flows.
- 5. Diversity:** range of options available for routing freight, suppliers, carriers, clients, or energy sources.
- 6. Visibility:** degree of supply chain and supplier visibility; stakeholder awareness and capacity, and the nature and speed of communication about disruptions.
- 7. Workforce:** capacity, safety, wellbeing, and awareness of logistics workers, contractors and suppliers in managing disruptions.

8. Cyber and digital: robustness of digital systems, data, and communications against cyber attacks, system failures, and data breaches.

9. Protection of goods in transit: the degree to which goods are safeguarded against damage, spoilage, contamination, theft, or loss during transport, handling, and storage.

In practice, most resilience measures are multi-functional, strengthening more than one attribute at a time. For example, diverting flows from high-risk routes reflects diversity by using alternative routing options, but it also depends on redundancy in the network – spare or parallel capacity that allows rerouting. Similarly, solar-powered cold storage provides redundancy (backup energy), creates diversity (an alternative power source), and enhances visibility when digitally monitored.

Table 6: Resilience measures for transport and logistics in supply chains

Logistics system	Resilience strategy		
	Avoid (reduce exposure)	Manage (prepare, respond, recover)	Strengthen (long-term structural resilience)
Infrastructure	○ Repositioning of nodes and assets from high-risk locations ○ Reducing dependence on more risk-prone modes ○ Additional logistics hubs ○ Increase storage capacity for additional inventory ○ Diversion of flows from high risk routes	○ Regular inspection and maintenance ○ Predictive maintenance ○ Strengthen assets against risk factors ○ Duplicate / spare critical equipment ○ Install back-up power supply and IT support ○ Real-time monitoring and early warning systems	○ Multimodal resilience within existing corridors ○ Retrofitting & upgrading existing infrastructure ○ Protective systems and barriers ○ Enhanced drainage systems ○ Nature-based & hybrid solutions ○ Smart monitoring & predictive maintenance ○ Energy & utility resilience
Operations	○ Near-sourcing ○ Reduce dependence on risk-prone suppliers and carriers ○ Supplier diversification / multiple source critical suppliers ○ Expanding client base	○ Raise inventory levels ○ Business continuity plans ○ Dynamic routing and emergency scheduling ○ Rapid response during disruptions ○ Relax delivery schedules ○ Increase flexibility to switch machines, processes	○ Advanced planning & coordination ○ Process hardening & flexibility ○ Enhanced inventory, storage & packaging ○ Transport & logistics optimization ○ Cyber & digital resilience
Workforce & stakeholders	○ Reduce deployment in hazard zones ○ Remote operations / automation to limit workforce exposure	○ Emergency/safety protocols ○ Contingency plans for staff ○ Workforce capacity and rapid mobilization ○ Early warning systems for workers and stakeholders ○ Staff awareness program of risk factors and impacts ○ Communication network	○ Stakeholder engagement & collaboration ○ Capacity building & specialized training ○ Institutionalizing resilience roles & functions ○ Wellbeing & workforce support ○ Knowledge & continuous improvement ○ Parametric insurance schemes for drivers, suppliers, and logistics SMEs

Measures help improve one or more of nine resilience attributes: sourcing, intermodality, redundancy, scheduling, diversity, visibility, workforce, cyber & digital.⁸ See Part D-9 for examples of indicators. Structure based on KCC Logistics in a 2° C World⁵, GCA Climate-Resilient Infrastructure Officer Handbook¹⁰⁶, World Bank Lifelines⁷, UNDRR Sendai Framework, and protection of goods in transit.⁵⁶ Examples are not exhaustive.

a. Compile a list of potential measures

Start by compiling a long list of measures to improve resilience to supply chain disruptions at the logistics-system level. Use Table 6 and Part D-10 for guidance. Gather ideas from research, best practices, and stakeholder input relevant to the critical link - as done for avocados in Table 7 - to create a list of measures that different actors can lead. At this stage, the focus should be on identifying structural/physical and social measures, while supplementary institutional measures are addressed later in Step 2.3.

➡ **Part D-10. Resilience measures that strengthen existing routes and its transport modes and logistics hubs**

Box 4: Case Study: Improving resilience of road and rail freight networks after Australia's Black Summer bushfires ^{74, 75, 76}



The 2019–2020 “**Black Summer**” bushfires in Australia burned an estimated 24–33 million hectares, destroyed over 3,000 homes and hundreds of businesses, caused around A\$4–5 billion in insured losses, and resulted in the deaths of 33 people, with many more affected by smoke-related health impacts. The fires disrupted critical supply chains including agriculture and food distribution, mining and resources exports, forestry, and regional freight transport, highlighting vulnerabilities across road, rail and port networks.

Long-term resilience. A national review recommended strengthening the long-term resilience of freight supply chains through measures such as building redundancy into key corridors, hardening vulnerable assets, and embedding risk-based planning through vulnerability mapping. Key implementation steps since 2020 include:

- ❑ “Betterment” in recovery funding – Disaster Recovery Funding Arrangements (DRFA) now permit rebuilding damaged infrastructure (e.g. roads, bridges) to higher, hazard-resistant standards.
- ❑ Dedicated resilience finance – establishment of the Disaster Ready Fund, allocating A\$1 billion over five years to support pre-disaster risk-reduction upgrades, including transport and logistics networks.
- ❑ National coordination and data – reforms lead by the National Emergency Management Agency (NEMA), such as supply chain risk reviews, improved hazard data, and critical-infrastructure resilience planning to support long-term freight continuity.

Looking forward. The challenge will be to ensure these reforms are translated into systematic upgrades across critical freight corridors, so that Australia’s supply chains are not only capable of recovering from disasters but are progressively adapted to withstand the growing risks of future bushfires and climate-related hazards.

b. Check relevance to logistics challenges, stakeholders and synergies

Make a qualitative assessment of:

- ❑ Whether the potential measures address the right logistics challenges.
- ❑ Who are the main supply chain actors and stakeholders who would benefit.
- ❑ If measures within the same or in different SCEs can be combined for greater collective resilience. For example, aggregation points closer to farms can be combined with the use of plastic crates for safer transport and solar-powered mobile cold storage units that can extend the shelf life of fresh produce.

It may be more effective to do this early—right after compiling the measures—so that pre-selection is guided by solving real problems, meeting stakeholder priorities, and combined measures for greater collective resilience.

Table 7: Action measures that could improve first mile logistics resilience for an avocado supply chain from Kenya to Europe

Supply chain element	Action measure	How it improves resilience	Logistics challenges addressed	Key stakeholder beneficiaries	Synergies
Aggregation points	1. Pilot smaller aggregation points closer to the small-holder farms	Smaller aggregation points reduce the distance farmers must travel and enable more professional downstream transport, shortening vulnerable farm-to-market links	- Scattered farms, inefficient collection process - Open pick-ups/vans without AC (by buffering time/ temperature stress) - Unpaved roads (by shortening vulnerable trips) - Avocados shelf-life and vulnerability (indirectly, through shorter, better-managed transport)	Farmers and cooperatives; middlemen/aggregators; exporters; packhouse operators; local transport operators; government	2, 4
Aggregation points	2. Install solar-powered aggregation points with (mobile) cold storage	Solar-powered cold storage extends product shelf life in areas without reliable grid power, buffering against transport and market delays	- Lack of cool/ cold storage infrastructure - Avocados shelf-life and vulnerability	Farmers and cooperatives; middlemen/aggregators; exporters; service/solution providers; government	1, 3, 4
Packhouses	3. Develop packhouses in emerging production regions (e.g., North Rift/ Western counties in Kenya)	Regional packhouses reduce reliance on Nairobi, improve product quality, and spread risk across multiple facilities	- Lack of cool/cold storage infrastructure - Limited capacity at packhouses during peak season - Long transport lead times from Western counties - Avocados shelf-life and vulnerability	Farmers and cooperatives; middlemen/aggregators; packhouse operators; exporters; importers; LSPs; government; financiers/insurers	2, 4, 5
Road freight to aggregation points Aggregation points Road freight to packhouses	4. Use plastic crates to transport avocados from farm to packhouse, replacing buckets or plastic gunny bags/sacks	Plastic crates reduce bruising, cut waste, and speed up loading and unloading	- Inconsistent use of crates during transport (Ops) - Open pick-ups/vans without AC (partly, by reducing bruising during rough rides) - Avocados shelf-life and vulnerability	Farmers and cooperatives; middlemen/aggregators; exporters; packhouse operators; local transport operators; government; financiers/insurers	1, 2
All first mile elements	5. Real-time app about weather forecasts, harvest scheduling, pick up times, packhouse capacity (as well as prices)	Real-time apps improve coordination of harvest, storage, and collection, giving farmers and packhouses flexibility to adapt to disruptions	- Limited capacity at packhouses during peak season (by smoothing arrivals) - Scattered farms, inefficient collection process (by improving coordination) - Avocados shelf-life and vulnerability (by better timing harvest, storage, and pickup)	Farmers and cooperatives; middlemen/aggregators; exporters; packhouse operators; government; consumers; financiers/insurers	1, 2, 3, 4

c. Pre-select action measures

Based on the screening, pre-select the most promising action measures. This can be done qualitatively using pragmatic criteria, such as:

- Problem-solving: directly address priority logistics challenges, reducing vulnerabilities identified in Step 1.
- Stakeholder support: have strong stakeholder backing, especially from those likely to finance or implement them.
- Quick wins: are operationally straightforward and lower cost, offering near-term impact (e.g., research suggests that each additional dollar spent on road maintenance saves USD1.50 in new investments.⁷).
- Proven to work: have been tested in practice, either in the existing supply chain or elsewhere, and show potential for scaling. For example, a Uganda exporter already uses sealed fermentation drums that allow cherries to begin processing safely at the farm and during transportation by motorcycle down the mountain, avoiding molding issues in case of disruptions.⁵ This option might be scaled to multiple farms or even across a coffee region. Another example is parametric insurance that has been proven to work for smallholder farmers (see Box 5) and could be replicated or expanded to transport operators.
- Synergies: work effectively in combination with other measures, strengthening the overall package

Pre-selected measures are then carried forward to Step 2.2, where their feasibility, effectiveness for resilience, and broader impacts are assessed in more detail. In the avocado example, all five first-mile measures scored sufficiently well across these criteria and were therefore retained for detailed assessment.

Box 5: Case Study: Parametric insurance for smallholder women farmers

Parametric insurance provides payouts based on the occurrence of a predefined event, such as rainfall levels, temperature extremes, or flood depth, rather than on assessed losses. This allows for faster, more predictable compensation to farmers or other insured groups.

CelsiusPro Group (CPG) partnered with Frontier Markets, a rural social commerce platform, to help smallholder women farmers cope with climate risks. In India, smallholder women farmers represent 57% of agricultural labour and 28% of farmers. These smallholders rely on their crops for both subsistence and for income through selling to local markets. However, conventional insurance products are often unaffordable, inaccessible and ill-suited to the specific climate risks faced by women farmers, particularly in remote areas.

To address this gap, CPG structured a drought insurance product using its Water Balance Index, tailored to risks and vulnerabilities in the Indian provinces of Rajasthan and Uttar Pradesh. A survey of the target group was conducted to collect relevant exposure data, loss history data, and key insights to inform product design. Through Frontier Markets' platform, women smallholder farmers will be able to purchase policies and receive payouts directly to their linked bank accounts. The Natural Disaster Fund (NDF) – a source of reinsurance capacity for impactful parametric insurance programs in ODA-eligible countries – will have the opportunity to provide risk capacity for drought coverage.

Benefits for farmers. This example illustrates the potential of innovative parametric insurance mechanisms to strengthen the climate resilience of critical supply chains in emerging economies, particularly by targeting highly climate-vulnerable social groups. The “first mile” is strengthened in several ways:

- If smallholders suffer a loss due to heavy rainfall in the first 30-days, they can use the insurance pay-out to replant, ensuring continued food and income security.
- If smallholders suffer a loss due to drought during the growing season, they can use the pay-out as income compensation. This may help to encourage smallholders to continue farming rather than looking for alternative income sources.

Looking forward: Should parametric insurance be replicated for or expanded to transport operators, either in the first mile or further down the supply chain, then this will further increase supply chain resilience.



2.2 Assess feasibility and effectiveness for resilience

Once potential measures have been pre-selected, the focus turns to whether they are both practically feasible and genuinely effective in strengthening resilience, while avoiding maladaptation risks. The outcome of this step is a set of action measures that combine high feasibility across multiple dimensions, robust resilience outcomes, and the strongest returns on investment.

The process is not strictly linear. Measures that score highly on resilience may require revisiting their feasibility, and combinations of measures may change the overall assessment. Likewise, when cross-cutting filters and sustainability opportunities are applied in Step 2.3, this may lead back to re-examining feasibility or resilience effectiveness to refine the package.

Consistent with the partnership focus of Life-Links, the analysis should incorporate the perspectives of diverse stakeholders and actors, rather than being limited to a single-actor lens (e.g., a company).

a. Assess feasibility across multiple dimensions

Conduct a multi-dimensional feasibility assessment of each action measure, using the methodology described by the IPCC.^{78, 79} Begin by selecting feasibility dimensions or criteria (see Table 8), which may vary between projects or leading actors, recognizing that feasibility is context-dependent and may change over time. For each dimension, apply quantitative and/or qualitative indicators to determine feasibility. One useful approach is to assign each measure a score (e.g., low/medium/high) for each dimension, with optional weighting to produce an overall score.

Table 8: Feasibility criteria and example indicators

Feasibility dimension/criteria	Description	Quantitative indicator	Qualitative indicator
Economic	Affordability, cost-effectiveness, financing	Benefit-cost ratio of elevating a flood-prone road segment	Local operators consider the investment affordable
Technological	Availability and reliability of technologies / solutions and know-how	% of materials for port reinforcement that can be sourced locally	Expert judgement on reliability of available construction techniques under local conditions
Institutional	Governance, policies, organizational capacity	Number of permits/approvals already secured for the rail adaptation project	Measure is seen as aligned with national transport priorities (e.g. national transport strategy)
Socio-cultural	Social acceptance, values, behavior change	% of freight companies willing to adjust delivery schedules to avoid heat stress	Companies report willingness to change operating practices
Environmental-ecological	Impacts on ecosystems, biodiversity, natural resources	Volume of water required per km of upgraded corridor	Perceived risk of negative ecological impacts from building more packhouses
Geophysical	Physical / biophysical constraints (land, water, climate limits)	Road elevation relative to projected 1-in-100-year flood height	Expert judgement on whether the location is physically suitable for long-term resilience

Given the importance of building the case for investment and address market failures, it is recommended to integrate the 'triple dividend for resilience' (TDR) approach into the feasibility analysis (see Box 6). For example, an expressway rehabilitation in Manila, Philippines delivered additional dividends such as reduced congestion that allows more efficient business operation; alerts from the traffic management system for the whole population on weather and traffic congestion; and roadside trees that sequester carbon dioxide.⁸⁰

b. Evaluate effectiveness for resilience

Effectiveness is the extent to which an adaptation measure reduces climate-related risks, impacts, or vulnerabilities, and strengthens resilience — both in the short term and under future climate conditions, and across relevant stakeholder groups. It is also context-specific: it depends on whose risks and which climate hazards are being targeted. Table 9 gives an example for the avocado supply chain.

Assess the effectiveness of pre-selected action measures against the IPCC framing of resilience:⁸¹

- Vulnerability reduction: determine which of the nine resilience attributes are strengthened (sourcing, inter-modality, redundancy, scheduling, diversity, visibility, workforce)⁸. Example: reduced travel distances for local drivers and protection of goods in transit.
- Risk reduction: identify which previously assessed risks are lowered. Example: avoided downtime of freight corridors, reduced cargo loss.
- Resilience outcomes: assess system-level benefits such as improved reliability, continuity, and flexibility of logistics systems under climate stress.

Identify measurable indicators where possible, like was done as part of the feasibility analysis. These may be quantitative (e.g., % reduction in kilometres travelled, days of disruption avoided) or qualitative (e.g., stakeholder perceptions of improved reliability of supply).

Where possible, take broader considerations into account by:

- Considering short-, medium-, and long-term effectiveness (e.g., next year, 2030, 2050).
- Checking robustness under uncertainty (e.g., a measure may be effective in 2030 but fail under 2050 sea-level rise).
- Testing durability under multiple climate scenarios.

Assess whether a measure that appears resilience-effective might in fact undermine long-term resilience or have other unintended consequences. This is referred to as maladaptation – for example, an elevated freight railway that diverts floodwaters into nearby villages,

Box 6: Triple Dividend of Resilience (TDR) from climate adaptation and resilience investments^{8, 40}

Adaptation/resilience investments can generate a triple dividend: avoided losses, induced economic benefits, and social and environmental benefits.

Good adaptation is good development: induced economic benefits and social and environmental benefits accrue independent of whether a climate hazard event occurs.

Economic feasibility: In all analysed cases the second and third dividend alone generate benefit-cost ratios greater than 1 even when the value of avoided losses is not included. For 40 transport investments analysed (public transport, connectivity, bridges, waterways, ports), the economic internal rate of return (EIRR) was 27.2% covering the three dividends.

Catalyzing investments: governments, development finance institutions, funders and the private sector have better information on traditionally excluded economic, environmental and social benefits to help build the investment case.

Dividends	Examples of benefits
1. Avoided losses	○ Avoided goods/product loss or damage ○ Avoided infrastructure loss and damage ○ Avoided productivity or labour loss ○ Reduced or avoided mortality ○ Avoided emergency repair costs
2. Induced economic benefits	○ Higher transit-trade revenue ○ Reduced maintenance costs ○ Productivity or labour gains ○ Reduced travel time due to increased road performance ○ Improved energy efficiency
3. Social and environmental benefits	○ Well-being benefits ○ Avoided or reduced GHG emissions ○ Enhanced biodiversity due to improved habitats

increasing local flood risk. Because maladaptation overlaps with broader concerns such as climate-compatibility and equity, it is introduced here but explained in more detail in Section 2.3.

➔ *Part D-9: Examples of Metrics and Indicators*

Table 9: Effectiveness of resilience of action measures in the first mile of an avocado supply chain from Kenya to Europe

Supply chain element	Action measure	Vulnerability reduction (through the nine resilience attributes)	Risks reduction	Resilience outcomes
Aggregation points	Pilot smaller aggregation points closer to the small-holder farms	- Sourcing: reduces transport distance for farmers and local drivers - Scheduling: allows more reliable and professional downstream transport (better coordination of pick-up and delivery by aggregators/middle men) - Protection of goods in transit: products reach more professional downstream transport faster	- Food waste - Inefficient collection of goods - Road impassability - Transport delays	Improves continuity of product supply and reduces disruptions in first-mile collection
Aggregation points	Install solar-powered aggregation points with (mobile) cold storage	- Redundancy: provides a backup energy source (solar) independent of the unreliable grid, and adds storage capacity as a buffer against transport or market delays - Diversity: introduces an alternative power supply and storage solution compared to conventional, grid-dependent systems - Visibility: if digitally monitored, operators can track storage conditions and capacity in real time - Protection of goods in transit: cooler storage slows the ripening process	- Food waste - Loss of product quality - Transport delays	Increases reliability of product storage and flexibility in harvest timing
Packhouses	Develop packhouses in emerging production regions (e.g., North Rift/ western Kenya)	- Sourcing: expands the geography of procurement by adding facilities closer to production areas - Redundancy: increases overall packhouse capacity, reducing dependence on a few established hubs - Diversity: provides alternative locations for post-harvest handling, spreading risk across regions	- Loss of product quality - Transport delays - Long waiting times at packhouses	Strengthens continuity and reliability of product processing capacity
Road freight to aggregation points Aggregation points Road freight to packhouses	Use plastic crates to transport avocados from farm to packhouse, replacing buckets or gunny bags/sacks	- Redundancy: by protecting avocados during handling and transport, crates reduce post-harvest losses, effectively increasing the usable supply buffer - Protection of goods in transit: standardized crates improve loading, stacking, and unloading efficiency, reducing damage of products during transfers - Visibility: if linked with aggregation points, crates can be better tracked, stored, and circulated back for reuse	- Food waste - Loss of product quality - Inefficient collection of goods - Long waiting times at packhouses	Improves reliability of product quality and reduce variability in delivery
All first mile elements	Real-time app about weather forecasts, harvest scheduling and pick up times, packhouse capacity (as well as prices)	- Visibility: provides farmers, aggregators, and packhouses with real-time information on weather, harvest timing, and market conditions - Scheduling: improves coordination of harvest, storage, and collection, aligning on-farm activities with packhouse and transport capacity - Diversity: enables more informed decisions on where and when to sell or deliver, creating alternative marketing and timing options - Workforce: reduces driver waiting times and improve predictability of work schedules - Cyber & digital: reliable data in a protected digital environment	- Food waste - Loss of product quality - Inefficient collection of goods - Transport delays - Long waiting times at packhouses	Improves supply coordination, ensuring accurate, protected information flows across the chain.

c. Select a package of proposed measures

Select a core package of action measures that combine high feasibility across multiple dimensions, robust resilience outcomes, and the strongest returns on investment. Selection involves comparing individual measures and combining those that reinforce each other across infrastructure, operations, and workforce.

At this stage the focus remains on feasibility and resilience effectiveness, with maladaptation risks explicitly avoided. Broader cross-cutting filters such as equity, inclusion, and climate-compatibility are applied in step 2.3 to further strengthen and safeguard the package.

The selected package is further refined in Step 2.3 to avoid unintended risks and capture additional benefits.

2.3 Add safeguards and decarbonization and sustainability opportunities

Once a core package of feasible and resilience-effective measures has been identified, the next step is to safeguard it against unintended risks and add complementary opportunities for decarbonization and sustainability. This step produces an updated package that is protected against maladaptation and inequities, and strengthened with the most compelling opportunities for decarbonization and sustainability — ensuring it is both resilient and future-proof.

a. Apply maladaptation, equity and sustainability considerations

Cross-cutting considerations apply to both feasibility and effectiveness and are core elements of climate-resilient development. They ensure that options are not only doable and impactful, but also fair, inclusive, and sustainable.

Box 7: Case Study: Digitizing coffee payments in Uganda – a logistics measure with multiple benefits ²²

Physical cash payments were once a major bottleneck in Uganda's coffee supply chain. Kyagalanyi Coffee Limited (KCL), one of the country's largest exporters, had to transport cash across long distances to pay over 6,000 farmers and 900 traders, sourcing from about 50,000 smallholders. Cash was often carried in backpacks on boda-bodas or taxis, creating high risks of theft, delays, and significant transport-related emissions.

Digital payments. In 2015, the United Nations Capital Development Fund's Mobile Money for the Poor (MM4P) programme partnered with KCL, MTN Uganda (telecoms company), and MicroSave Consulting to pilot digital payments in the Mount Elgon coffee value chain. The project replaced weekly road transport of cash with a bulk digital disbursement system. This involved building mobile network infrastructure, designing a payment platform, and onboarding more than 250 mobile money agents and 300 rural merchants.

Donor grants of around USD 400,000 supported farmer education, agent recruitment, and pilot operations, while the Bill & Melinda Gates Foundation financed technical design. As confidence grew, MTN Uganda scaled up its commercial investment, and the approach expanded to other value chains such as fish, maize, tea, and dairy.

Value creation. Outcomes demonstrate strong resilience and sustainability value:

- 50,000 farmers gained faster, safer, and more transparent payments.
- Reduced theft and payment delays increased household stability and farmer trust.
- Financial inclusion improved as farmers used digital receipts to access credit and insurance.
- Cash-related GHG emissions were avoided by eliminating weekly motorbike and taxi trips to distribute cash.
- Private sector scale-up showed how donor de-risking can unlock lasting commercial engagement in rural markets.

Looking forward. The Ugandan coffee payments pilot illustrates how digital finance can be a logistics intervention. By removing the need for physical cash transport, it not only cut risks and costs but also strengthened the resilience of both farmers and supply chains. Digitization can be an opportunity for agricultural and other supply chains to improve resilience in a way that benefits farmers and their communities, companies, countries, and ultimately consumers.



These considerations do not fit neatly into a single feasibility dimension, yet they influence all of them and are often difficult to capture through simple indicators.

For each action measure, assess whether these considerations are relevant and how they should shape the overall evaluation:

- Equity: who bears the costs and who benefits?
- Justice: are decisions fair, inclusive of diverse voices, and mindful of future generations?
- Inclusion: have marginalized or less powerful groups been actively involved?
- Co-benefits and trade-offs: what additional positive outcomes or unintended side effects arise?
- Climate compatibility: does the measure avoid increasing GHG emissions or lock in high-emissions activity?
- Maladaptation: could the measure increase vulnerability elsewhere or in the future?

Box 8: Case Study: Community and business inclusion in building long-term resilience after floods in Germany ^{91 94 95}

In July 2021, devastating **floods in Germany's Ahr Valley** killed more than 180 people and wiped out homes, businesses, transport infrastructure and power systems. Local industries – particularly wine production, agriculture, forestry, tourism and spa clinics – were heavily disrupted, and supply chains were cut off when roads, bridges, and rail lines were destroyed. The German federal government and the state of Rhineland-Palatinate launched a coordinated reconstruction plan that went beyond simple replacement of destroyed assets, focused on long-term climate adaptation with community participation and empowerment.

Community involvement. Residents, associations, and local businesses took part in forums and consultations on future land use, reconstruction priorities, and infrastructure needs. NGOs, citizen initiatives and volunteers supplemented government efforts, so that recovery priorities reflected both social and economic needs.

Long-term resilience. The floods triggered debate about whether to rebuild on a “like-for-like” basis or to incorporate long-term resilience. Several measures were adopted or piloted:

- Climate-adapted buildings: replacement of vulnerable oil-based heating in flooded basements with heating networks that reduce fossil fuel use and are less exposed to flood damage.
- Infrastructure upgrades: bridges and roads were reinforced and redesigned to withstand higher water levels and to reconnect cut-off areas more quickly in the future. This was critical for local supply chains, from moving goods to enabling staff and customers to access businesses.
- Integrated planning: reconstruction was linked to broader spatial and climate strategies to avoid recreating risk, for example, by avoiding the most flood-prone zones and aligning with climate and sustainability goals.

Looking forward. Despite successes, recovery was uneven, and pressure for fast “like-for-like” rebuilding often conflicted with resilience goals. Trust and legitimacy were improved in areas where participation was meaningful, but frustrations emerged where communities felt excluded or reconstruction was delayed. Still, the Ahr Valley shows how disasters can become a turning point. By connecting reconstruction to climate adaptation, infrastructure resilience, and business continuity, recovery can empower communities and economies that are better prepared for the next extreme event.



Table 10: Additional considerations for enhancing the package of action measures

Consideration	Description	Examples
Equity	Concerns distribution of costs, risks, and benefits of adaptation/mitigation options across groups, regions, and generations. A measure may fail socially or politically if it imposes costs disproportionately on vulnerable group.	- Positive: exporters and logistics companies benefit from reduced disruptions; urban consumers benefit from more reliable deliveries. - Negative: smallholder farmers and SMEs may bear higher freight tariffs if infrastructure costs are passed down, while large companies absorb them more easily.
Justice	- Procedural: inclusive and transparent decision-making processes. - Recognition: diverse values, cultures, and knowledge systems are respected. - Intergenerational: today's measures protect and do not harm future generations.	- Procedural: local communities displaced by construction (e.g. informal settlements along a road corridor) were consulted or compensated. - Recognition: planners considered middlemen and informal transport operators whose livelihoods are affected by closer packhouses. - Intergenerational: engineers used design standards for developing additional bridges that are robust to long-term climate projections.
Inclusion	Decision-making must actively include vulnerable or marginalized groups (women, Indigenous peoples, informal workers, local communities)	Planning resilient freight corridors with only government and large logistics firms may exclude small trucking companies, warehouse workers, or women traders who rely on the system.
Co-benefits and trade-offs	Additional benefits beyond climate/supply chain risk reduction (health, employment, biodiversity, wellbeing), or unintended negative effects. Considering co-benefits often makes measures more feasible and attractive across stakeholders, while ignoring trade-offs can undermine long-term sustainability.	- Co-benefits: avoided supply chain disruptions will secure the immediate continuation of food products, as well as avoid that prices for coffee, cocoa, potatoes, olive oil and other products risen due to climate change will increase even further.⁸⁶ - Co-benefits: elevated rail line reduces road freight diversion during floods, cutting congestion and emissions; could also serve as a protective levee for nearby communities. - Trade-offs: construction of an elevated rail line may increase embodied carbon (cement/steel) and ecological disruption (wetland loss), offsetting some environmental gains.
Climate-compatibility (also part of maladaptation)	Ensures adaptation or resilience actions must be designed and implemented in ways that avoid an increase greenhouse gas (GHG) emissions, do not lock systems into high-emission pathways, and are consistent with mitigation and sustainable development goals.	- Expanding cold storage along supply chains to reduce food losses during heatwaves may significantly increase GHG emissions if powered by diesel generators or inefficient cooling systems. - More examples of the relationship between decarbonization and resilience are provided by Prof. Alan McKinnon, and found that in most cases are synergistic.⁸
Avoid maladaptation	Actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence.	- Protecting a container terminal with a seawall may deflect floodwaters into surrounding low-income neighborhoods, increasing their vulnerability. - If design relies on energy-intensive pumping systems, it locks supply chains into higher operating costs, undermining long-term resilience. - More examples of infrastructural, institutional, and behavioral maladaptation are provided by E. Shipper⁸⁷ and several guidelines in Part D-5.

b. Seek opportunities for decarbonization, sustainability and institutional measures

Actively seek out opportunities to complement resilience measures with additional actions that deliver decarbonization and wider sustainability benefits. In many cases, such opportunities stem from policies, projects and ideas already planned by stakeholders. Aligning these initiatives with resilience measures expands the overall impact, strengthens the investment case, and enhances partner commitment.

Scan for additional measures already planned or under consideration by stakeholders that can be linked to the critical link. These may be vertical (integrated into the same link alongside a resilience measure) or horizontal (upstream or downstream but directly influencing the link). Examples include:

- A logistics service provider already planning to install solar panels on warehouses could combine this with floodproofing, or vice versa.
- Redevelopment of port infrastructure could integrate nature-based solutions, such as mangrove restoration, to provide storm surge protection and carbon benefits.
- Reinforcement of railway embankments to withstand heavier rainfall and flood risk could be paired with tree planting, adding slope stability and carbon sequestration.
- New packhouse facilities in avocado-producing areas could be designed with cooled storage powered by rooftop solar, reducing food loss and emissions while strengthening supply chain performance.

- A new railway line planned for regional connectivity could be equipped with reefer trains, as recently piloted between Nairobi and Mombasa,⁸⁸ to enable temperature-controlled exports of fresh produce.
- A new packhouse could be designed for multi-use, for instance also serving as a community centre or school.

These complementary actions can deliver economic, environmental, and social benefits in addition to resilience, strengthening both the investment case and stakeholder commitment.

Identify institutional measures to supplement the package – these can be existing or new measures – such as those identified by UNECE:¹¹⁸

- Economic: contingency or disaster response funds; demonstrated resilience incentives; investment pre-conditions for new infrastructure; financial penalties; insurance requirements; grants and loans.
- Regulation: health and safety requirements; standards and codes of practice; non-compliance enforcement and penalties; legal protection for vulnerable habitats with risk reduction role.
- Policy and programmes: strategic adaptation planning (local/regional/international); zoning according to risk; set back, buffer area or relocation policies; build-back-better (or out-of- the-way) policies; diversification.

Alignment of resilience measures with existing national priorities can strengthen the package. The Asian Transport Observatory highlights multiple examples of adaptation policies relevant to the transport sector, including climate-resilient planning and design, integrated land use and transport, updated infrastructure standards and

codes, upgrading existing assets, nature-based solutions, emergency preparedness, digital strategies, and transport financing and investment planning.⁸⁹

Make sure to evaluate how the identified measures reinforce the resilience objectives of the critical link,

and that they do not inadvertently undermine them. For example, solar-powered cold storage can reduce emissions while also improving reliability during power outages, and mangrove restoration in port redevelopment can enhance both storm protection and biodiversity. Similarly, shifting from diesel to electric trucks can cut emissions, but you must make sure charging points are not located in flood-prone areas and that the grid is reliable, otherwise the measure could increase rather than reduce vulnerability.

c. Safeguard and strengthen the package of proposed measures

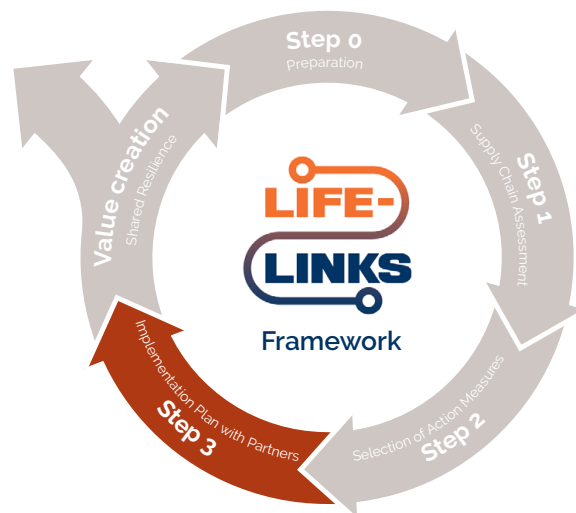
Update the package developed under Step 2.2.c by incorporating the results of the safeguard checks (Step 2.3.a) and the additional opportunities identified (Step 2.3.b). Prioritization should focus on how well these opportunities build on initiatives already planned or under consideration by stakeholders, reinforce resilience objectives, and add wider benefits. Incorporating the strongest opportunities ensures the package is not only practical but also more persuasive for partners and financiers.

The outcome of this sub-step is an updated package of measures that has been safeguarded against maladaptation and inequities, and strengthened with the most compelling opportunities for decarbonization, sustainability and institutional strengthening.. This ensures the package is both resilient and future-proof.

Step 3. Implementation Plan with Partners

Outcome: Agreed implementation plan with feasible action measures that deliver value individually and added value together

Step 3: Implementation Plan with Partners



- 3.1 Commit on a package of action measures
- 3.2 Agree collaboration, financing and monitoring
- 3.3 Launch and communicate the plan as partners

Partnerships working on project or initiative implementation often face serious challenges. Even when analysis has identified feasible action measures, it can be difficult to align priorities, secure financing, and agree on responsibilities. Questions such as “who pays what” and how to balance individual gains with collective benefits are common bottlenecks. Without a shared commitment and clear plan, even well-prepared packages risk stalling before they deliver impact. The Life-Links concept hinges on bringing companies on board to collaborate and co-invest in implementing feasible action measures. To enable this, three challenges must be overcome:

- **Preference for control.** Companies are more comfortable investing where they retain control. Their order of preference is: within their own company; with direct partners; in projects with a select group of partners; through industry-level alliances with peers; as part of multi-stakeholder platforms or networks; and finally at different levels and types of partnerships.⁹⁰
- **Risk delegation in supply chains.** Multinational producers, manufacturers, and retailers (“shippers”) share logistics networks with many other companies and often delegate risk to their logistics service providers (LSPs). LSPs carry liability and face strict due-diligence requirements. Because they are bound by contracts with tight service-level agreements (SLAs), their risk exposure is heightened. Yet with thin margins and risks only partly insurable, they are unlikely to invest without strong customer backing.
- **Difficult business case.** Action measures reduce the risk of disruption – helping companies avoid potential losses rather than generate new revenue. For CFOs, such “insurance-like” investments are harder to justify than measures with a clear return on investment or tangible payback period.

To move past these barriers, Life-Links focuses on three things that make collaboration with companies possible:

- **Focus on critical links.** By concentrating on the most vulnerable parts of a supply chain rather than the whole supply chain or logistics network, measures become more concrete, manageable, and easier to justify in terms of resilience and decarbonization benefits.
- **Mobilize diverse finance sources.** Public finance, development partners, insurers, and private investors can all play a role in making resilience investments viable. This can range from government agencies upgrading roads, to development banks co-funding projects, to insurers offering parametric insurance, or blended finance arrangements that combine concessional and commercial capital. Together, these mechanisms help reduce risk for companies and make it more attractive for them to co-invest.
- **Allow for flexible collaboration.** Different measures within a package can be implemented in different ways – some coordinated separately, others jointly funded – while still holding together as a coherent package. This avoids leaving any measure as an isolated action. The table below illustrates this flexibility, showing the progression from isolated action to coordinated action to collective investment.

In this step, the proposed package of action measures is turned into a shared commitment and implementation plan. The process begins with agreeing on which measures from the proposed package will be taken forward and clarifying their value for different actors (sub-step 3.1). Partners then define how each measure will be implemented, including roles, financing, and monitoring arrangements (sub-step 3.2). Finally, the package is launched and communicated, making collaboration visible, building trust, and attracting further support (sub-step 3.3).

Table 12: Levels of collaboration for implementing the package of action measures on the critical link
 Left to right: increasing collaboration intensity, transaction costs, and system-wide resilience impact

➔ *Part D-11: Key Factors for Supply Chain Collaboration*

Levels	Isolated Action	Coordinated Action	Collective Investment
			
Description	Individual actors take action measures alone	Partners coordinate around one or across multiple action measures, without financial transfers	Partners pool or unlock finance for action measures through co-funding, guarantees, or risk-sharing, including through public-private partnerships (PPPs)
Characteristics	- Minimal coordination effort - Fast to implement - Lowest system-wide resilience impact	- Builds trust and readiness for deeper partnerships - Greater system-wide resilience than isolated actions - No redistribution of risk/capital between partners	- Highest trust, highest transaction costs - Strong, long-term system-wide resilience impact - Often requires enabling governance/legal frameworks
Sub-types		Co-implementation (joint implementation of the same action measure – each funds their own scope) Alignment (coordinated implementation of respective action measures so they reinforce each other) Expansion (new partners join in the implementation or scaling of action measures initiated by others – each still funds their own scope) Support coordination (information sharing, common standards/specifications, shared implementation calendar for the package, central monitoring)	Cost-sharing / co-funding (direct co-finance or pooled structures e.g. collective investment vehicles (CIVs)) Guarantees & credit enhancements (e.g. offtake/forward purchase commitments; partial credit guarantees; warehouse-receipt finance; value chain finance) Risk-sharing (e.g. insurance pools, parametric insurance, price-risk facilities, emergency/contingency funds) Blended & catalytic finance (concessional + commercial capital to crowd in others, e.g. concessional credit lines, first-loss/mezzanine, market instruments such as resilience bonds and insurance-linked securities (ILS))
Examples	Infrastructure: a warehouse installs flood barriers without coordination with transport operators Infrastructure: a trucking company adds backup power only for its depot, leaving nearby firms exposed Operations: an exporter adopts a returnable plastic crates (RPCs) system without engaging transporters or pack-houses, limiting uptake Workforce: A port operator trains staff on storm standard operating procedures, but marine and road freight carriers are not included Network: a government agency develops a contingency plan not aligned with private-sector measures	Co-implementation: port authority, carriers, and customs coordinate storm preparedness across port, sea lane, and hinterland access roads Alignment: a road agency hardens access roads, while logistics companies and exporters jointly roll out an RPCs system along that route Alignment: a regional trade corridor platform invites private firms to time their logistics upgrades with donor-supported infrastructure works Expansion: multinational retailers and producers join a rural-road improvement program's implementation schedule to add their own measures on adjacent feeder routes, using the same specs and timeline Support coordination: partners use a simple data-sharing protocol for works notices, risks alerts and monitoring of package implementation along the critical link	Co-funding: port authority elevates quays and upgrades drainage; a group of shipping lines pay a temporary per-call resilience surcharge into a ring-fenced fund that services the loan for the works Guarantees: a retailer provides a product offtake guarantee, enabling a producers cooperative to secure a bank loan for a new packhouse Risk-sharing: transport cooperatives and an insurer implement a parametric insurance scheme for drivers with a corridor contingency fund to provide rapid liquidity after extreme events. Blended finance: a development bank blends concessional finance with private capital to expand cold-chain infrastructure Blended finance: a corridor authority issues a resilience bond to finance drainage and embankment upgrades

3.1 Commit to package of action measures

Not all stakeholders will be direct partners in implementation, but the package and its business cases should consider the interests of all affected stakeholders to ensure broad benefits and avoid negative impacts. At this stage, supply chain actors commit in principle to a shared package of feasible action measures, confirming their collective intent and agreeing on broad principles of value and fair sharing of costs and benefits, which lays the foundation for building trust among partners.

a. Select measures from proposed package

Partners take a critical look at the proposed package from Step 2 and decide which action measures are most feasible and resilience-effective for the critical transport links, while also offering opportunities for decarbonization and wider sustainability. Building on this evidence base, each partner will weigh the benefits for themselves and prioritize accordingly. This makes the final selection both technically grounded and responsive to the interests of those who need to commit resources.

For example, in the avocado case a cooperative, shippers, and local authorities might agree to prioritize upgrading a packhouse, since this reduces spoilage and shipment delays while creating community benefits. At the package level, partners then consider how the different selected measures fit together, ensuring the overall package is realistic, balanced, and supported across stakeholders.

b. Define value proposition and business cases

Clarify each stakeholder's role and the benefits they can expect, ensuring that value is visible both individually and collectively. Producers and workers gain more secure livelihoods, cooperatives and associations strengthen their bargaining power, and communities see more reliable access to markets and services. Shippers and logistics service providers benefit from fewer disruptions and lower losses, while authorities and financial institutions see stronger connectivity and reduced risk.

For example, introducing closer aggregation points, reusable crates (RCSs), and portable cold storage together creates a much stronger case: farmers and cooperatives reduce losses, small transporters can offer more reliable services, shippers and exporters see higher-quality shipments, LSPs face fewer liability issues, and communities benefit from more stable local markets.

At a larger scale, coordinated action on a transport corridor or port can deliver similar shared value. A public-private partnership to upgrade a rail link or strengthen a port against flooding requires public investment but also depends on private actors. Governments or road/rail agencies may finance and build the infrastructure, while shippers commit to routing volumes through the improved link, LSPs coordinate services, and insurers help de-risk the investment. Without this alignment, new infrastructure risks being under-used or failing to deliver resilience benefits. With it, however, both public and private actors can secure more reliable trade flows and lower disruption risks.

Regulatory requirements provide an additional driver for collaboration. Companies are increasingly subject to due diligence, disclosure, and carbon-pricing rules such as the EU CSRD, CSDDD, and CBAM, as well as national supply chain acts and deforestation regulations. By investing in resilience measures and integrating them with supply chain mapping and reporting, companies not only reduce disruption risks but also demonstrate compliance with these frameworks. This makes it easier to justify co-investment, particularly for shippers and retailers under high scrutiny from regulators and investors.

Business cases therefore extend beyond direct financial returns to include avoided losses, regulatory compliance, reputational gains, social benefits, and environmental improvements. This stage also confirms that all stakeholders benefit – or at least are not disadvantaged – so that collaboration shifts the balance toward more equity rather than reinforcing existing power imbalances.

c. Agree on fair sharing of costs and benefits

Confirm that the costs and benefits of the selected action measures will be shared fairly among partners and wider stakeholders. At this stage, the focus is on principles rather than final arrangements – for example, that companies will not be expected to bear all costs alone, that communities should see tangible benefits, and that public actors or financial institutions may support enabling investments. The detailed question of “who pays what” is then addressed in Step 3.2, when specific collaboration types and financing mechanisms are agreed for each measure.

3.2 Agree collaboration, financing, and monitoring

In this step, partners move from commitment in principle to concrete arrangements for implementation, agreeing how each measure will be carried out, who pays for what, and how progress will be tracked, while ensuring that the perspectives of wider stakeholders are considered.

a. Define roles and responsibilities

Specify who is responsible for implementing each action measure and for coordinating the package overall. This includes choosing the appropriate level of collaboration intensity for each measure, from coordinated action to joint investment or public-private partnership.

For example, if a packhouse upgrade is selected, a cooperative could oversee operations, an engineering firm may be contracted for construction, the local authority could provide permits and inspections, and a donor or development bank might finance technical assistance. At the package level, partners then agree who ensures alignment across measures, who convenes meetings, and how wider stakeholders are consulted and updated during implementation.

b. Assign financing and select mechanisms

Agree how costs will be covered for each measure and for the package overall, matching financing mechanisms to the collaboration type chosen. Different collaboration types come with different transaction costs, which should be taken into account when selecting financing mechanisms. Companies may co-fund operational improvements,

governments or road agencies can invest in infrastructure, cooperatives might contribute in-kind resources, and financial institutions or insurers can reduce risk through blended finance, guarantees, or parametric insurance.

For example, in the avocado case, a cooperative might contribute labour and local management for a packhouse, shippers and exporters could co-finance equipment such as reusable crates and cold storage, and the road agency could support by improving maintenance of unpaved feeder roads to ensure reliable access. Retailers could reinforce these efforts by offering offtake guarantees once improved reliability and quality are demonstrated, reducing investment risks for other partners. Financial institutions and insurers can also play a role by de-risking investments through blended finance or insurance products.

The Zurich Climate Resilience Alliance has identified emerging models for private participation in infrastructure, such as collective investment vehicles or CIVs (group funds that pool many investors' money) and mezzanine finance (a middle step between loans and ownership that helps close funding gaps while protecting main lenders).¹³¹

c. Establish monitoring and reporting

Set up arrangements to track progress, financing flows, and delivery of benefits. Monitoring should cover both implementation (whether measures are fully implemented) and outcomes (resilience, equity, sustainability). Transparent reporting creates accountability among partners, builds trust with wider stakeholders, and provides evidence to attract further support and investment.

Box 9: Case Study: Agri-commodity Hub in West Coast Africa combining cocoa exports and food aid ¹³²

Collaborations between companies and humanitarian organizations can lead to shared resilience.

A logistics service provider (LSP) established a 5,000 m³ **agricultural commodity facility** in West Coast Africa for cocoa bean exports to Europe. The hub was designed to cope with climate challenges: located close to farms, with controlled humidity (below 70%), moisture (6–8%), and temperature (below 25 °C), as well as an integrated logistics service from farm to ship. However, volatile volumes due to seasonal peaks and varying yields posed a challenge.

Partnership for value creation. To address this, the LSP partnered with a humanitarian organization to store and distribute rice within the region. By alternating between cocoa and rice, the partners aligned logistics schedules and shared infrastructure, ensuring profitability for the LSP – which exceeded 40% – while expanding humanitarian reach. The storage facility thus became both a commercial hub and a distribution channel for food aid, supporting local development. This business case demonstrates how co-investment in logistics capacity can deliver both commercial returns and social benefits, providing a model for long-term resilience planning.

Looking forward. With climate shocks driving extreme price volatility – for example, the world market price for cocoa rose by 300% in February 2024 compared to the previous year due to droughts and record temperatures in West Africa¹³³ – partnerships like this hub are becoming essential for both supply continuity and regional food security.

3.3 Launch and communicate the plan as partners

With the implementation plan in place, partners can make their collaboration visible and demonstrate impact.

a. Launch partnership for collaborative action

Partners formally launch their joint initiative, signaling readiness to move from planning to action. A visible launch — through announcements, case studies, or events — builds trust, creates momentum, and makes the collaboration tangible to wider stakeholders.

b. Communicate progress, results and lessons

Partners share milestones, results, and lessons learned through joint announcements, case studies, and regular updates. Ongoing communication strengthens accountability between partners, demonstrates openness to wider stakeholders, and helps attract new supporters.

c. Demonstrate impact of collaboration

Reporting should highlight not only activities completed but also the outcomes achieved through joint action. This includes results at the level of individual measures (e.g. reduced spoilage from new cold storage) and at the system level (e.g. fewer shipment delays along a corridor). Demonstrating impact in economic, social, and environmental terms shows that collaboration delivers real benefits, strengthens trust, and builds the case for scaling up.

What partners have achieved in this step is an agreed implementation plan with feasible action measures, reflecting fair sharing of costs and benefits, matched with appropriate collaboration types and financing mechanisms, and supported by clear roles, monitoring, and communication. This makes the package both actionable and credible, and demonstrates that coordinated collaboration can build trust and deliver system-wide resilience.

Box 10: Case Study: Roads4People in Côte d'Ivoire – Partnership for building resilient rural roads, empowering communities 🌱

Roads4People (R4P) in Côte d'Ivoire is a real-world example of how Life-Links works in practice: uniting stakeholders to co-invest in resilient logistics links, creating shared value across supply chains, and turning resilience into an opportunity for climate action and sustainable development.

Agriculture is the backbone of Côte d'Ivoire's economy, contributing 27% of GDP. Cocoa, cotton, cashew nuts, palm oil, rubber and other export crops all depend on rural roads to reach processing hubs and ports. Yet fewer than 10% of roads are paved, many become impassable during rainy seasons, and climate change is worsening risks from flooding and heat. In 2020, only 60% of the population lived within two kilometres of a road usable year-round – a major constraint on food security, health and education access, and inclusive economic growth. Women and marginalized groups are especially affected, as 42% of Ivorian women work in agriculture and depend on safe rural roads for both income and daily needs.

The R4P, a partnership between UNIDO, ORIS and the Government of Côte d'Ivoire, introduces digital tools and advanced analytics to assess climate risks, prioritize investments, and plan both major and rural road interventions. Adaptation measures include climate-appropriate materials, improved drainage, raised road sections, culverts, and nature-based solutions. Social impact indicators are fully integrated to ensure equitable benefits, with communities directly involved in identifying priority interventions.

Value creation. Quantified results already show the scale of opportunity:

- 📌 6% reduction in pavement construction costs through optimized design.
- 📌 10% reduction in greenhouse gas emissions compared to standard road projects.
- 📌 8% less natural resource extraction (aggregates, asphalt, etc.).
- 📌 Improved safety through measures aligned with international iRAP standards.

Savings from optimized major road projects are reinvested into a Rural Roads Fund, creating a financing mechanism to maintain and expand rural road networks. This ensures year-round connectivity for communities, secures livelihoods for up to 31 million people, and reduces disruption to agricultural supply chains.

Looking forward. By improving the climate resilience of rural roads – critical links in agricultural supply chains – the programme safeguards livelihoods, secures food supply chains, and empowers rural communities to participate more fully in the economy. The next step is to broaden collaboration. Côte d'Ivoire is the world's largest cocoa producer and an important source of cotton, cashew nuts and other crops. Multi-national buyers and retailers sourcing from these supply chains have a direct stake in reliable rural roads. By aligning their investments with the R4P framework – for example, financing adjacent feeder routes using the same specifications and timeline – companies could expand the Rural Roads Fund, extend resilience benefits, and help safeguard the "critical links" that connect producers to global markets.



Value Creation: Shared Resilience

The ultimate goal of Life-Links is “Resilient supply chains for good”, as set out in its vision: to make supply chains that connect producers and consumers across the globe drivers of resilient climate action and local sustainable development.

In practice, this means supply chains that are more resilient, while also reducing emissions and supporting sustainability, with benefits shared across communities, companies, countries and consumers.

The Implementation Plan leads to value creation, showing how agreed measures generate benefits for supply chains actors and stakeholders. While this follows step 3, the potential value is already relevant from the preparation in Step 0, when it helps bring partners on board and set expectations for collaboration and investment.

Value is created at two levels: supply chains and stakeholders (see Figure 13 and Table 13)

- **Supply chain resilience** is achieved through enhanced resilience of the logistics system and goods and products, reducing disruptions and delays and improving reliability and efficiency across networks, combined with co-benefits of reduced emissions and improved sustainability.
- **Stakeholder resilience** applies to key stakeholders in the real economy, including communities, countries, companies, consumers, and other stakeholders.

What makes this value creation possible is a **shared interest in resilient supply chains**. Through collaborative action, the outcome is **shared resilience**: everyone benefits when disruptions are reduced, when logistics systems continue to function under stress, when trade and supply are stabilized, and when social and environmental co-benefits are realized.

The value for supply chains and stakeholders becomes tangible in the form of three types of benefits, known as the **Triple Dividend of Resilience (TDR)**:

- Avoided losses – avoiding damages and losses from disruptions or disasters.
- Induced economic benefits – economic or development benefits that arise even when no disaster occurs.
- Social and environmental co-benefits – benefits that enhance community well-being and sustainability.

Table 13 gives examples of metrics/indicators that can be used to measure value at both the supply chain and stakeholder levels across the TDR.

Figure 13: Value creation through Life-Links partnerships



Table 13. Value creation from improved stakeholder resilience – examples based on the Triple Dividend of Resilience

Supply chains / Stakeholders	Avoided losses	Induced economic benefits	Social and environmental benefits
Supply chains (logistics systems and goods flows)	- Reduced disruption hours and delays on critical links (metric: reduction in expected annual disruption hours – EADH) - Reduced product spoilage or cargo losses in transit (metric: % loss reduction) - Lower emergency rerouting or demurrage costs (metric: \$ avoided/year)	- Higher throughput and utilisation of logistics assets (metric: % increase in volume handled) - More reliable export and import performance (metric: % on-time shipments) - Increased private investment in supply chains (metric: \$ invested/year)	- Reduced freight-related emissions and waste (metric: t CO₂/tonne-km or % waste reduction) - Improved safety and working conditions for logistics workers (metric: % reduction in accidents or heat stress incidents) - Greater inclusion of SME and women-owned logistics operators (metric: % share of contracts awarded)
Communities (local communities, their workers, producers, and natural resource base)	- Reduced spoilage of perishables in storage and transit (metric: % reduction in tonnes) - Fewer days of road/rail closure after flooding (metric: % reduction in downtime days)	- Lower first-mile transport costs for farmers and aggregators (metric: \$/tonne saved) - Increased local employment in logistics hubs (metric: # jobs created)	- Safer and more inclusive working conditions for women in warehouses and ports (metric: % of women reporting improved conditions) - Reduced local air pollution from electric freight vehicles (metric: PM_{2.5} emissions)
Countries (government bodies/authorities; affiliated entities; international governmental bodies)	- Lower infrastructure repair costs on roads, bridges and ports (metric: \$ avoided/year) - Reduced border clearance delays during climate events (metric: hours saved/shipment)	- Strengthened rural road networks attracting new trade (metric: % increase in trade volume) - Increased customs and transit revenues from reliable flows (metric: \$ collected/year)	- Improved national food and medicine security (metric: % reduction in national-level shortages) - Enhanced nature protection alongside resilient infrastructure (metric: hectares of ecosystems restored/preserved)
Companies (producing / manufacturing / retail; transport & logistics)	- Avoided factory stoppages due to timely delivery of raw materials (metric: downtime hours caused by delayed shipments) - Avoided revenue losses from delayed or cancelled trips (metric: % billable trips completed)	- Increased sourcing of products from reliable transport networks (metric: % growth in volumes sourced) - Lower insurance premiums for resilient logistics facilities or for driver insurance (metric: % premium reduction)	- Reduced emissions intensity of own or outsourced freight (metric: tonne CO₂/tonne-km) - Improved compliance with EU sustainability and due-diligence regulations (metric: % of logistics suppliers' data accessible)
Consumers (local end-users, consumers & households; consumers in export markets)	- Fewer stockouts of essential goods in local markets (indicator: % time shelves stocked) - Reduced price spikes linked to logistics disruption (metric: % variance in price)	- More stable consumer prices for goods (metric: % reduction in price volatility) - Better price–quality ratio for goods (metric: % of goods meeting standards at stable prices)	- Healthier people from increased availability of fresh food (metric: % increase in fresh food consumption) - Consumer product schemes able to include sustainable transport in certifications (metric: # of schemes integrating transport criteria)
Other (company owners; corporate customers; finance; other service providers; research and academia; civil society; international development & aid organizations; environment and future generations)	- Reduced insurance claims for damaged logistics assets or goods (metric: \$ claims avoided/year) - Sustained loan repayments from upgraded transport infrastructure (metric: % of repayments made on time)	- Greater investment flows into resilient corridors (metric: \$ invested/year) - More partnerships piloting logistics innovations (metric: # pilots launched)	- Wider use of shared logistics data and visibility tools (metric: # datasets or platforms shared) - Improved humanitarian aid logistics using shared transport networks (metric: % of aid deliveries reaching target on time)

Box 11: Case Study: Upgrading the Middle Corridor for Resilient Rail Freight

Logistics disruptions affecting supply chains

The Middle Corridor is a multimodal trade route between Asia and Europe that carries consumer goods, agricultural commodities, and bulk goods. A critical link is the East–West railway line from Azerbaijan's capital, Baku, to Boyuk-Kesik on the Georgian border, operated by Azerbaijan Railways (ADY). Key logistics challenges include infrastructure gaps (such as aging bridges and limited electrification), limited availability of rail slots and rolling stock, and customs delays. These issues are further exacerbated by climate hazards such as flooding, extreme heat, and snow, as well as the risk of earthquakes. Disruptions and delays raise ADY's operating costs and affect workers, reduce Azerbaijan's transit-trade revenues, and influence the supply and price of goods for customers and consumers.

Railway upgrades as resilience and climate opportunity

To strengthen this link, Azerbaijan Railways (ADY) introduced the Railway Sector Development Program, financed by the Asian Development Bank (ADB). ADB's loans initially supported improvements in financial and railway management, followed by a USD 47 million loan targeting digitalization, operational efficiency, resilience, and decarbonization.⁸³

ADY is also progressively undertaking a major upgrade of the physical infrastructure along the link during 2020–2027, with multiple action measures that collectively enhance resilience while generating decarbonization and sustainability benefits.

- ❑ The first measure is a large-scale upgrade of the electric network, replacing the outdated 3 kV DC system with 25 kV AC. This reduces electricity losses, improves substation availability, and enables a better integration with the national grid, laying the foundation for more energy-efficient electric traction. Upgrading the final section of the link will be completed by 2027.
- ❑ Next, Alstom, a global rail transport manufacturer and ADY partner, supplied 40 modern electric freight locomotives (Alstom Prima T8 AZ8A), built in the region. These replaced roughly 100 locomotives from the Soviet era, many of which were more than 40 years old and often unavailable. The modern locomotives are more powerful, reliable and built for harsh climates (–25°C to +50°C). Regenerative braking further improves energy efficiency, and their modular design simplifies

maintenance and reduces costs. The new locomotives were designed with the wellbeing and safety of drivers in mind: climate controlled cabins, ergonomic driver seats, and cooking and fridge facilities.

- ❑ Finally, operations are partly powered by renewable electricity. This was made possible through the installation of rooftop solar on locomotive depots under ADB loans, supplying both rail operations and the national grid. Further installation of solar along railway rights-of-way is also being investigated.

Value creation

The combined value from these parallel measures delivers a Triple Dividend of Resilience:

1. Avoided losses

- ❑ Infrastructure: fewer locomotive failures, with availability increasing from ~70% to ~90%.
- ❑ Operations: digitalized systems and processes reduce delays and improve reliability.
- ❑ Workforce: avoided productivity loss and safety incidents involving drivers and maintenance staff.
- ❑ Energy system: reduced risk of electricity network failures.

2. Induced economic benefits

- ❑ Reduced travel time, as average speeds doubled from ~20 km/h to ~40 km/h.
- ❑ Lower maintenance costs due to modular locomotives and fewer failures.
- ❑ Improved energy efficiency of locomotives and the electricity network.
- ❑ Higher transit-trade revenues for Azerbaijan and other countries along the Middle Corridor.
- ❑ More reliable services for companies shipping goods along the corridor.
- ❑ Increased freight volumes on the Middle Corridor (or specifically this rail segment) from under 800,000 tonnes (2019–2020) to more than 4.5 million tonnes (2024), with planning toward 10 million tonnes by 2027.

3. Social and environmental benefits

- ❑ Better working conditions for drivers and maintenance staff thanks to modern locomotives and fewer failures.



- ❑ Reduced greenhouse gas emissions and cleaner air from rail electrification combined with renewable electricity generation.
- ❑ Strengthened income resilience for workers and communities whose livelihoods depend on trade along the Middle Corridor.

Looking forward

Improvements to the Middle Corridor are set to significantly strengthen connectivity between Asia and Europe, lowering transport costs while boosting capacity. In an era of geopolitical uncertainty and frequent supply chain disruptions, this enhanced corridor has become especially valuable. Its successful upgrade not only demonstrates the viability of modernizing neglected routes, but also provides a model for reviving underinvested rail networks elsewhere, such as freight corridors in Africa. Since the improvements, freight volumes on the Middle Corridor have risen sharply, and its user base has expanded. In 2023, multinational shipping giant Maersk launched a dedicated service through the corridor, offering faster transit times between the Far East and Europe compared with traditional sea routes.^{84–85} The company has also extended this option to shippers in Japan and South Korea seeking more reliable access to European markets, as well as to exporters in the United States and Europe looking to reach Central Asia. Continued upgrades to the rail network and improved links to the port of Baku are expected to further strengthen multi-modal transport connectivity along this strategic route.



Resources

D-1. Key Definitions

Adaptation – In human systems, the process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects (IPCC Glossary ⁹⁶).

Avoided losses (first dividend of resilience) – the losses and damages that are prevented or reduced when a climate hazard or shock occurs because of resilience or adaptation interventions (WRI ⁸⁰).

Co-benefits – a positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment. Co-benefits are also referred to as ancillary benefits (IPCC Glossary ⁹⁶).

Climate compatible development (CCD) – a form of development building on climate strategies that embrace development goals and development strategies that integrate climate risk management, adaptation and mitigation (IPCC Glossary ⁹⁶).

Critical link: a transport or logistics link in a supply chain that is at risk of disruption, with the risk exacerbated by climate change, and whose failure would have significant impacts on stakeholders whose prosperity depends on the supply chain.

Exposure – the presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected (IPCC Glossary ⁹⁶).

Effectiveness – the extent to which a measure reduces climate-related risks, impacts, or vulnerability, and increases resilience.

Hazard – the potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources (IPCC Glossary ⁹⁶).

Induced economic benefits (second dividend of resilience) – The economic gains and development potential that are unlocked even in the absence of a hazard, by reducing background risk and enabling more confident investment, innovation, asset accumulation, and productive behavior (WRI ⁸⁰).

Infrastructure Resilience – the timely and efficient prevention, absorption, recovery, adaptation and transformation of national infrastructure's essential structures and functions, which have been exposed to current and

potential future hazards. Implementing resilient across all disruption phases should be done through collaborative risk and uncertainty management, multi-hazard assessment, and methods that embrace the systemic nature of national infrastructure (UNDRR ¹¹³).

Logistics challenges – problems or inefficiencies that make it difficult to move, store, and handle goods efficiently in a supply chain. They can relate to infrastructure, operations, workforce, flows or the external environment.

Logistics hub – a site where goods are transferred, consolidated, handled, or temporarily stored as part of the transport chain.

Net Resilience Gain – a long-term collaborative commitment to both (a) address systemic resilience loss, which reduces or removes actions that erode, reduce or undermine systemic resilience; and (b) to enhance systemic resilience, which prioritizes actions that create systems intrinsically resilient to disruptions (UNDRR ¹¹³).

Maladaptation – actions that may lead to increased risk of adverse climate-related outcomes, including via increased greenhouse gas (GHG) emissions, increased or shifted vulnerability to climate change, more inequitable outcomes, or diminished welfare, now or in the future. Most often, maladaptation is an unintended consequence (IPCC Glossary ⁹⁶).

Mitigation (of climate change): A human intervention to reduce emissions or enhance the sinks of greenhouse gases (IPCC Glossary ⁹⁶).

Multi-criteria analysis – integrates different decision parameters and values without assigning monetary values to all parameters. Multi-criteria analysis can combine quantitative and qualitative information. Also referred to as multi-attribute analysis (IPCC Glossary ⁹⁶).

Resilience – the capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation. In the context of the logistics system, resilience is the ability of supply chains and logistics systems/networks to withstand, adapt to, and recover from disruptions, while maintaining efficient goods movement (IPCC Glossary ⁹⁶).

Risk – in the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making (IPCC Glossary ⁹⁶).

Social and environmental benefits (third dividend of resilience) – The wider co-benefits to society and the environment stemming from resilience interventions, beyond avoided losses and induced economic gains, which may accrue regardless of whether a disaster occurs (WRI ⁸⁰).

Supply chain – a channel of goods distribution, which starts with the supplier of raw materials or components, moves through an operational process to the distributor and retailer, and finally to the consumer (CIPS ⁹⁷).

Supply chain element (SCE) – an individual element within a supply chain representing a node, transport or logistics hub activity.

Supply chain node – a place in the supply chain where goods are produced, transformed, sold, or consumed (adapted from SFC ⁶¹).

Systemic resilience – a property of an infrastructure system that arises dynamically when the [national] infrastructure is organized in such a way that it can provide agreed critical services (power, heat, communication channels, mobility services, potable water, and wastewater and waste removal) despite endogenous and/or exogenous hazards, and despite the addition, modification and removal of infrastructure components (IPCC Glossary ⁹⁶).

Transport or logistics link – a transport segment of the logistics network that connects two points (Life-Links Framework).

Transport Chain Element (TCE) – an individual element within a transport chain representing either a transport activity or a hub activity (SFC ⁶¹).

Transport mode – the means by which goods are moved between nodes and hubs (adapted from SFC ⁶¹).

Triple Dividend of Resilience – the threefold set of benefits arising from investments that reduce risk and build resilience: (1) avoided losses during shocks, (2) induced economic or development gains through increased confidence and investment, and (3) wider social and environmental co-benefits that enhance well-being and sustainability at all times (WRI ⁸⁰).

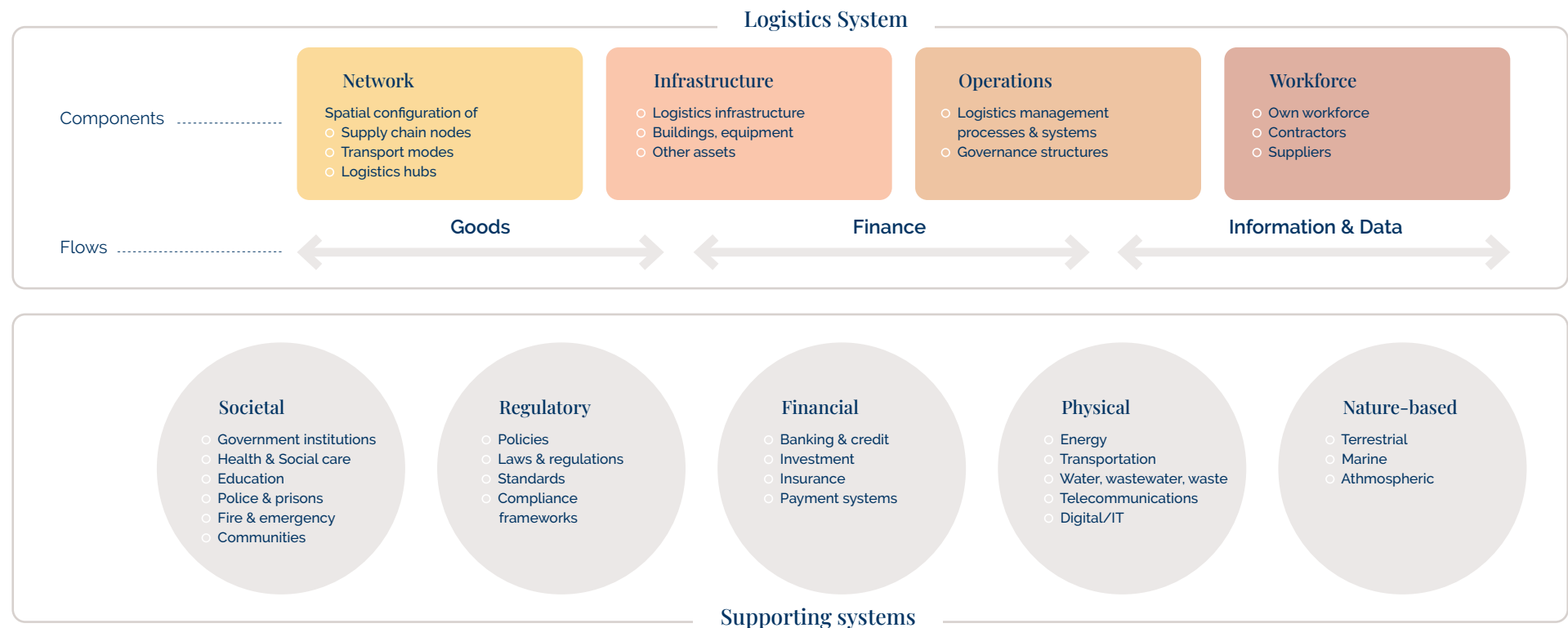
Vulnerability – the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt (IPCC Glossary ⁹⁶).

D-2. Logistics system and supporting systems

The figure below is based on the UNDRR ¹²⁰, MCII ¹¹² UNCTAD ¹¹⁶, UNEP ⁹⁸ guidelines, ITF's framework ⁸ and the KCC white paper ⁵. The logistics system consists of network, infrastructure, operations and workforce, and a

disruption affects the flow of goods, finance or information and data. Supporting systems include societal, regulatory, financial, physical, and nature-based.

Figure D-2: The logistics system and supporting systems



D-3. Three Global Agendas

Key aspects of three global agendas relevant to transport and logistics within global supply chains are shown below.

Sustainable Development Goals under the 2030 Agenda for Sustainable Development ⁵⁵



Target 1.5 Build resilience to environmental, economic and social disasters

By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.

Target 9.1 Develop sustainable, resilient and inclusive infrastructures

Develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.

Target 9.6 Facilitate sustainable infrastructure development for developing countries

Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States.

Target 13.1 Strengthen resilience and adaptive capacity to climate-related disasters

Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Sharm El-Sheikh Adaptation Agenda ⁵⁵

Six systems:

1. Food and agriculture
2. Coastal & Ocean
3. Water and Natural
4. Health
5. Human settlements
6. Infrastructure



2030 Adaptation outcomes ⁸

Infrastructure systems: Transport infrastructure is resilient to climate hazards through the adaptation of new technology, design and materials.

Key challenges for transport infrastructure:

- Very little progress has been made to build resilient transport infrastructure and increase access to mobility for goods and people. An estimated 30% of global rails and roads are currently exposed to extreme flooding and cyclones.
- Transport and energy are not strongly represented in countries' planning efforts for adaptation and resilience. Even though 94% of countries include transport in some way in their NDCs, these still mostly relate to decarbonization of transport.
- There is currently no common taxonomy and supporting metrics, as well as a lack of standards and guidelines, to define, build, and operationalize resilience in the transport sector.
- Current A&R funding levels for transport fall dramatically short of projected needs, and growth needs to accelerate urgently to ensure climate resilience of transport systems.
- Workforce availability in general is a major constraint in the construction industry, but a lack of A&R expertise in specific presents a critical constraint.

Sendai Framework for Disaster Risk Reduction 2015-2030 ⁵⁶

Outcome:

Reduced disaster risk and losses in lives, livelihoods and health and all assets of persons, businesses, communities and countries

Goal:

Prevent and reduce existing disaster risk through measures that reduce exposure, increase preparedness for response and recovery, and strengthen resilience

7 Global targets

Reduce:

1. Mortality / global population
2. Affected people / global population
3. Economic loss / global GDP
4. Damage to critical infrastructure & disruption of basic services

Increase:

5. Countries with national & local DRR strategies
6. International cooperation to developing countries
7. Availability and access to multi-hazard early warning systems & disaster risk information and assessments

Priorities for action (local, national, regional, global):

- Understanding disaster risk
- Strengthening disaster risk governance to manage disaster risk
- Investing in disaster risk reduction for resilience
- Enhancing disaster preparedness for effective response and to build back better in recovery, rehabilitation and reconstruction

13 Guiding principles

In support of the Sendai Framework, six Principles for Resilient Infrastructure were developed, which also apply to transport and logistics infrastructure. These are summarized in the table below, along with a supporting Handbook for implementation.

Table D-3: Principles for Resilient Infrastructure ⁹⁹

Principle	1. Continuously learning	2. Proactively protected	3. Environmentally integrated	4. Socially engaged	5. Shared responsibility	6. Adaptively transforming
Goal	Develop and update understanding and insight into resilient infrastructure	Proactively plan, design, build and operate infrastructures that are prepared for current and future hazards	Work in positively integrated way with the natural environment	Develop active engagement, involvement, and participation across all levels of society	Share information and expertise for coordinated benefits	Adapt and transform to changing needs
Key actions relate to	1. Assumptions 2. Monitoring 3. Improvements 4. Stress tests	1. Safety requirements 2. Requirements critical components 3. Interdependencies connected networks 4. Emergency management 5. Design infra to fail safely 6. Design for multiple scales 7. Maintenance 8. Long-term investments	1. Environmental impact 2. Environmental solutions 3. Ecosystem information 4. Natural environment 5. Local sustainable resources	1. Inform about disruptions 2. Resilience literacy 3. Demand behavior 4. Community participation	1. Harmonized open standards 2. Collective management 3. Shared responsibilities 4. Connectivity for information sharing 5. Data safety for trust 6. Shared risk and return information 7. Avoidable resilience losses	1. Manageable solutions 2. Adaptive capacity 3. Flexible management 4. Capacity for transformation 5. Human discretion

D-4. Mind Shifts that enable Systems Change

At the foundation of systems change based on the Six Conditions of Systems Change lie the change of mental models or mind shifts, tailored to Life-Links. ⁵⁷

Box D-4: Mind Shifts at the basis of systems change for resilient supply chains



From managing risks to adapting to risks

Countries and companies focus on more immediate priorities and still underinvest in climate adaptation. It is feasible and beneficial to act now and prevent and manage supply chain disruptions. Three reasons to do things differently.

- ❑ Current strategies are insufficient to face the extreme climate change now and in the decades ahead.
- ❑ They ignore our dependence on various materials and products from few locations – think about coffee, cocoa or copper.
- ❑ We are aggravating the loss of livelihoods of local communities, financial burden of companies, and the cost of living for consumers. Life-Links looks to complement current risk management strategies with adaptation measures.



From fragmented perspectives to a shared resilience objective

Countries, companies and local communities look at supply chains and impacts from disruptions from their own perspectives, such as costs, the economy, livelihoods. Organizations that try to help them mirror these perspectives: a development bank prepares an infrastructure loans for governments as their client, a service provider may assess supply chain risks for locations important to their corporate customer, and an NGO might look at development and rights of local communities they serve. As a result, measures and responses tend to be isolated and provide only partial protection. Life-Links puts supply chains at the center, recognizes that actors need each other by making shared resilience as the common objective and by extension looks to deliver benefits for all stakeholders.



From power imbalance to local community empowerment

Big businesses have the resources, knowledge and expertise, or are able to access these through service providers, to assess risks from supply chain disruptions, develop response strategies and influence policies and resource flows in their favor. Local communities and very often also governments, especially in the Global South, usually lack all of this. Life-Links helps address this power imbalance by making supply chain risk assessments and action measures inclusive of all stakeholders. Instead of positioning local communities and Global South countries mainly as vulnerable and in need of protection, our starting point is that without them our supply chains would not exist. Therefore we should seek ways to include and empower them when strengthening supply chains to make these truly resilient, so we will all benefit.



From corporate social responsibility to a business case

Many businesses consider supply chains a transactional instead of a strategic part of their business. While Life-Links acknowledges the ethical responsibility to look after local communities, workers and producers, the emphasis lies on redefining the system by presenting the business case to companies and unlock finance from the real economy.

- ❑ A common approach to risk assessment allows businesses to fill the supply chain blind spots (that are often also out of their control), while their own action measures can be supplemented by unique and different action measures from peers and other stakeholders.
- ❑ Different models work in business' favour. In a pain-to-gain model, for example, in the network of agricultural commodities, investments made in physical infrastructure like bridges, roads and 'intangible' assets like

workshops or frameworks, can bring benefits across a business' relevant supply chain stakeholders. In a gain-to-gain model, the savings earned by a business due to investments or partnerships in their logistics activities can be translated into an increase of their own profits, while bringing earnings to e.g. farmers as well (monetary profits, development in their own communities.)

- ❑ In case of (inevitable) disruptions, the country's national disaster risk management office (NDMO) takes change and may request international and humanitarian aid, also to get business operations back up. The speed of response is higher and costs are lower evidenced by "one dollar spent in preparedness activities within the humanitarian logistics sector is equivalent to saving 7 dollars in logistics cost while attending an emergency".

D-5. Guidelines and Tools

Guidelines

The Life-Links Framework builds on existing guidelines – the main ones are listed in Table D-5a below, while

acknowledging that many more guidelines exist. For each guideline the most relevant uses for the Life-Links steps are explained.

Table D-5a. Guidelines and relevance to Life-Links steps

Author	Title	Description	Main uses for Life-Links steps
Asian Development Bank	Disaster-Resilient Infrastructure – unlocking opportunities for Asia and the Pacific ¹⁰¹	Report for national governments, sectoral ministries, and infrastructure owners/operators with 16 opportunities to strengthen infrastructure resilience, considering the full asset life-cycle, accounting for benefits for all stakeholders, improving risk information, and coordination between decision makers	- Consideration of people and economies as users of infrastructures (step 0.3) - Determination of how costs and benefits are shared – risk sharing (Step 3.1) - Identification of financing and funding opportunities for action measures (step 3.2)
Department for International Development (DFID)	Sustainable Livelihoods Guidance Sheets ¹⁰²	Guidance to help understand and analyse the livelihoods of the poor and assess the effectiveness of existing efforts to reduce poverty. It covers vulnerability (trends, shocks, seasonality), livelihood assets (human, social, natural, physical and financial capital), public and private sector structures, and livelihood strategies and outcomes	- Identification of communities and consumers and their interests/needs (step 0.3) - Safeguarding and consideration of sustainability for the package of measures (step 2.3) - Fair sharing of costs and benefits (step 3.1)
German Agency for International Cooperation (GIZ)	Climate Risk Management (CRM) framework ¹⁰³ and a 6-step climate risk assessment (CRA) methodology ¹⁰⁴	Guide for managing climate-related risks including climate risk assessment, measures to minimise losses, and decision-making and implementation in national policy planning and governance systems – supplemented with case studies from Tanzania and India	- Assessment of climate-related risks and impacts (step 1) - India example includes action measures for improved transport infrastructure at the community level (step 2.1)
Global Alliance for Improved Nutrition (GAIN)	Supply Chain Analysis for Nutrition (SCAN) ¹⁰⁵	Guidance for analysing specific food supply chains for their current and potential impact on nutrition, covering three dimensions: characteristics of the food environment, aspects of the supply chain, and stages of the supply chain	- Mapping of supply chains for agri-food products (step 0.2) - Identification of stakeholders and their contribution for agri-food supply chains (step 0.3)
Global Center on Adaptation (GCA)	Climate-Resilient Infrastructure Officer Handbook ¹⁰⁶	Guidance, tools and knowledge for practitioners on how to integrate climate resilience into the infrastructure public-private-partnership (PPP) project cycle (identification, appraisal, tender and award, and contract management)	- Identification of stakeholders and their contribution (step 0.3) - Examples of resilience solutions for transport infrastructure (step 2.1) - PPPs as a contracting structure for collective investment by partners (step 3)
Inter-American Development Bank (IDB)	Disaster and Climate Change Risk Assessment Methodology ¹⁰⁷	Technical guidance identifying, assessing, and managing disaster and climate change risks in projects financed by the IDB, including a list of 100+ available programs/software models, and a list of resilience options for roads and bridges	- Assessment of climate-related risks and impacts (step 1) - Resilience measures applicable to roads and bridges (Step 2.1)

Table D-5a. Guidelines and relevance to Life-Links steps

Author	Title	Description	Main uses for Life-Links steps
International Association of Ports and Harbours (IAPH)	IAPH Risk and Resilience Guidelines for Ports ¹⁰⁸	Guideline for port authorities to establish an effective risk and resilience strategy: define and inventorise risks, manage stakeholders, and build a resilient operational model	- Identification of stakeholders for ports (step 0.3) - Identification of hazards and exposure and factors of influence in a port context (step 1.1)
International Coalition for Sustainable Infrastructure (ICSI)	Port Resilience Framework for Action ¹⁰⁹	A holistic framework to enhance port resilience through 10 goals and actions across three dimensions (economy and society; leadership and strategy; infrastructure and ecosystems)	- Identification of stakeholders, their contribution, and key benefits in a port setting (step 0.3) - Consideration of communities – equity, justice, inclusion (step 2.3)
International Transport Forum (ITF)	Transport System Resilience – Summary and Conclusions ¹¹⁰	Resource on disruptions to transport systems (climate, pandemics, geopolitical conflicts), predicting vulnerabilities, policy measures (avoid, coping, redundancy), and recommendations	- Hazards, vulnerabilities, cascading effects (step 1.1, 1.2, 1.3) - Policy measures to increase transport resilience (step 2.3)
International Transport Forum (ITF)	Enhancing the connectivity, sustainability and resilience of regional freight transport in Central Asia + four working papers ¹¹¹	Report summarising a study on large-scale regional freight transport infrastructure projects and policy pathways for six countries in Central Asia, examining how policies and infrastructure investment can help to achieve connectivity, decarbonisation, and resilience goals across the region.	- Identification of action measures (step 2.1) - Assessment of resilience effectiveness of measures based on resilience attributes (step 2.2)
Munich Climate Insurance Initiative (MCII)	Integrating Insurance into Climate Risk Management: Conceptual Framework, Tools and Guiding Questions: Examples from the Agricultural Sector ¹¹²	A framework and step-by-step guidance, tools and questions for integrating insurance solutions into climate risk management strategies following disaster risk management phases (prevention, retention and transfer, preparedness, response and recovery), and specifically focusing on the agricultural sector	- Identification of stakeholders and their needs (step 0.3) - Assessment of climate-related risks and impacts (step 1) - Role of insurance in action measures that build resilience (step 2.1)
OECD	OECD Supply Chain Resilience Review ¹¹³	Approach to navigating supply chain risks without undermining the upside benefits that come with global trade, drawing on a review of OECD's work, data, indicators and monitoring of supply chains.	- Understanding of various strategies for resilience in supply chains (step 2.1) - Identification of relevant government policies and plans and trade-offs (step 2.3)
PIANC (World Association for Waterborne Transport Infrastructure)	Climate Change costs to Ports and Waterways: Scoping the Business Case Assessment for Investment in Adaptation ¹¹⁴	Guidance on the factors that are the most appropriate to the business case for adaptation planning and intervention for ports at the levels of facility/asset; transportation; supply chain; or wider safety, social and environmental context	- Assessment of feasibility and resilience effectiveness (step 2.2) - Value proposition and business case (step 3.1) - Identification of financing and funding opportunities for action measures (step 3.2)
PIARC (World Road Association)	PIARC International Climate Change Adaptation Framework ¹¹⁵	Framework to help organisations identify adaptation principles and increase the climate resilience of road transportation assets, operations, and services, in four stages: preparation, assessment pathways, adaptation measures, and incorporating findings.	All steps from a road perspective, especially: defining a road or road segment as critical link (Step 0.2), exacerbating effects from climate change (step 1.3), selection of measures (step 2), and committing to a package of measures (step 3.1)

Table D-5a. Guidelines and relevance to Life-Links steps

Author	Title	Description	Main uses for Life-Links steps
UN Conference on Trade and Development (UNCTAD)	Building Capacity to Manage Risks and Enhance Resilience – Guidebook for container ports ¹¹⁶	Step-by-step approach for ports to build resilience before, during and after disruptions caused by natural and human-made hazards, supported by case studies for 23 ports.	- Define critical link in a port setting (step 0.2) - Identification of stakeholders (step 0.3) - Assessment of climate-related risks and impacts (step 1) - Identification of resilience measures for ports (Step 2.1) and indicators for resilience (step 2.2.)
UN Development Programme (UNDP)	Climate and Disaster Risk Finance and Insurance (CDRFI) in National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs) ¹¹⁷	Review on how CDRFI can be integrated in national climate plans (NAPs and NDCs), combining risk reduction, adaptive strategies and financial protection instruments; grouped as before (ex-ante) and after (ex-post) shocks and for reoccurring small scale (risk retention) and low-frequency severe (risk transfer) events.	- Identifying relevant government policies and plans (step 2.3) - Analysing options for financing of the action measures included in the package (step 3.2)
UN Economic Commission for Europe (UNECE)	Towards climate resilient transport systems. ¹¹⁸	Resource on transport system resilience including future climate conditions; supportive policies and legislation (international and EU levels); climate impact assessment methods; adaptation measures (across structural/physical, social and institutional, and including mode-specific examples); and case studies	- Identification of climate hazards for transport (step 1.1) and impact assessment (step 1.3) - Identification of action measures (step 2.1) - Identification of institutional measures; and maladaptation examples (step 2.3)
UN Environment Programme (UNEP)	Adaptation & Resilience Impact – a measurement framework for investors ¹¹⁹	Guidance for assessing the positive adaptation and resilience impacts of investment; embedding impact assessment in the investment cycle; and setting supportive metrics for people, planet and economy	Metrics and indicators for impacts for stakeholders (step 1.2), feasibility assessment (step 2.2), and monitoring (step 3.2)
UN Office for Disaster Risk Reduction (UNDRR)	Technical guidance on comprehensive risk assessment and planning in the context of climate change ¹²⁰	Guidance on conducting risk assessment of climate change withing broader human and ecological systems, integration of results into decision-making and planning processes of governments, and dealing with challenges	Assessment of climate-related risks and impacts (step 1)
UN Office for Disaster Risk Reduction (UNDRR)	Handbook for Implementing the Principles for Resilient Infrastructure ⁹⁹	Guidance for countries in enhancing the resilience of their infrastructure systems. Key actions are provided for each of the six Principle for Resilience Infrastructure, combined with stakeholder roles and performance indicators, along with a governance framework.	- Identification of stakeholders (step 0.3) - Value proposition / benefits for different stakeholders (step 3.1) - Stakeholder roles (step 3.2)
UN Office for Disaster Risk Reduction (UNDRR)	Nature-based Solutions for comprehensive disaster and climate risk management ¹²¹	Toolkit to support countries in making nature-based solutions (NBS) an integral part of planning and implementation of disaster risk reduction and climate change adaptation	- Identification of action measures that build resilience to include NBS (step 2.1) - Assessment of feasibility and resilience effectiveness of NBS (step 2.2) and safeguards concerning nature (step 2.3)
US Agency for International Development (USAID)	Climate Risk Screening and Management Tools ¹²²	Tools to support climate risk screening and management in strategy, project and activity design, across nine sectors, such as agriculture, disaster readiness, health, governance, education, and infrastructure, construction, and energy	Assessment of climate-related risks and impacts (step 1) and measures/ opportunities (step 2.1) at the sectoral level

Table D-5a. Guidelines and relevance to Life-Links steps

Author	Title	Description	Main uses for Life-Links steps
World Bank	Climate Toolkits for Infrastructure PPPs ¹²³ and for Roads ¹²⁴	Framework and guide for integrating climate considerations into the project selection, preparation, structuring considerations and tender process of infrastructure projects delivered through public-private partnerships (PPPs)	Embedding the Life-Links concept into PPP projects (steps 1, 2 and 3)
World Bank	Disaster and Climate-Resilient Transport Guidance Note ¹²⁵	Strategic guidance to integrate climate resilience into investments in every phase of transport infrastructure life-cycle (system planning & financing, engineering & design, operations & maintenance, contingency planning, and institutional capacity & coordination), supported by case studies, best practices, and indicators.	- Resilience measures for roads, urban transport, railways, maritime/inland waterways, aviation, coastal (step 2.1) - Indicators for feasibility assessment (step 2.2), and monitoring (step 3.2)
World Bank	Low-Carbon and Climate-Resilient Rural Logistics in the Sahel: Strategic Framework for Investment Planning ¹²⁶	Strategic framework that integrates climate considerations to evaluate social and economic development through rural transportation and logistics solutions in the Sahel region. It guides investment across the logistics system, integrated with supply chains, with indicators for investment appraisal.	- Identification of communities and local consumers and their interests/needs (step 0.3) - Identification of logistics challenges related to rural roads (step 1.2) exacerbated by climate (step 1.3) - Identification of action measures, feasibility analysis for logistics nodes, and safeguarding (step 2)
World Bank	Transport Connectivity for Food Security in Africa – Strengthening Supply Chains ¹²⁷	Book that explores the relationships between transport, logistics and food security, and identifies vulnerabilities and opportunities along the entire food supply chain in order to improve the resilience of food systems in Africa.	- Identification of broader exposure (step 1.1), vulnerabilities and impacts (step 1.2) - Identification of resilience measures for roads, logistics (step 2.1) and broader measures that improve connectivity (step 2.3)
World Bank	Transport Resilience Financing, Resources and Opportunities (English) ¹²⁸	Information on 42 global financing facilities, 33 public funds, and 29 tax measures, offering valuable insights into financing transport resilience in developing countries	Identification of financing and funding opportunities/mechanisms for action measures (step 3.2)
World Bank	Sub-sectoral Roadmaps to Promote Private Sector Participation in Transport Resilience: Roads, Railways, and Urban Transport ¹²⁹	Roadmaps include risk assessment and project pipeline development, incorporating resilience considerations for private sector participation projects, and funding and financing.	Building the case for private sector participation and investment for resilience of roads and railways infrastructure (step 3.1)
World Business Council for Sustainable Development (WBCSD)	Adaptation Planning for Business – Navigating uncertainty to build long-term resilience ¹³⁰	A guide supporting businesses to integrate adaptation and resilience across the whole business, covering: set the scope and goals; design adaptation solutions; build the plan & implement; and monitor & evaluate. (Forthcoming: CEO Handbook on Addressing Physical Risks in Value Chains)	- Feasibility assessment of measures (step 2.2) - Development of implementation plans from a company perspective (step 3) - Building the business case (step 3.1)
Zurich Climate Resilience Alliance (ZCRAlliance)	Adaptation finance and the private sector: opportunities and challenges for developing countries ¹³¹	Overview of the potential for the private sector to help bridge the adaptation finance and funding gap in developing countries under current scenarios and with innovation, including for transport infrastructure.	Identification of financing and funding opportunities/mechanisms for action measures (step 3.2)

Table D-5b lists a range of leading tools with different approaches available to support resilience across different parts of the supply chain system. Digital tools — most of them developed commercially and used by the private sector — provide the data, visibility, and predictive intelligence needed to anticipate risks, design effective responses, and coordinate action across partners. Yet these tools differ widely, for example in:

- **Service scope:** Some tools emphasize visibility and disclosure (e.g. Sourcemap, Altana), while others focus on risk management and optimization (e.g. Kinaxis, AIMMS, Microsoft Dynamics), or deliver real-time visibility and monitoring services (Platforms like Project44 and Prewave).
- **Supply chain scope:** Tools vary in whether they map suppliers and customers (Resilinc, Sourcemap, Exiger), locations and assets (MunichRe, Jupiter), or transport/logistics networks (Project44, ORIS) – many combine multiple perspectives.
- **Hazard/risk scope:** Generalist risk platforms cover multi-hazard disruption and supplier risks (Resilinc, Everstream, Prewave), while climate-specialized tools focus on physical hazard and climate risks (Jupiter, Correntics, MunichRe).
- **Risk management scope:** Capabilities include assessment and scoring (Resilinc DVI, MunichRe, Jupiter), predictive analytics and control towers (Everstream Reveal, Kinaxis RapidResponse), and response planning or mitigation and resilience/adaptation measures (AIMMS SC Navigator, Microsoft Dynamics, ORIS).

Table D-5b. Tools relevant to supply chain resilience and logistics (not an exhaustive list)

Author	Title	Description
AIMMS SC Navigator	Decision-support tool for scenario modelling, what-if analysis, and network design optimization.	https://www.aimms.com/network-design
Altana	Federated supply chain mapping platform with multi-tier visibility, risk screening, and privacy-preserving collaboration.	https://www.altana.ai
Correntics Climate Risk Analytics Platform	Climate & weather risk analytics SaaS platform quantifying exposure and financial impacts in supply chains.	https://www.correntics.com
Everstream Analytics	Predictive risk intelligence suite with disruption monitoring, risk-optimized planning, and Reveal early-warning tool.	https://www.everstream.ai
Exiger	Risk, compliance, and supply chain intelligence (SDX, DDIQ). Provides provenance mapping, due diligence, and risk monitoring.	https://www.exiger.com
Jupiter ClimateScores Global	Climate risk scoring system with high-resolution, peril-specific metrics for supply chains and infrastructure.	https://www.jupiterintel.com/climatescore-global
Kinaxis	Supply chain planning platform (RapidResponse) offering concurrent planning, scenario analysis, and AI-powered forecasting.	https://www.kinaxis.com
Microsoft Dynamics 365 SCM	Enterprise supply chain management suite with unified visibility, AI insights, and logistics coordination, supporting resilience and operational continuity.	https://www.microsoft.com/en-us/dynamics-365/products/supply-chain-management
MunichRe – Location Risk Intelligence	Geospatial risk analytics platform assessing natural hazard & climate risks at site/supplier level.	https://www.munichre.com/rmp/en/products/location-risk-intelligence.html
ORIS Materials Intelligence	Digital platform dedicated to streamline adaptation and mitigation measures for transportation infrastructure, using material science, lifecycle assessment, and climate scenarios	https://www.oris-connect.com/en
Prewave	AI-driven risk intelligence platform for supply chain monitoring, compliance, orchestration, and reporting.	https://www.prewave.com
Project44	Transportation visibility platform with multimodal shipment tracking, predictive ETAs, and disruption alerts.	https://www.project44.com
Resilinc	Supply chain risk monitoring & mapping platform with multi-tier visibility, event alerts, risk scoring, and Disruption Vulnerability Index (DVI).	https://www.resilinc.com
Sourcemap	Supply chain mapping & transparency platform with supplier onboarding, verification, impact scoring, and due diligence support.	https://sourcemap.com

D-6. Stakeholders and Actors

Table D-6a presents an overview of stakeholders and actors from a supply chain perspective. In the context of Life-Links a stakeholder has an interest in or affected by or can influence the outcome of the project, whereas actors actively participate in the project and making decisions.

Table D-6a: Overview of stakeholders and actors

Groups	Stakeholders/actors and descriptions/examples
Communities	Local communities (residents, households, indigenous groups living in areas affected by or engaged with a project and dependent on land, forests, water, or other natural resources for their livelihoods and cultural identity)
	Workers & producers - Individual workers, employees, contractors - Farmers and other producers - Informal labour groups, trade unions and formal worker representatives
	Vulnerable groups (groups often marginalized, underrepresented in decision-making, and who may pose a salient human rights risk for companies) - - Children/youth - Ethnic minorities - Indigenous Peoples - People with disabilities - Women - Other
Consumers	Local end-users, consumers & households (individuals and families purchasing and using goods and services within local or national markets, directly affected by pricing, availability, and quality of products and services)
	Consumers in export markets (buyers and end-users in foreign markets whose demand, purchasing power, consumer rights, and standards influence production, and who are also impacted by pricing, availability, and product safety across global supply chains)
Countries	Government bodies/authorities (actors who set policy, make laws, regulate and enforce/supervise) - National / central government bodies – ministries, departments, national agencies - Regional / local government bodies – provincial, municipal, or district authorities - Regulatory/ enforcement / supervisory authorities – independent or semi-independent watchdogs overseeing specific sectors - Central banks & monetary authorities – independent public financial institutions managing currency, monetary policy, and financial stability (e.g., European Central Bank, US Federal Reserve, national reserve banks).

Table D-6a: Overview of stakeholders and actors

Groups	Stakeholders/actors and descriptions/examples
Countries	Government/State affiliated entities (actors that deliver public services, manage state assets, or support policy implementation but don't set broad government policy) - Public utilities – state run providers of essential services such as energy, water, waste, and public transport. - Public service providers – hospitals & social care institutions, police & prisons, fire & emergency - State Owned Enterprises (SOEs) – government owned companies operating in sectors like transport, energy, banking, and manufacturing. - State-owned media - Government affiliated research & academic institutes – state funded think tanks, policy research centers, and technical institutes (e.g., agricultural research centers, national health research bodies). - Sovereign wealth & public investment funds – state owned investment entities managing national wealth and reserves. - Public Private Partnerships (PPPs) – hybrid organizations jointly run by government and private actors to deliver infrastructure or services.
	International governmental bodies (create binding rules, standards, or policies as well as international conventions or treaties across countries) - Supranational bodies (e.g., European Union) - Intergovernmental organizations with regulatory roles (e.g., World Trade Organization (WTO), International Maritime Organization (IMO), World Health Organization (WHO)) - Regional policy bodies (e.g., African Union, ASEAN, MERCOSUR)
Companies	Producing/manufacturing/retail (shippers or freight buyers) - Energy - oil & gas companies, electricity producers, renewable energy providers - Mining & raw materials - companies that extract metals, minerals, and other natural resources - Agriculture & food (farming, food production, and processing businesses) - Industrial & manufacturing - factories making machines, vehicles, electronics, chemicals, and other goods - Construction & real estate - companies that build, develop, and manage properties and infrastructure - Consumer goods & retail - brands and stores selling everyday products, clothing, electronics, and more - Healthcare & life sciences – private hospitals, pharmaceutical companies, biotech firms, and medical device makers
	Transport and logistics - Carriers - own and operate transport vehicles: shipping lines, airlines, trucking fleets, rail operators, pipeline transport - Logistics service providers or LSPs - freight forwarders, third-party logistics (3PL), and fourth-party logistics (4PL) providers handling shipment planning, customs, warehousing, fulfilment, and end-to-end supply chain management - Logistics hubs & infrastructure operators - ports, airports, rail terminals, intermodal hubs, warehouses, and distribution centers, enabling the flow and transfer of goods between modes - Last-mile & specialized delivery - parcel and courier services for home/retail delivery; plus specialized logistics (e.g. cold chain, hazardous goods, oversized) - Informal & intermediary players - freight brokers, middlemen, popular transport, consolidators
Secondary stakeholders (working with, for, or on behalf of stakeholders)	Company owners – company owners, shareholders, equity owners
	Company customers - corporate clients / business (B2B) customers

Table D-6a: Overview of stakeholders and actors

Groups	Stakeholders/actors and descriptions/examples
Secondary stakeholders (working with, for, or on behalf of stakeholders)	Finance - Banking – retail, commercial, and credit institutions - Insurance – life, health, property, and reinsurance providers - Investment & asset management – investment banks, asset managers, pension funds, private equity - Financial technology (Fintech) – digital payments, online lending, blockchain solutions - Specialized financial services – credit rating, leasing, financial advisory - Informal & community finance – microfinance institutions, savings groups, moneylenders, pawnshops, and mobile money agents
	Other service providers - Technology & software – software developers, IT service providers, hardware manufacturers, cloud platforms, and cybersecurity companies - Telecommunications – providers of mobile, broadband, and satellite communication services - Media & creative industries – commercial media, broadcasting, publishing, digital media platforms, advertising, and creative agencies - Professional & business services (consulting firms, legal services, accounting, market research, and other expert advisory services)
	Research and academia - Universities & higher education institutions – public and private universities, colleges, and polytechnics conducting research and education - Research institutes & laboratories – public and private research centers, corporate and independent laboratories - Technology transfer & innovation hubs – technology transfer offices, university-linked innovation hubs, science parks - Incubators & accelerators – organizations supporting research-based startups and innovation-driven enterprises - Experts & academic professionals – individual scientists, researchers, and academic experts contributing knowledge and thought leadership
	Civil society - Informal & traditional civil society – religious and faith-based networks, traditional and community leaders, social movements and informal networks, mutual aid and voluntary groups - Advocacy & activism – advocacy and activist groups, watchdog and accountability organizations, issue-based campaigns and networks - Community & grassroots organizations – community-based organizations (CBOs), citizens and resident associations, cultural and creative organizations, cooperatives (e.g., farmer or savings cooperatives) - Non-governmental organizations (NGOs) – mission-driven organizations delivering services, humanitarian aid, policy advocacy, watchdogs (national or international) - Member-based associations – professional associations, chambers of commerce, federations, and networks representing collective member interests - Philanthropy & funding organizations – philanthropic organizations and foundations, charitable trusts and endowments - Media & communication platforms – independent and community-based
	International development & aid organizations - Multilateral development banks (MDBs): e.g., World Bank, African Development Bank, Asian Development Bank. - UN development agencies & programs: e.g., UNCTAD, UNDP, UNEP, UNICEF, UNIDO, WFP. - Bilateral development & cooperation agencies: e.g., GIZ, JICA, DFID (now FCDO).
	Environment & future generations (affected stakeholders without the ability to be actively engaged or influence) - Environment (climate, biodiversity, water, other) - Future generations

Table D-6b groups these same stakeholders and actors from a company perspective using the EU Corporate Sustainability Reporting Directive categories of affected

stakeholders, users of sustainability information and business relationships (value chain partners).

Table D-6b: Corporate stakeholders and actors and the EU CSRD / CSDDD

Stakeholder group	Stakeholders/Actors	Stakeholder/actor categorization based on EU CSRD / CSDDD		
		Affected stakeholders	Users of sustainability information	Business relationships (value chain partners)
Communities	Local communities	✓		
	Workers & producers	✓		
	Vulnerable groups	✓		
Consumers	Local end-users, consumers & households	✓		
	Consumers in export markets	✓		
Countries	Government bodies/authorities		✓	
	Government/State affiliated entities		✓	✓
	International governmental bodies		✓	
Companies	Producing/manufacturing/retail			✓
	Transport and logistics			✓
Other actors working with, for, or on behalf of stakeholders, or affected otherwise	Company owners		✓	
	Corporate customers		✓	✓
	Finance		✓	✓
	Other service providers			✓
	Research and academia		✓	
	Civil society		✓	
	International development & aid organizations			✓
	Environment and future generations	✓		

D-7. Hazards to Supply Chains and Logistics

This table presents a categorization of hazards along with examples drawn from the guidelines and a selection of tools listed in Part D-2. Hazard categories are based on the risk categories as applied by WEF Global Risk Report,⁴² and splitting natural hazards into geophysical, and

climate-related acute physical and chronic physical to be consistent with TCFD's recommendations regarding climate-related risks.¹³² The climate-related hazards are from the IPCC Sixth Assessment Report and called 'climate impact-drivers'.¹³³

Table D-7: Hazards

Natural Hazards			Human-made	
Extreme weather events (acute physical)	Heat and cold	Extreme heat	Geopolitical	Wars / armed conflicts
		Cold spell		Political instability / civil unrest
		Frost		Geopolitical sanctions (political, economic, trade)
	Wet and dry	Landslides	Geopolitical	Pandemics
		Droughts		Epidemics
		Wildfires		Disease/virus outbreaks (waterborne, insects, other)
		River flood		Spread pests and diseases (e.g. malaria, dengue)
		Heavy precipitation and pluvial flood	Safety	Public safety
		Landslide		Risks to individuals
		Aridity	Urban / society	Urbanization challenges (overcrowding, informal settlements)
		Hydrological drought		Migration and displacements
		Agricultural and ecological drought		Aging infrastructure
		Fire weather		Resource scarcity (e.g. water, energy)
		Tropical cyclone	Urban / society	Cyber (data breach, denial of service, phishing, ransomware, vulnerability)
		Sand and dust storm		IT system failures
	Snow and ice	Heavy snowfall and ice storm	Economic and Financial	Sabotage subsea cables
		Hail		Financial crises / recessions
		Snow avalanche		Demand shocks
	Coastal	Coastal flood		Inflation
	Open ocean	Marine heatwave		Capital availability issues

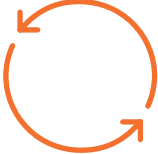
Table D-7: Hazards

Natural Hazards			Human-made	
Extreme weather events (acute physical)	Other	Air pollution weather	Labour	Strikes
	Heat and cold	Mean air temperature		Labor shortages
	Wet and dry	Mean precipitation		Lack of skilled workforce
	Wind	Mean wind speed		Worker absence (illness, holidays)
Shifts in climate patterns (chronic physical)	Snow and ice	Snow, glacier and ice sheet	Security	Theft
		Permafrost		Piracy
		Lake, river and sea ice		Corruption
	Coastal	Relative sea level		Smuggling and illicit trade
	Coastal	Coastal erosion		Crime (organized crime, robbery, shooting)
	Open ocean	Mean ocean temperature		Terrorism
		Ocean acidity		Vandalism / sabotage
		Ocean salinity		Piracy / criminal attacks
Geophysical		Dissolved oxygen	Accidents / Failures	Equipment failures
		Seismic (earthquakes, tsunamis)		Infrastructure (fuel, network, power, telecom, water/sewage)
		Sinkholes		Transport infrastructure (bridge, mine, tunnel, dams, dikes/levees)
		Glacial lake outburst floods (GLOFs)		Industrial (e.g. chemical spills, explosions, hazardous materials)
		Geomagnetic storms		Fires (industry, vehicle, vessel, other)
		Volcanic eruptions		Transportation
			Corporate	Financial (financial health, insolvency, M&A)
				Production (operations, product, workplace)
				Suppliers
			Regulatory	Industry (regulations, directives, advice)
				Trade (sanction, restriction, regulation)
				Litigation / legal issues
			Transportation	Aviation
				Customs
				Ground transportation
				Maritime
	Environmental, climate-related physical			
	Environmental, geophysical			
	Economic			
	Societal			
	Geopolitical			
	Technological			

D-8. FAIR Guiding Principles for Data

The FAIR guiding principles can support the assessment of supply chain risks and impacts, especially when data is obtained and integrated from multiple sets and sources.

Table D-8: The FAIR guiding principles for scientific data management and stewardship ¹³⁴

Findable	Accessible	Interoperable	Reusable
			
F1. (meta)data are assigned a globally unique and persistent identifier F2. data are described with rich metadata (defined by R1) F3. metadata clearly and explicitly include the identifier of the data it describes F4. (meta)data are registered or indexed in a searchable resource	A1. (meta)data are retrievable by their identifier using a standardized communications protocol A1.1 the protocol is open, free, and universally implementable A1.2 the protocol allows for an authentication and authorization procedure, where necessary A2. metadata are accessible, even when the data are no longer available	I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation. I2. (meta)data use vocabularies that follow FAIR principles I3. (meta)data include qualified references to other (meta)data	R1. meta(data) are richly described with a plurality of accurate and relevant attributes R1.1. (meta)data are released with a clear and accessible data usage license R1.2. (meta)data are associated with detailed provenance R1.3. (meta)data meet domain-relevant community standards

D-9. Indicators covering risks and resilience for logistics

It is acknowledged that metrics, indicators and KPIs are context-specific and highly depend on the nature of the supply chain, the transport modes and logistics nodes, the actors and stakeholders and other factors. Table D-10a explains for which steps in the Life-Links Framework

metrics or indicators are likely needed (quantitative or qualitative), along with illustrative examples of quantitative metrics. Examples were sourced from guidelines listed in Table D-5.

Table D-9a. Examples of metrics and indicators for selected steps of the Life-Links Framework

Step	What is being measured	Metrics examples
Step 1.1 Identify hazards and characterize exposure	Hazards	- Days above critical heat thresholds per year (e.g. >40oC dry-bulb) - Flood depth at a port (from sea level rise to storm surge) at a 100-year return period - Number of thunderstorms above wind force ?? per year
	Exposure	- Km of road/rail within a 100-year floodplain % of warehouses within mapped wildfire zones - Number of workers/drivers along a corridor routinely exposed to heat
Step 1.2 Assess logistics vulnerabilities, risks and impacts	Logistics vulnerabilities (see also Table Dg-b)	- Average km between farms and nearest aggregation points (sourcing / connectivity) % of packhouses with tested backup power (redundancy / energy reliability) % of freight vehicles or shipments with real-time tracking (visibility / information flow)
	Risk of disruption	- Hours or days of impassable road segments or bridges - Hours or days of delays in berthing at ports - Hours or days of waiting time at packhouses
	Impacts from disruptions (connected to benefits stakeholder resilience)	- Loss of income for farmers and middlemen as fresh produce cannot reach packhouses - Additional costs due to rerouting of sea container ships due to port closures - Number of downtime hours in a factory due to shipment delays
Step 1.3 Assess exacerbating effects from climate change	Exacerbated logistics challenges	- Increase in days that roads are impassable due to more heavy rainfall in 2030 - Increase in berthing delays as ports to higher risk index for severe thunderstorms from today to 2050
	New future climate hazards	Days at a logistics hub with temperature exceeding 35oC (which did not happen in the past)
	Compounding	Increase in days with power blackouts due to heatwaves that affect rail operations

Table D-9a. Examples of metrics and indicators for selected steps of the Life-Links Framework

Step	What is being measured	Metrics examples
Step 2.2 Assess feasibility and effectiveness for resilience*	Feasibility	See Table 8 for examples economic, technological, institutional, socio-cultural, environmental-ecological, geophysical
	Resilience – vulnerability reduction (see also Table Dg-b)	- Reduced average km between farms and aggregation points (strengthened sourcing / local connectivity) - Increased share of packhouses or logistics assets with backup power and spare capacity (enhanced redundancy) - Higher share of shipments with end-to-end digital visibility and alert systems (improved visibility / information resilience)
	Resilience - risk reduction	- Reduction in days of impassable roads segments or bridges (next year, in 2030, 2050) - Reduction in delays in berthing at ports - Reduction in waiting time at packhouses - Reduction in average expected annual disruption hours (EADH) on critical links (baseline vs 2030, 2050)
	Resilience – system level outcomes	- Increased on-time delivery performance across supply-chain nodes - Reduced annual value of losses (in USD) from logistics disruptions - Robustness of performance across scenarios (range of on-time delivery under multiple climate or socio-economic futures) - Continuity of goods flows during disruptions (% of planned shipments or volumes delivered) - Improved coordination across partners (average waiting or idle time at aggregation points / packhouses) - Existence of a monitoring–evaluation–learning (MEL) cycle to update measures over time - Sustained or increased incomes of logistics-dependent actors (e.g. farmers, drivers, warehouse operators)
Step 2.3 Add safeguards and decarbonization and sustainability opportunities	Equity	% of resilience investments benefiting vulnerable or low-income groups along the corridor
	Justice	Extent to which decision-making includes representation from affected local communities (e.g. # of stakeholder consultations or representation share)
	Inclusion	% of women or minority-owned SMEs participating in supply chain resilience projects or contracts
	Co-benefits	Reduction in tonnes CO₂ (absolute) or tonnes CO₂ per tonne-km (intensity)
	Climate compatibility	Change in total lifecycle GHG emissions of the measure compared to baseline (% or tonnes CO₂e)
	Maladaptation safeguards	Change in population or asset exposure among vulnerable groups relative to baseline (% change)
Step 3.1 Commit to package of action measures	Business case (connected to feasibility assessment in Table 8 and value creation in Table 13)	- Number of people benefiting from enhanced climate resilience flood measures at ports - Increased income of smallholder farmers benefiting from closer aggregation points - Volume of additional goods storage capacity due to packhouse expansion - Reduced risk of fines due to regulatory non-compliance
Step 3.2 Agree collaboration, financing, and monitoring	Project implementation	Actual versus planned timelines, costs, other factors
	Outcomes	Actual versus expected impacts on resilience, sustainability, other

* Note: Standard supply-chain performance indicators (e.g. reliability, responsiveness, flexibility, cost, and asset-management metrics such as those in the Supply Chain Operations Reference (SCOR) model) remain useful for company-level monitoring and can complement the Life-Links resilience metrics by showing how resilience measures affect logistics performance over time.

Table D-9b: Examples of metrics or indicators for resilience relevant to exposure/vulnerability reductions of transport, logistics and supply change ^a

Attribute	Definition	Metrics examples
Sourcing	Average distance freight consignments move in a supply chain, SCE or trip, and how far and from where goods are procured.	○ Average length of haul for total freight tonnage or for tonnage by specific transport modes ○ Share of tonne-km with origin or destination outside the country ○ Import penetration by commodity group as a share of total sales
Intermodality	Extent to which using different transport modes spreads disruption risk, and the ability to switch modes before or during disruptions.	○ Share of freight tonne-km moved by different modes ○ Share of freight moved on intermodal services ○ Spatial density of intermodal terminals compared to network length ○ Differences in average transit time between modes, including intermodal services ○ Differences in average reliability of modes
Redundancy	Amount of spare capacity and inventory in the logistics system to buffer interruptions to the flow of goods.	○ Average utilisation of network and terminal capacity ○ Average utilisation of vehicle capacity ○ Average level of inventory as the ratio of the value of inventory to sales for different commodity groups or business sectors
Scheduling	Degree to which production and logistics processes are synchronized (e.g. just-in-time, replenishment) and flexibility in timing and coordination of flows.	○ Average order lead times (based on company surveys) ○ Share of orders delivered just-in-time by commodity group or business sector ○ Distribution of freight deliveries over the 24-hour cycle
Diversity	Range of options available for routing freight, suppliers, carriers, clients, or energy sources.	○ Indices of alternative routing options for different modal networks ○ Share of freight vehicles with access to mobile communications ○ Share of suppliers visible in digital supply chain mapping platforms
Visibility	Degree of supply chain and supplier visibility; stakeholder awareness and capacity, and the nature and speed of communication about disruptions.	○ Performance standards for transport alerting systems ○ Share of freight vehicles with access to mobile communications ○ Country-specific metrics used by online supply chain risk and resilience platforms
Workforce	Capacity, safety, wellbeing, and awareness of logistics workers, contractors and suppliers in managing disruptions.	○ Number of logistics worker days lost due to disruptions ○ Frequency of workplace accidents in logistics operations ○ Share of workers trained in emergency and digital logistics procedures
Cyber and digital	Robustness of digital systems, data, and communications against cyber attacks, system failures, and data breaches.	○ Number of cyber incidents affecting logistics operations per year ○ Share of logistics partners meeting minimum cybersecurity standards ○ Average system downtime due to digital failures
Protection of goods in transit	The degree to which goods are safeguarded against damage, spoilage, contamination, theft, or loss during transport, handling, and storage.	○ Cargo losses during transport and storage as a share of total shipments ○ Share of perishable goods arriving within acceptable temperature ranges ○ Number of theft or tampering incidents reported in transit

D-10. Resilience measures that strengthen existing routes

Action measures to improve resilience by strengthening existing routes and its transport modes and logistics hubs are listed below, and are subdivided into infrastructure, operations and workforce.

Table D-10: Overview of resilience measures that strengthen existing routes*

Logistics System	Resilience Measures to strengthen existing routes and its transport modes and logistics hubs <i>(not an exhaustive list)</i>
Infrastructure	Multimodal resilience within existing corridors - Strengthen multimodal integration in current corridors - Enhance hub connectivity to ports and airports
	Retrofitting & upgrading existing infrastructure - Retrofit and upgrade roads, bridges, ports, and logistics hubs to meet higher design thresholds (e.g., seismic retrofitting, wind- and heat-resistant materials, stronger bridge piers) - Reinforce pavements and embankments with geosynthetics or concrete armor for durability under floods or landslides - Strengthen critical nodes (e.g., loading docks, cranes, airport runways) to maintain operations during extreme events
	Protective systems and barriers - Levees, sea walls, and storm surge barriers to shield ports, coastal roads, and low-lying logistics hubs - Slope stabilization with retaining walls, rockfall barriers, or vegetative cover in landslide-prone corridors - Windbreaks and protective screens near critical airport and port facilities
	Enhanced drainage systems - Upgraded culverts, retention basins, and enlarged storm drains along key corridors - Permeable pavements and bioswales in logistics areas to reduce surface runoff. - Integrated drainage networks connecting roads, rail, and adjacent facilities to prevent localized flooding
	Nature-based & hybrid solutions - Integrate wetlands, mangroves, and vegetative buffers to protect critical corridors from flooding and storm impacts - Green corridors: bioengineered embankments and living barriers to complement hard infrastructure
	Smart monitoring & predictive maintenance - IoT-based condition monitoring for roads, bridges, warehouses, and ports - Predictive maintenance programs using AI to anticipate failures - Digital twins of key infrastructure for stress-testing
	Energy & utility resilience - Backup power systems (microgrids, solar + battery) for logistics hubs - Redundant utility connections for ports, airports, and warehouses - Resilient cold chain facilities with backup energy and climate-resistant enclosures

Table D-10: Overview of resilience measures that strengthen existing routes*

Logistics System	Resilience Measures to strengthen existing routes
Operations	Advanced planning & coordination - Integrated logistics management platforms for end-to-end visibility - AI-based demand & disruption forecasting - Digital twins for stress-testing supply chains and logistics operations
	RProcess hardening & flexibility - Flexible contracts with carriers and suppliers - Standardized emergency operating procedures - Surge capacity protocols for post-disruption recovery
	Enhanced inventory, storage & packaging - Upgraded storage facilities with climate-resilient retrofits, humidity control - Mobile storage and cooling units - Packaging solutions against shocks, weather, temperature - Load protection e.g. straps, lashings, anti-slip mats, winter tires - Smart sensors for real-time product monitoring - Strategic contingency stockpiles at existing warehouses
	Transport & logistics optimization - Dynamic routing systems for disruptions - Multimodal contingency options within existing corridors - Fleet modernization for climate resilience and efficiency
	Cyber & digital resilience - Hardened IT infrastructure for logistics operations - Cloud-based platforms for continuity - Cyber incident response protocols embedded into operations

Table D-10: Overview of resilience measures that strengthen existing routes*

Logistics System	Resilience Measures to strengthen existing routes
Workforce & Stakeholders	Capacity building & specialized training - Advanced training for drivers, warehouse staff, and port operators - Certification programs for disruption-specific competencies - Cross-training employees for multi-role capability
	Institutionalizing resilience roles & functions - Dedicated resilience teams within logistics firm - Embedding resilience KPIs into workforce performance - Formal partnerships with emergency services
	Wellbeing & workforce support - Climate control systems (AC/heating e.g. in trucks, cabins, warehouses) - Flexible working hours to avoid high-risk times - Mental health programs for logistics staff - Emergency allowances & on-site support systems - Resilient communication channels for workforce coordination
	Stakeholder engagement & collaboration - Public-private emergency logistics alliances - Joint training programs with suppliers, clients, and authorities - Stakeholder councils for collective resilience planning - Information-sharing protocols and data exchange platforms across partners
	Knowledge & continuous improvement - Post-incident debriefs for lessons learned - Regular resilience drills with partners - Best-practice sharing platforms across logistics networks - Recovery command structures and coordination mechanisms - Public awareness initiatives for logistics users (e.g., service disruption protocols)

* Sources and further reference:

- GCA Climate-Resilient Infrastructure Officer Handbook ¹⁰⁶
- ISO 22301 - Business Continuity Management Systems ¹³⁵
- ITF - Transport System Resilience ¹¹⁰
- McKinsey - Risk, resilience, and rebalancing in global value chains ⁴³
- NIST - Community Resilience Planning Guide ¹³⁶
- OECD - Supply Chain Resilience Review ¹¹³
- OECD/ITF - Adapting Transport Networks to Climate Change and Extreme Weather ¹³⁷
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- UIC - Future Proof Railways ¹³⁸
- UNDRR - Nature-based solutions for comprehensive disaster and climate risk management: toolkit ¹²¹

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- World Resources Institute - Strengthening the investment case for climate adaptation ⁶
- UNEP/FAO - Sustainable Cold Food Chains ¹⁴⁰
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- Deloitte - AI for Infrastructure Resilience ¹⁴²
- Kuehne Climate Center - Logistics in a +20C World ⁵
- OSHA - Heat Stress Guide ¹⁴³
- KCC & GNTP - Popular Transport in Africa ¹⁴⁴
- DP World - Climate Proofing the Supply Chain ¹⁴⁵

D-11. Key Factors for Supply Chain Collaboration

The figure below lists the risk and success factors for supply chain collaborations from four different perspectives: general company, sector, and developing countries. These were prepared by students from the ESCP Business

School as part of the company consultancy project „Supply Chain Collaboration on Climate Resilience“ in January 2025. Results of this study will be developed as a separate resource for the Life-Links Framework.

Table D-11: Key risk and success factors for supply chain collaboration

Strategic alignment	- Goals - Objectives - Expectations	General	Company scale	Cooperation with business partners along value chains	- Single supplier reliance - Compliance & standards alignment - Companies reputation
Relationship	- Trust - Communication - Cultural conflicts			Project-level financing and implementation partnerships	- Unequal risk sharing - Resource dependencies - Community engagement
Governance & structure	- Governance - Power dynamic - Accountability & ownership			Industry-level pre-competitive business alliances	- Reluctance to join - Participation and commitment - Information sharing
Resources management & operational execution	- Budget constraints - Implementation - Monitoring			Multistakeholder institutions, platforms and networks	- Tracking & transparency - Decision-making - Local applicability
External environment	- Cross-border security risks - Unexpected disasters / geopolitical tensions - Local vendors opposition to change			Coordination different levels and types of partnerships to drive systemic change	- Long-term commitment - Overlap with development banks - Strategic prioritization
Logistics & infrastructures	- Dependency & infrastructure limitations - Interconnected ecosystems - Ownership issues	Sector	Developing countries	Political context	- Political instability - Public distrust in government
Financial institutions & insurance	- Climate risk - Regulations & law - Data privacy & technology			Local awareness	- Local resistance - Security
Agricultural & food security	- Cultural resistance - Market risk - Infrastructure			Institutional & physical barriers	- Physical barriers - Institutional weaknesses - Regulatory weaknesses
Health & humanitarian support	- Crisis management - Supply chain challenges - Community engagement			Resource & funding	- Lack of budget for public actors - Skilled resource shortages
Innovation & technology	- Technology integration - Intellectual property - Adoption & readiness			Willingness to participate	- Developing countries engagement - International financial contribution

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