Climate-ready Supply Chain

Urgent guidance for ports, waterways and logistics operations to adapt and build resilience in the face of climate change.

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Guidelines for Climate-ready Supply Chain

Contents

Foreword

The global supply chain continues to evolve with technological innovation and consolidation. However it has experienced, and continues to experience, increasing disruptions as a result of climate change and geopolitical factors.

Ports, terminals, and logistics operations, which are vital to economic prosperity and higher standards of living, underpin global trade and are being routinely exposed to climate-related hazards that threaten their operational models, safety and long-term economic output. Adaptation and resilience of global supply chains is therefore an essential consideration for all businesses.

This whitepaper, **Climate-ready Supply Chain: Urgent Guidance for Ports, Waterways and Logistics Operations**, arrives at a critical moment. It offers a comprehensive and practical framework for understanding climate risks, planning adaptive responses and embedding resilience into the core of business strategy.

It is essential we distinguish between climate adaptation and climate resilience. Adaptation refers to the specific actions taken to adjust systems, infrastructure and operations in response to actual or anticipated climate impacts—such as elevating quay walls, reinforcing drainage systems, or modifying shift patterns during heatwaves. Resilience, by contrast, is the broader capacity of a system to absorb shocks, recover quickly and continue functioning effectively. Adaptation is the toolkit; resilience is the outcome.

Recent events have made the stakes abundantly clear. In 2024, extreme weather events caused widespread disruption across every continent. In Europe, heatwaves forced factory shutdowns and slashed agricultural yields, with economic losses estimated to exceed $10 billion. In Asia, devastating floods in China and India crippled transportation infrastructure and inundated warehouses. In Africa, prolonged droughts in the Horn of Africa disrupted inland logistics and food distribution networks. In the Americas, hurricanes in the Atlantic basin disrupted shipping lanes and port operations, while wildfires in California were projected to have an economic cost of $50 billion and led to widespread air pollution, impacting worker productivity and logistics continuity.

In New South Wales and Queensland, Australia, between 2022 and 2025 heavy rainfalls and extreme flooding have resulted in widespread infrastructure damage and closures, devastation of communities and freight disruptions both to and from ports. Significant reconstruction of impacted areas and infrastructure has occurred, together with permanent relocation of some residents from low lying areas and continues to occur today. This highlights the vulnerability of even well-developed infrastructure to climate extremes.

These events are not anomalies; they are signals of a new normal. According to the Intergovernmental Panel on Climate Change (IPCC), average global temperatures are projected to rise by 2.5°C to 3°C by the end of the century under current emissions trajectories. This warming is predicted to intensify the frequency and severity of extreme weather events, from heatwaves and wildfires to flooding and storms.

The economic consequences are already profound, with a recent report estimating that more than $122 billion annually of economic activity is at risk from the impact of extreme climate events, a figure that exceeds the GDP of some countries. A separate study suggests that, if left unaddressed, cascading climate impacts could result in between $4 trillion and $25 trillion in global economic losses by 2060.

This whitepaper equips ports, terminals, and logistics operations with the tools to act. It provides guidance on interpreting climate data, assessing vulnerabilities, integrating climate risk into business planning and implementing both immediate and long-term adaptation strategies. It also highlights the benefits of early action, not only in reducing future costs and disruptions but in enhancing reputation, attracting investment and securing long-term operational continuity.

At TT Club, we are committed to supporting our members and the wider industry in navigating these challenges. We believe that building a climate-ready supply chain is not just a matter of compliance or risk mitigation, it is a strategic imperative for business sustainability and growth.

We commend this white paper to all who share in the responsibility for shaping a resilient, future-ready ports, terminal and logistics sector.

Marika Calfas

Marika Calfas, Director Through Transport Mutual Insurance Association Limited (Bermuda), CEO NSW Ports.

1. INTRODUCTION

1.1. Document Goals

This guidance document has been prepared to empower readers to take informed, effective action in the face of climate change. The document aims to emphasise that climate change can have significant impacts on ports, waterways and logistics operations, highlighting the need for urgent action to adapt and build resilience. It articulates the benefits of acting quickly, including safeguarding infrastructure, maintaining operations, reducing risks, and ensuring economic stability. The document provides practical steps that you can take to become more climate resilient by assessing vulnerabilities, implementing adaptive measures, and collaborating with stakeholders. The document aims to provide insight on multiple topics, broadly covering the following key themes:

Raise Awareness	Explain Benefits	Outline Next Steps
▪ Understanding climate data (purpose, utilisation, scenarios, models) ▪ Consequences of inaction (increased costs, global risks) ▪ Importance of integrating climate resilience	▪ Empowering informed decision-making ▪ Highlighting proactive action benefits ▪ Practical measures and case studies	▪ Climate resilience journey (risk assessment, adaptation planning, monitoring) ▪ Integration with business strategy ▪ Accessing support and resources

Following the Introduction, the document has been developed in eight sections:

- **Section 2 – Climate Data Insights** describes the availability of climate data and their utilisation.
- **Section 3 – Consequences of Inaction** discusses the general impacts of climate change on assets and operations.
- **Section 4 – Getting started guide** showcases the different steps that can be followed to begin a climate adaptation and mitigation journey.
- **Section 5 – Business Risk Integration** describes the various business risks associated with climate change, and the importance of integrating these risks into the wider company strategies.
- **Section 6 – Practical measures** showcases the short term, medium term and long term measures that can be taken to adapt assets and operations to become climate resilient, including examples from world class ports and cargo terminals.
- **Section 7 – Reference Documents** lists the supplementary reference documents that provide additional support.
- **Section 8 – Annexes** lists the references used to prepare this document and provides additional resources for the various sections.

Climate	The average weather conditions in a region over a long period, typically 30 years or more.
Climate Change	A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer.
Additional definitions of important climate resilience terms are provided in the Glossary.	

1.2. Climate Risks Overview

As port operators, your businesses face various risks, including natural hazards like hurricanes, floods, and earthquakes that can damage infrastructure. Operational risks encompass equipment failure, accidents, and supply chain disruptions.

Your infrastructure and operations are also vulnerable to climate change risks such as sea-level rise, increased storm frequency and intensity, and extreme temperatures. These factors can cause coastal flooding, storm damage, and heat-related impacts on operations and equipment, as demonstrated by Figure 2 and Figure 3.

1.3. Climate Opportunities Overview

Data-Driven Insights

Climate data can be used to provide actionable insights into climate change opportunities which could enhance your business. For instance, you could utilise real-time data and monitoring for early warning systems. Early warning systems informed by climate data can optimise resource allocation, ensuring that personnel, equipment, and materials are positioned where they are most needed during an emergency. Additionally, you could analyse historical weather patterns or projections to identify optimal storage locations to minimise climate-related risks.

Utilising Internet of Things (IoT) devices and AI for real-time monitoring and predictive maintenance can enhance efficiency and reduce downtime. These technologies paired with climate data analytics can optimise operations and improved decision-making can lead to cost savings and increased efficiency.

Figure 1: Containers sit in a flooded pile from Hurricane Katrina September 11, 2005

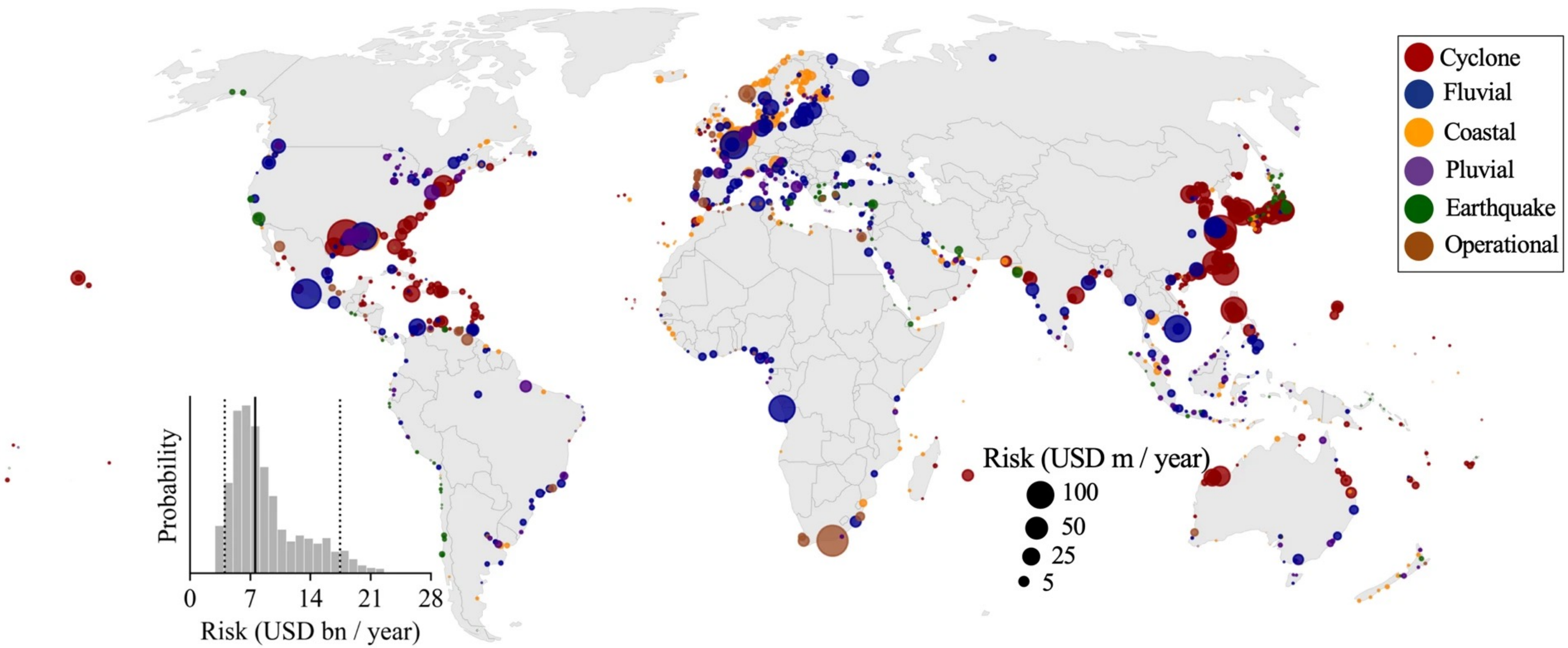

Figure 2: The median risk per port is expressed in USD m per year, with the colour indicating the dominant hazard. The histogram illustrates the globally aggregated risk across the 10,000 samples, with the black line indicating the median and the dashed lines indicating the 5th and 95th percentiles. © *Verschuur, et al. (2023)*.

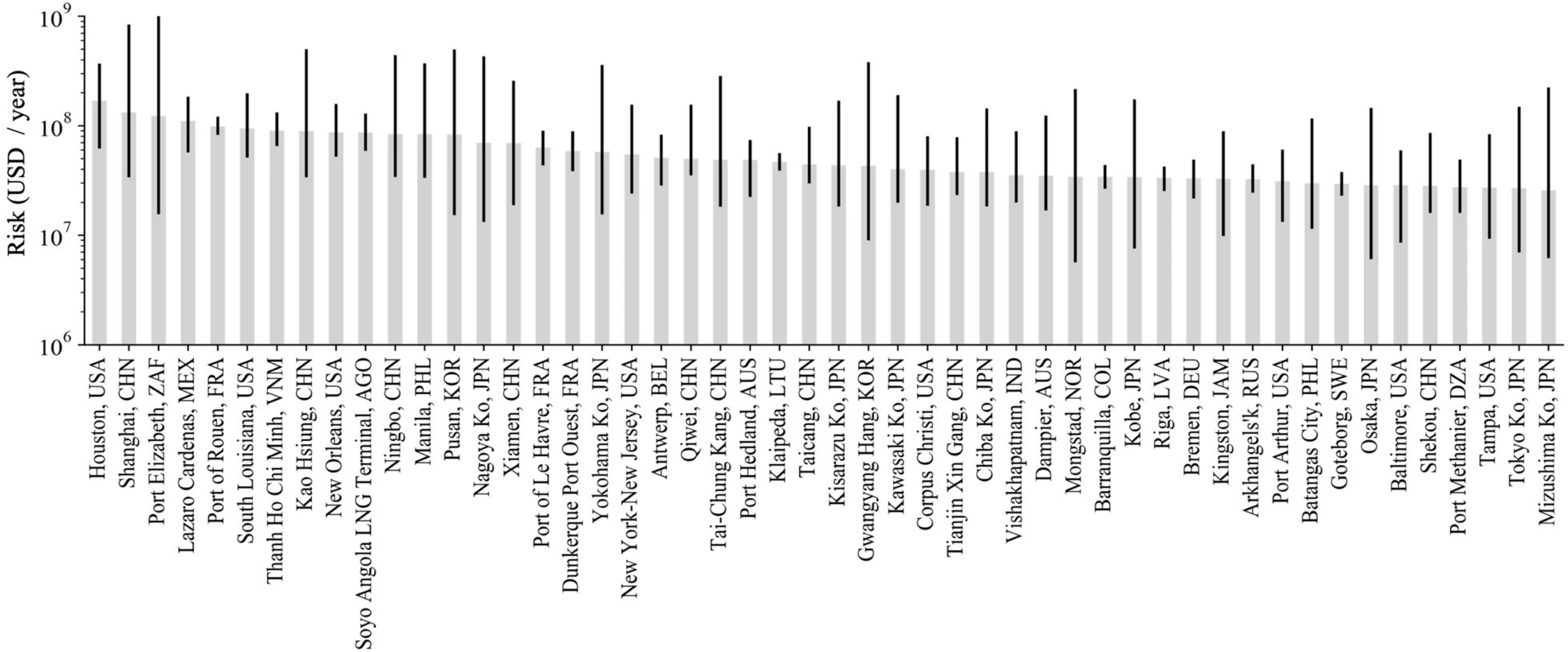

Figure 3: The top 50 ports in terms of median expected risk (bars). The error bars reflect the 5–95th percentile of the risk estimates based on the 10,000 samples. Note the logarithmic y-scale. © *Verschuur, et al.* (2023).

2. CLIMATE DATA INSIGHTS

Understanding climate change is like piecing together a complex puzzle with pieces from many different places and times. By studying this data, we can better understand our planet's climate history and predict future trends.

2.1. Purpose of the Data

What is climate data and why is it useful?

Climate data includes quality-controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, pressure etc. Climate data is derived from a combination of direct measurements and indirect proxies. In contrast, weather refers to the constantly changing conditions in the atmosphere. Weather data can change from minute to minute, hour to hour, and day to day, and sometimes, frequently and rapidly within a day, whereas the climate is typically assessed over a period of 30 years or more.

The purpose of climate data is to provide a comprehensive understanding of the Earth's climate system. This data is used to monitor current climate conditions, understand the causes of climate change, and predict future climate conditions. By studying this data, scientists can identify trends and patterns in our climate, which can inform our understanding of how our climate might change in the future.

Data complexity

Climate data can be divided into different levels based on how the data is processed and utilised.

Level 1 – Direct use of data	Level 2 – Climate modelling	Level 3 – Further analysis
This is the simplest level where the data is used as it is, without any additional processing or analysis. For example, you might use current temperature data to decide whether to operate certain equipment.	At this level, the data is used as input for climate models to generate useful outputs. For instance, historical temperature and precipitation data could be used to model future precipitation patterns. These models can help you plan for potential changes in weather patterns.	At this level, further analysis is undertaken of the climate model data. For example, flood data could be used for economic analysis to estimate potential damage and financial loss. This information can help you make informed decisions about infrastructure investments and risk management strategies.

2.2. How Climate Data Should be Used

- **Risk Assessment**
  Historic data can help understand how the climate has changed in the past to reach its current, baseline scenario. Additionally, projections from climate models can help predict how the climate is likely to change in the future. Climate data can be used to assess the risk of climate-related hazards, such as sea-level rise, storm surge, and extreme weather events. This can help you to identify vulnerable infrastructure and develop strategies to mitigate both the present-day and future risks.

- **Infrastructure Planning and Design**
  Climate projections can inform the planning and design of new infrastructure. For example, if projections indicate an increase in sea level in the future, new infrastructure should be designed to accommodate this change.

- **Operational Planning**
  Climate data can inform operational planning. For instance, if projections indicate an increase in the frequency or intensity of storms in the future, you could adjust your operations to ensure their safety and efficiency. These changes may also help to address current risks and improve efficiency in the short-term.

Extreme Water Levels and Storm Surge	Climate models can predict the likelihood of extreme water levels and storm surges. You can use this information to design and implement protective measures such as sea walls or flood barriers. You can also develop emergency response plans for when a storm surge is predicted.
Wind Speed and Direction	Predictions about changes in wind patterns can be used to design wind-resistant and resilient infrastructure. They can also inform operational decisions, such as the scheduling of loading and unloading operations, to ensure safety during high wind events.
Increased Rainfall Intensity	Climate models can predict the likelihood of increased rainfall intensity. This information can inform operational decisions, such as the scheduling of loading and unloading operations, to protect vulnerable cargoes and ensure safety.
Drought Conditions	If climate data predicts drier conditions, you can plan for water conservation measures and fire prevention strategies. This could include the installation of water-efficient systems and the creation of firebreaks.
Heatwaves	Predictions of increased frequency or intensity of heatwaves can inform the implementation of measures to protect staff and sensitive cargo. This could include the provision of cooling facilities, heat stress training for staff, and temperature-controlled storage for heat-sensitive cargo.
Changes in Ocean Currents	Climate data can predict changes in ocean currents, which may impact navigation routes and the movement of cargo vessels. As an operator, you can use this information to adjust shipping routes and schedules.
Sea Ice Predictions	For ports in colder climates, predictions about sea ice can inform the planning of ice-breaking operations and the scheduling of shipping routes.
Coastal Erosion	If climate data predicts an increase in coastal erosion, port operators can plan for protective measures such as the reinforcement of shorelines and the implementation of sustainable land use practices.

2.3. Climate Scenarios

A range of climate scenarios have been developed to help us understand the potential consequences of our actions today on the future climate. Climate scenarios are essentially stories about the future. They describe potential future changes in greenhouse gas emissions and other factors that influence the climate, such as land use changes and aerosol concentrations. The scenarios are used by climate modellers to project possible future climate conditions.

The scenarios allow us to explore a range of possible futures and understand the impacts of different levels of greenhouse gas emissions. This can help policymakers to make informed decisions about how to mitigate climate change. In essence, the scenarios provide a tool for scientists and policymakers to envision possible futures, understand the potential impacts of climate change, and plan strategies for mitigation and adaptation.

Representative Concentration Pathways (RCPs)

The 5th Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) used a range of emission scenarios called Representative Concentration Pathways (RCPs). The RCPs relate to concentrations of greenhouse gases that would result in target amounts of radiative forcing (measured in watts per square meter (W/m^2)) at the top of the atmosphere by 2100, relative to pre-industrial levels. Radiative forcing is a measure of the influence of factors (like greenhouse gases) on the energy balance of the Earth's atmosphere.

- **RCP2.6**: Pathway where radiative forcing peaks at approximately 3 W/m^2 mid-century and then declines to 2.6 W/m^2 by 2100. This would require significant reductions in greenhouse gas emissions and aims to limit global warming to below 2°C.
- **RCP4.5**: Represents a stabilization of radiative forcing at 4.5 W/m^2 by 2100 without overshooting. It assumes that emissions will peak around 2040 and then decline.
- **RCP6.0**: Pathway stabilizes radiative forcing at 6 W/m^2 by 2100. Emissions peak around 2080 and then decline.
- **RCP8.5**: Radiative forcing reaches 8.5 W/m^2 by 2100. It assumes continued increases in greenhouse gas emissions throughout the 21st century.

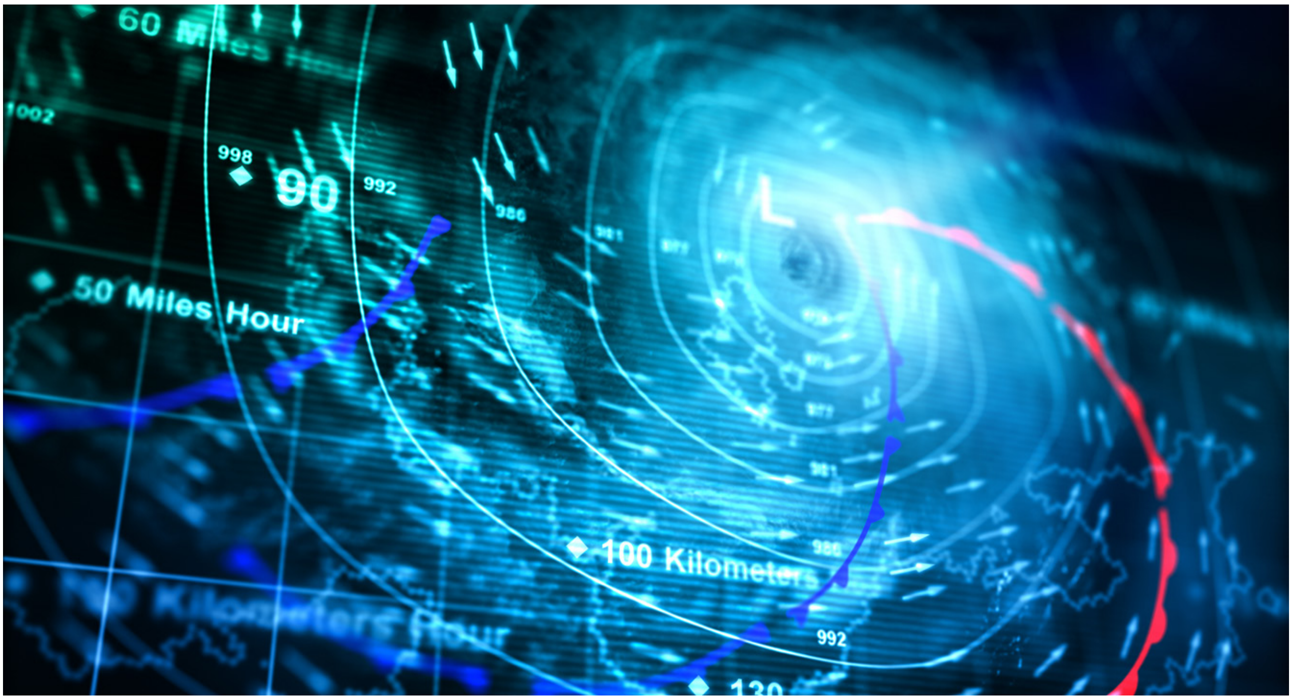

Figure 4: Storm weather mapping

Shared Socioeconomic Pathways (SSPs)

The latest scenarios used by the IPCC in the 6th Assessment are called Shared Socioeconomic Pathways (SSPs). The SSPs are scenarios that describe different ways in which global society, demographics, and economics might evolve over the 21st century. They are used alongside the RCPs to explore how different socioeconomic futures could influence greenhouse gas emissions and climate change.

- **SSP1**: Pathway focused on sustainability, with low challenges to mitigation and adaptation. It can be aligned with lower RCPs like RCP2.6.
- **SSP2**: Scenario follows historical trends without significant changes in policy and can be aligned with intermediate RCPs (e.g. RCP4.5).
- **SSP3**: Pathway describes a fragmented world with high challenges to mitigation and adaptation. It is typically aligned with higher RCPs (e.g. RCP6.0 or RCP8.5).
- **SSP4**: Scenario envisions a world with high inequality, leading to high challenges for adaptation but lower challenges for mitigation. It can be associated with a range of RCPs depending on the level of emissions control achieved.
- **SSP5**: Pathway describes a world with rapid economic growth and high energy use, leading to high challenges for mitigation. It aligns with higher RCPs, e.g. RCP8.5.

RCP	SSP	Estimated Temperature Increase by 2100
RCP2.6	SSP1	~1.5°C – 2°C
RCP4.5	SSP2	~2.5°C – 3°C
RCP6.0	SSP3	~3°C – 3.5°C
RCP8.5	SSP5	~4°C – 5°C

2.4. Climate Models

Climate models are mathematical representations of the interactions between the atmosphere, oceans, land surface, and ice. They are used to study the dynamics of the climate system and predict future climate conditions.

Climate models can be global or regional. Global models cover the whole Earth and can only show climate trends on a very large scale. Regional climate models, on the other hand, zoom in on specific areas and have much finer resolutions, allowing them to capture local details that affect the climate system.

The Intergovernmental Panel on Climate Change (IPCC) assesses multiple global climate models as part of the international climate change assessment reports. These models form the foundation for predictions of future extreme weather and climate event scenarios.

National Aeronautics and Space Administration (NASA) has developed several climate models, including the Goddard Institute for Space Studies (GISS) model and the Prithvi-weather-climate foundational model. These models use artificial intelligence and other advanced techniques to simulate weather and climate.

Additional sources for accessing climate data have been provided in *Annexe 2 – Accessing Climate Data*.

3. CONSEQUENCES OF INACTION

3.1. General Impacts of Climate Change

Climate change is expected to amplify the impacts of future coastal hazards for many of the world's 3,700 maritime ports and their supply chains that enable global and local commerce. A study from the University of Oxford's Environmental Change Institute (ECI) (*Verschuur et. al, 2023*) demonstrates that nearly nine in ten major ports globally are exposed to damaging climate hazards, resulting in escalating economic impacts on global trade. For instance, Hurricane Katrina (2005) shut down (for up to four months) three ports in the US – ports of New Orleans, Mobile and South Louisiana that handle almost half the country's agricultural exports (*Schnepf & Chite, 2005*). The 2011 Tōhoku earthquake and tsunami damaged maritime assets worth $12 billion (*Rafferty and Pletcher, 2024*). Port downtime associated with these natural hazards puts trade worth $67 billion at risk every year.

As operators, if you choose not to implement climate change adaptation measures, you risk facing significant costs and disruptions, which can have long-term financial and operational impacts. In addition to the more obvious infrastructure damage and operational disruptions, workforce safety is a growing consideration in the context of climate change. Not least, dehydration and heat stress can quickly lead to fatigue, increasing safety risks for workers.

3.1.1. Infrastructure Damage

Climate change can lead to more frequent and severe weather events, such as storms, hurricanes, and floods. These events can cause significant damage to port infrastructure, for example:

- High winds and storm surges, resulting in severe wave conditions can damage or destroy docks and piers, leading to costly repairs or replacements.
- Flooding can damage goods stored in warehouses and affect below-ground electrical and IT infrastructure, leading to financial losses and the need for repairs.
- Access routes to and from the port can be affected, disrupting the flow of goods and increasing repair costs.

Figure 5: Container ship at Port of Napier, Hawke's Bay, New Zealand

3.1.2. Operational Disruptions

Extreme weather events can disrupt operations in several ways:

- You may need to close temporarily during severe weather, halting the movement of goods and causing delays in the supply chain.
- Loading and unloading operations can be affected and ships may be delayed in docking or departing, leading to increased costs for shipping companies and potential penalties for late deliveries.
- You may need to invest in temporary measures, such as sandbags or pumps, to mitigate the effects of flooding, adding to operational costs.

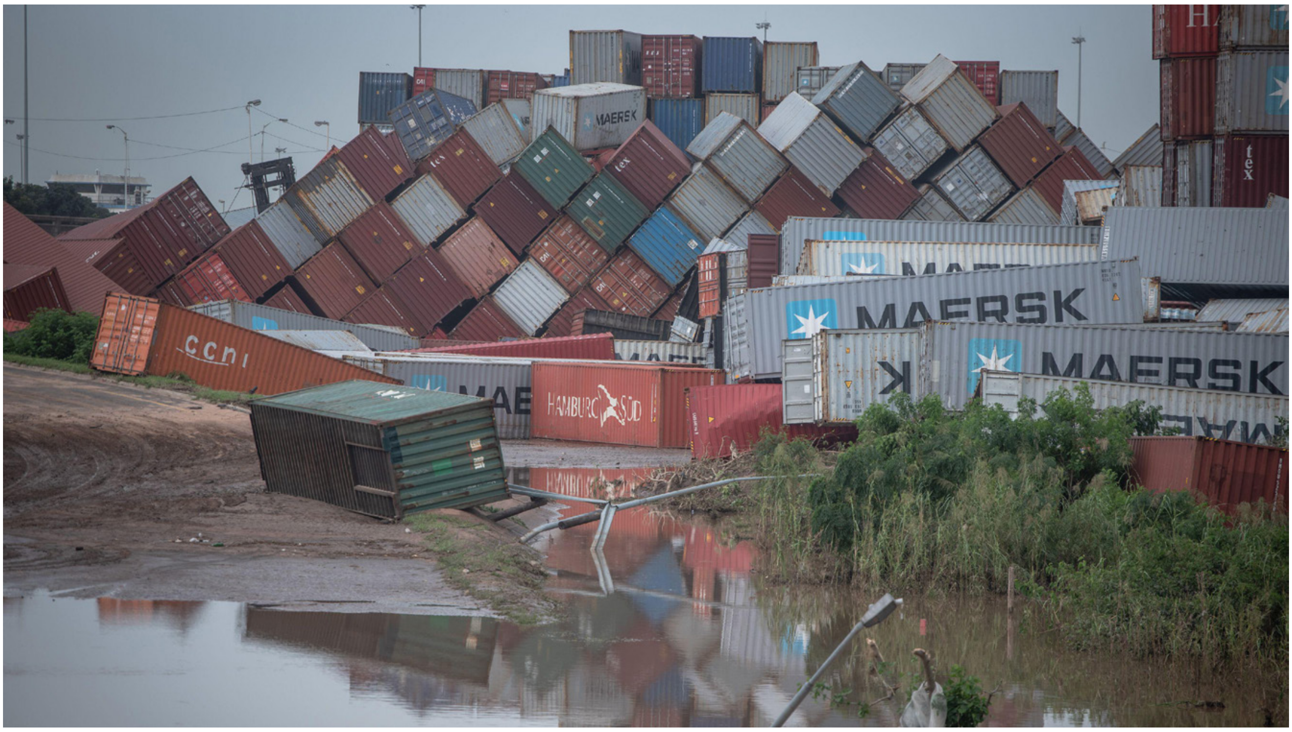

Figure 6: Containers in flood water in Durban, South Africa, April 2022

3.2. Consequences of Inaction vs Adaptation Benefits

A report from the Environmental Defense Fund (EDF) reveals that the global shipping and port industry is susceptible to billions of dollars in infrastructure damage and trade disruption from climate change impacts. Assuming a steady growth rate, global trade is expected to grow to reach 120 billion tons in 2100 – but under the worst-case climate scenario, that growth could be stunted by up to nearly 10% (*EDF, 2022*).

While the initial costs of implementing climate adaptation measures can be substantial, the long-term benefits in terms of reduced future costs, improved resilience, and enhanced reputation are likely to outweigh these expenses. There are various low-cost non-structural climate resilience measures which can also have a significant positive impact. By taking proactive actions, you can secure your operations against future climate risks and position yourselves as leaders in sustainability.

Examples		
Reduced Costs	**Improved Resilience**	**Enhanced Reputation**
By investing in climate adaptation measures now, you can avoid or reduce the costs associated with climate-related damage and disruptions in the future.	Climate adaptation measures can make your business more resilient to climate change, enabling them to continue operating effectively under a range of future climate conditions.	Taking proactive steps to address climate change can significantly enhance your reputation among stakeholders. Port operators that are seen as leaders in sustainability and climate adaptation can potentially attract more business and investment.
A study on the **Port of Rotterdam** estimated that investing in flood defences and other adaptation measures could save up to €1 billion in potential damage costs by 2050 (*Becker, 2020*). Similarly, the Port of New York and New Jersey has projected savings of $2 billion over 50 years by implementing climate resilience measures (*Puig et. al.,2024*).	The **Port of Brisbane** in Australia has implemented measures to withstand extreme weather events, resulting in a 30% reduction in downtime during such events (*Zhang, 2016*). This improved resilience ensures that ports can continue to function effectively, minimising economic losses and maintaining supply chain stability.	The **Port of Los Angeles** has received numerous accolades for its environmental initiatives, which have helped attract over $1 billion in green investments (*Becker, 2020*). This enhanced reputation can lead to increased customer loyalty and better relationships with regulators and the community.

Figure 7: Aerial view of APM container terminal, Rotterdam, Netherlands (June, 2016)

3.2.1. Case Studies

These case studies illustrate the tangible benefits of investing in climate adaptation measures, including significant cost savings, improved operational resilience, and enhanced reputations.

Port Metro Vancouver has undertaken extensive climate adaptation planning to address sea level rise and increased storm intensity. By investing in flood defences and adaptive infrastructure, the port aims to mitigate potential damage costs estimated at over CAD 1 billion by 2050. This proactive approach not only protects the port's assets but also ensures continued operational efficiency (*Zhang, 2016*).

The **Port of Long Beach** has implemented a comprehensive Climate Adaptation and Coastal Resiliency Plan. This plan includes measures such as elevating critical infrastructure, improving stormwater management, and enhancing shoreline protection. These efforts are projected to save the port millions of dollars in potential damage costs and reduce downtime during extreme weather events.

Both the **Port of Los Angeles** and the **Port of Long Beach**, USA, have been leaders in implementing green initiatives and climate mitigation measures. Their green initiative efforts include switching to low-sulphur fuels, providing shore power to docked ships, and investing in energy-efficient technologies. These measures have significantly reduced emissions and improved air quality, attracting over $1 billion in green investments and enhancing their reputation as sustainable ports (*Bertrand & Williams, 2022*).

The **Port of Brisbane** has focused on building resilience to extreme weather events. By upgrading infrastructure and implementing advanced weather monitoring systems, the port has reduced downtime by 30% during such events. This improved resilience ensures that the port can maintain operations and minimize economic losses.

A study across 14 major container ports in Greater China demonstrated the effectiveness of climate adaptation measures in reducing risks and costs. By integrating cost and risk analysis into their planning, these ports have been able to implement efficient adaptation measures that balance investment with risk reduction (*Yang, Ng, et. al., 2017*).

Figure 8: Port of Long Beach, USA

4. GETTING STARTED GUIDE

By integrating climate change considerations into your risk management practices, you can safeguard the long-term resilience and sustainability of your port and container terminal operations. As a mutual insurance company, we're here to support you in navigating these complex climate challenges.

Members can seek services and support, wherever they are on this journey – whether it is initiating data collection, making sense of data and understanding their risks or identifying and prioritising adaptation measures. These steps are further discussed below.

Figure 9: Climate Resilience Journey © Haskoning

Through this chapter, we will showcase an example of the life cycle of a climate resilience solution – from inception to implementation.

4.1. Hazard and Risk Insights and Awareness

To safeguard your future, it is crucial to develop a shared understanding of your climate change challenges, both within your business as well as with your external stakeholders. By aligning on the evolving climate risks and recognizing the need to respond, you can gain a clear comprehension of the risks you face and reach consensus on your response options. Insights and awareness of climate hazards and risks bring clarity, enabling you to make informed decisions in a changing world.

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
Vulnerability	The propensity or predisposition to be adversely affected. This encompasses a variety of concepts including sensitivity or susceptibility to harm and lack of capacity to cope and adapt
Exposure	The presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected
Additional definitions of important climate resilience terms are provided in the Glossary.	

4.1.1. Climate Hazards

By analysing real-time data, you can gain an objective and quantified view of climate risk. The following approach will enable you to make informed and future-ready investment decisions:

1. Define the current baseline climate by gathering historical climate data, including, but not limited to temperature, precipitation, sea levels, and storm frequency.
2. Evaluate the current climate conditions and how they have impacted assets and operations in the past.
3. Use data derived from climate models to predict future climatic conditions. Consider various possible climate scenarios to understand potential changes in temperature, sea level rise, storm intensity, and other climatic factors.
4. Identify and map potential climate hazards such as flooding, storm surges, erosion, and extreme weather events.
5. Evaluate the likelihood and potential impact of these hazards on port operations, infrastructure, and supply chains.

Worked Example (part 1):

A port authority has conducted a climate risk assessment, including a baseline assessment of the current climate and the impact on their assets. From the climate models and local data for their site, they should check:

- Which parameters are going to change significantly over the next 20 to 30 years?
- Do these parameters impact the design of our long-term infrastructure?

In this example, the daily average and maximum temperature in the near future was projected to be significantly higher than the current conditions, with temperatures in the summer months expected to regularly exceed 35°C.

Climate Hazard		
Climate Variable	**Description**	**Indicator/Threshold**
Acute Climate Hazards		
Extreme sea levels or storm surge	Extreme sea levels refer to unusually high or low sea levels that occur due to a combination of factors such as high tides and storm surges, and surface waves.	The indicator for extreme sea level and storm surge is the increase in sea level above the normal tide level. Extreme sea levels and storm surge may cause coastal flooding, depending on the local topography. The extent or depth of flooding can be used as an indirect indicator.
Extreme Precipitation	Extreme precipitation is when the amount of rain or snow significantly exceeds normal levels for a given location and time period.	Extreme precipitation can be classified by the daily or multi-day total rain or snowfall. Rainfall intensity thresholds can also be used. These thresholds vary between countries so should be confirmed with local meteorological office.
Extreme Storms	An extreme storm is a severe weather event characterised by intense atmospheric disturbances, such as strong winds, heavy rainfall, thunder, lightning, or snow. Extreme storms can include hurricanes, tornadoes, and severe thunderstorms.	Extreme storms can be classified by wind speed, e.g. using the Beaufort Wind Scale or the Saffir-Simpson Hurricane Wind Scale.
Extreme low temperatures	Extreme low temperature events occur when temperatures fall significantly below the average for a particular region and time of year. This complex variable is also affected by chronic changes over time. Extreme low temperature conditions often interact with other climate hazards such as storms, snowfall and hail.	Extreme low temperature is classified by the daily or multi-day minimum temperature compared to the annual average.
Extreme high temperatures	Extreme high temperature events and heatwaves occur when temperatures rise significantly above the average for a particular region and time of year. This complex variable can be affected by chronic changes over time. Extreme high temperature conditions can interact with other climate hazards, such as storms and lightning.	Extreme high temperature is classified by the daily or multi-day minimum temperature compared to the annual average. Heatwaves can be classified by the duration of the high temperature event (number of days above a defined temperature threshold). Different regions, even within the same country, can have varying temperature and duration thresholds for categorising heatwaves, based on the local climate and historic temperature data so this should be confirmed with the local meteorological office.

Climate Hazard		
Climate Variable	**Description**	**Indicator/Threshold**
Acute Climate Hazards		
Hail	Hail is a form of precipitation consisting of solid ice balls known as hailstones, which can vary in size. Hail forms within strong thunderstorm updrafts.	Hail events are often measured in tandem with storm events. The size or intensity of hail can be a measure of the severity of the event. The damage caused by hailstorms can be used as an indirect indicator.
Lightning	Lightning occurs during thunderstorms and is caused by the buildup of electric charges within clouds and between the clouds and the ground. When these charges become too great, they are released in the form of a lightning bolt, producing intense light and heat.	Lightning activity can be classified by the level of lightning activity and number of lightning strikes.
Fog	Fog is a meteorological phenomenon characterised by the suspension of tiny water droplets or ice crystals near the Earth's surface. Fog can lead to a significant reduction in visibility.	Fog is often classified based on visibility, with the classification varying locally.
Chronic Climate Hazards		
Sea level rise	Sea level rise is the increase in the average level of the world's oceans, driven by thermal expansion due to global temperature increases, and accelerated melting of glaciers and ice sheets.	Sea level rise can be measured using tide gauges and satellite altimetry. Tide Gauges measure sea levels at specific coastal locations, recording the height of the sea relative to a fixed point on land, providing long-term data on local sea level changes. Satellites equipped with radar altimeters are also used to measure sea levels globally.
Average temperature increase	Average temperature increase is a chronic climate change variable which reflects gradual change compared to historic average temperatures over an extended period of time, often decades or longer. Long-term temperature increases interact with other climate variables such as precipitation.	Long term or chronic increase in temperatures are measured by comparing the annual or seasonal average temperature against historic values.

Climate Hazard		
Climate Variable	**Description**	**Indicator/Threshold**
Chronic Climate Hazards		
Changing average precipitation	Changing average precipitation refers to long-term shifts in the patterns and amounts of rainfall and snowfall in a region. As a chronic climate change variable, it reflects gradual changes over extended periods of time. Long-term precipitation changes interact with other climate variables such as temperature. Precipitation changes depend on location, with climate projections showing increases or reductions in average precipitation, with the projected change varying over time.	Long term or chronic changes in precipitation are measured by comparing how the annual or seasonal average temperature compares to historic values.
Increased frequency of storms	This variable refers to the long-term trend of more frequent and intense storm events, including hurricanes, typhoons, and severe thunderstorms. This trend is driven by several factors related to climate change including warmer ocean temperatures, increased atmospheric moisture and changing atmospheric circulation.	The change in frequency of storm events is measured by comparing the number of storms occurring in a defined time period against historic values. This can be supported by information about precipitation, wind speed and lightning.

4.1.2. Exposure and Vulnerability

Risk arises where hazard, exposure, and vulnerability intersect. The higher the levels of these factors, the greater the risk. Conversely, risk decreases if any of these factors are absent. To understand vulnerability, it is essential to determine the susceptibility of port infrastructure, operations, and surrounding communities to identified hazards. Additionally, identifying the assets, people, and operations exposed to climate risks helps determine the level of exposure.

Worked Example (part 2):

The risk assessment for the example port should determine:

- Which assets and operations are exposed to changing climate?

It was found that the open-air areas of the port are exposed to extreme temperatures and heatwaves. The infrastructure in these areas is not vulnerable to increasing temperatures but there could be health impacts for staff working outside.

A risk assessment considers three key factors:

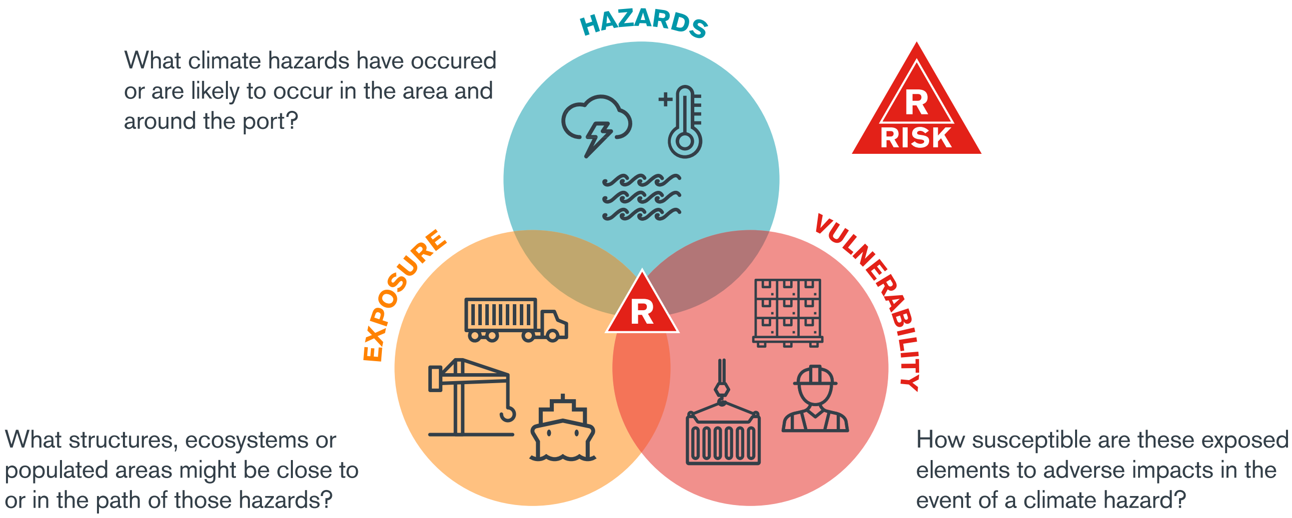

Figure 10: Factors considered by a risk assessment (Source: *Climate Risk and Ports, IADB, 2021*)

Types of Risks	
Acute Risk	These are risks driven by specific, short-term weather events or hazards, such as heatwaves, floods, wildfires, and storms
Chronic Risk	These are risks driven by longer-term shifts in climate patterns, such as rising sea levels and increasing average temperatures
Physical Risk	This encompasses both acute and chronic risks, referring to the potential for adverse impacts due to climate-related physical events or trends
Transition Risk	These are risks related to the transition to a lower-carbon economy, which can include policy changes, technological advancements, and shifts in market preferences
Additional definitions of important climate resilience terms are provided in the Glossary.	

Potential acute risks to assets and operations		
Climate Variable	**Impact on climate-related physical conditions**	**Example impact on infrastructure assets and operations**
Extreme sea levels or storm surge	Tidal Flood Risk	Infrastructure damage, operational disruptions
	Increased tidal range	Structural stress, navigational challenges
Extreme Precipitation	Increase in extreme river flows and levels – Fluvial Flood Risk	Flooding of access routes, damage to infrastructure
	Pluvial Flood Risk	Surface water flooding, damage to equipment
	Increase in frequency and intensity of extreme precipitation events	Operational delays, increased maintenance costs
Extreme Storms	Increase in storm intensity (wind speed)	Damage to cranes and equipment, safety of people
	Increase in extreme wave height	Erosion and structural damage, operational disruptions
Extreme low temperatures	Change in frequency of ice conditions	Navigational hazards, damage to vessels and infrastructure
	Change in frequency and quantity of snowfall	Operational slowdowns, increased maintenance needs
Extreme high temperatures	Increased frequency and severity of heatwaves	Safety of people, equipment malfunctions
Hail	Change in frequency of hail events	Damage to infrastructure and equipment, operational delays
Lightning	Change in the frequency of lightening events	Safety of people, damage to electrical systems
Fog	Change in frequency of fog conditions	Visibility issues, operational delays
Sea level rise	Increasing risk of tidal flooding	Infrastructure damage, operational disruptions
	Change in flow patterns and associated sedimentation	Navigational challenges, infrastructure stress
	Increased coastal erosion	Loss of land, damage to infrastructure

Potential acute risks to assets and operations		
Climate Variable	**Impact on climate-related physical conditions**	**Example impact on infrastructure assets and operations**
Average temperature increase	Change in water quality	Pollution, operational costs
	Change in environmental conditions	Biodiversity loss, operational adjustments
Changing average precipitation	Drought	Water shortages, increased costs
	Reduced/increased average river levels	Navigational restrictions, operational delays, flooding
	Reduced/increased groundwater levels	Water supply issues, infrastructure stress, flooding
	Increase/reduction in saline intrusion	Corrosion, change in water quality
Increased frequency of storms	Increase in frequency of storm conditions	Damage to infrastructure, operational disruptions
	Change in storm patterns, e.g. wind direction	Navigational challenges, safety risks

4.2. Climate Adaptation and Mitigation Planning

Climate adaptation planning involves developing a comprehensive roadmap towards climate resilience that outlines the steps needed to enhance the resilience of business infrastructure and operations including timelines, responsible parties, and specific actions to address identified climate risks.

Once the vulnerability and exposure from various climate hazards have been determined, it is important to understand when each hazard will become significant. Some of the critical situations in the future may require planning now. So, you should assess which hazards are critical now or in the short-term, which will become critical in the future and when in the future. This will allow you to prioritise the adaptation actions considering the potential impact and likelihood of each risk.

The adaptation planning should include a review of the existing processes, capacity and capability to deliver the potential adaptation solutions and actions. Specific, chronological steps required in short-term, medium term and long term to achieve these solutions will have to be laid out, including allocating responsibilities, budgets and timelines. An action plan may have to be put in place with regular review to make sure that progress is on track. Any additional support or gaps to implement these solutions will also have to identified during the adaptation planning stage.

Developing an adaptation plan will help map possible requirements (physical or operational) against any shortcomings and gaps identified in risk assessment.

Worked Example (part 3):

From the previous steps in the example, it has been identified that staff could be vulnerable to heatwaves. One of the recommended ways to adapt is preparing the staff to respond to and safeguard themselves during heatwaves. The adaptation plan might address the following questions:

- Are there adequate shaded and/or cool areas for staff to rest?
- Is there an adequate drinking water source for the staff?
- Are the staff trained to respond to such conditions?

4.3. Climate Resilience Solutions

After prioritising the required actions by undertaking climate adaptation planning, you can develop suitable resilience solutions.

Solutions may include designing and implementing **effective physical or engineering adaptation measures** such as strengthening port and terminal infrastructure to withstand extreme weather, elevating critical areas and improving drainage, constructing sea walls or enhancing flood defences, or upgrading infrastructure to withstand higher temperatures. The use of renewable energy sources could also provide resilience. For example harnessing solar energy could provide greater levels of independence from the national grid to keep critical systems in operation in the event of a power outage.

Sustainable solutions should be implemented to reduce emissions. This can be achieved by using eco-friendly materials and construction methods to minimise ecological footprints, and by promoting the use of cleaner fuels. Where appropriate, solutions could include the use of natural barriers like mangroves and coral reefs to protect coastal areas. Additionally, habitat restoration projects such as wetland restoration and new green spaces could be incorporated.

Solutions can also include enhancing the **operations and maintenance** of assets, e.g.:

- Undertaking consistent and regular condition assessment and rigorous maintenance schedules to reduce the risk of equipment failure.
- Implementing advanced weather forecasting and early warning systems to minimize downtime and damage.
- Developing flexible operational plans to quickly adapt to changing conditions, such as adjusting shipping schedules to avoid extreme weather events or implementing heat stress protocols for workers.
- Prioritise investments in critical areas, possibly through phased upgrades.
- Develop tailored solutions for your assets and establish a feedback mechanism for continuous improvement based on experiences and changing conditions.

Businesses are looking to maximise the return on their investments, so this may require cost-benefit analysis to evaluate the economic feasibility and effectiveness of the proposed measures. This analysis starts with identifying costs (such as capital expenditures and maintenance), and benefits (including reduced damage costs and improved efficiency). Benefit-cost ratios help to ensure benefits outweigh costs, with sensitivity analyses accounting for uncertainties. Non-monetary benefits like environmental and social improvements are also considered. Sometimes, public-private partnerships and other innovative financing mechanisms can enhance financial feasibility. Long-term planning, adaptive management, and ongoing monitoring ensure resilience measures remain effective over time.

Worked Example (part 4):

From the previous step in the example, it has been recommended that staff will need a shaded place to rest and should be trained to respond appropriately during extreme high temperatures. Development of the Climate Resilient Solution would include thinking about:

- How many staff are at risk and need relevant training?
- How big does the shaded area need to be; where is the best place to locate it?
- What materials will be best to build the shaded rest area?
- What is the timescale for providing the training; who will undertake this?
- How much will these solutions cost; do we have the budget for it?
- Do we need to phase the implementation over a longer period of time to accommodate budget constraints?
- What is the best way to implement this solution?

The final implementation could look like:

Short term measures (within a year)
- Train staff to respond to health emergencies during heatwaves, such as fainting due to dehydration.
- Rearranging staff rosters to include more breaks or rotate work activities between open-air and closed areas of the port.

Medium term measure (within 3 years)
- Use available rooms (within suitable proximity) as temporary rest areas until a fully functional system is in place.
- Provide portable air conditioners and drinking water in these temporary areas.

Long term (within 10 years)
- Construct rest areas within suitable locations in the open-air section of the port
- Ensure drinking water pods are available across all working areas within the port.

* The time frames above are for illustrative purposes only. Your site-specific risk assessment should determine the urgency of action.

4.4. Staying Climate Resilient

4.4.1. Monitoring Initiatives

Staying climate resilient requires a proactive approach through monitoring, forecasting, and decision support. This can involve simple monitoring measures or use advanced climate technologies, systems, and services. Monitoring reduces uncertainty through continuous improvement in climate understanding, enabling action to be taken based on real-time insights, to achieve long-term resilience.

Once the adaptation plan and any resilience solutions are in place, monitoring their effectiveness is crucial. This includes regular inspections of infrastructure, tracking equipment failures, and recording any incidents that occur due to extreme weather conditions. Regular monitoring enables issues to be identified early, and corrective action undertaken. Establishing a climate monitoring system can also be useful, which could involve installing weather stations to track local conditions, using remote sensing technology to monitor sea-level changes, and utilising climate data services for up-to-date projections. This information helps to assess the effectiveness of adaptation measures and identify emerging risks.

4.4.2. Plan Review and Update

Finally, it is important to regularly review and update the site's climate risk profile and adaptation plan, at least annually or after any significant incident. The review should consider changes in the risk landscape, the effectiveness of current measures, and any new solutions that may have become available. This ensures that the plan remains relevant and effective in managing risks. As climate science evolves, new research can provide updated projections and reveal new risks. Therefore, reassessing climate risks, evaluating current adaptation measures, and incorporating new climate science findings should be part of the regular review process.

Worked Example (part 5):

Now that the adaptive measures are in place, it will be important to monitor how they are used, and to enhance them over time if necessary. The port might consider addressing these questions:

- How many new staff are joining the workforce; how many of them need to be trained for heatwave emergencies? How frequently should the training be conducted?
- How frequently do the portable water stations run out of water? Do we need to increase the frequency of refilling or the standard size of the container?
- Do the air conditioning units need more frequent servicing?
- Is the capacity of the rest area sufficient?
- How many heatwave-related emergencies occur each year? Were we able to respond in the pre-agreed manner? Are the rest areas under-utilised?

5. BUSINESS RISK INTEGRATION

5.1. Importance of Integration

Integrating climate change considerations into the wider business risk strategy is crucial for operators. This integration ensures that climate-related risks are managed alongside other business risks, enhancing overall resilience and sustainability. Ports are critical nodes in global supply chains, and disruptions due to climate change can have far-reaching economic impacts. By embedding climate risk into the broader risk management framework, operators can better anticipate, prepare for, and mitigate these risks, ensuring continuity and protecting investments.

5.2. Transition Risks

Transition risks are the financial and operational challenges that arise as economies shift towards more sustainable, low-carbon practices. These risks can stem from regulatory changes, market dynamics, technological advancements, and shifts in consumer behaviour. For example, stricter emissions regulations may require significant investments in cleaner technologies and infrastructure. Additionally, changes in trade patterns due to climate policies or physical climate changes can affect cargo volumes and routes. Addressing these transition risks is essential for maintaining competitiveness and compliance with evolving standards.

5.2.1. Regulatory Changes

Governments worldwide are implementing stricter environmental regulations to combat climate change. For instance, the International Maritime Organization's (IMO) 2020 regulation mandates a significant reduction in sulphur emissions from ships. This regulation requires ships to use fuel with a sulphur content of no more than 0.5%, down from the previous limit of 3.5%. This transition has led to increased operational costs for shipping companies as they invest in cleaner fuels and technologies, such as scrubbers, to comply with the new standards. In July 2023, IMO adopted the 2023 IMO Strategy on Reduction of GHG Emissions from Ships which outlines the goals for reducing greenhouse gas (GHG) emissions from ships and provides guidelines on how to achieve these goals. The plan also suggests specific actions to take in the short and long term, along with timelines and how these actions might affect different countries.

5.2.2. Market Demand Shifts

As the global market increasingly favours sustainable products, industries must adapt to changing consumer preferences. For example, the automotive industry is experiencing a shift towards electric vehicles (EVs). Traditional car manufacturers like General Motors and Ford are investing heavily in EV technology to remain competitive. This transition also impacts supply chains, increasing demand for materials like lithium and cobalt.

5.2.3. Technological Advancements

The rapid development of renewable energy technologies poses risks for fossil fuel-dependent industries. Coal-fired power plants, for instance, are being replaced by solar and wind energy projects. In the U.S., several coal plants have been retired or converted to natural gas to reduce emissions and comply with new environmental regulations. This transition requires significant investment in new technologies and infrastructure, as well as workforce retraining.

5.3. Integration Steps

The general approach to integrating climate change considerations into the wider business risk strategy is:

1. **Evaluation and Data Gathering** – Begin by assessing current operations and identifying vulnerabilities to climate change. This involves collecting data on climate impacts, such as sea level rise, extreme weather events, and temperature changes.
2. **Risk Assessment** – Conduct a comprehensive risk assessment to understand the potential impacts of climate change on port operations. This should include both physical risks (e.g., infrastructure damage) and transition risks (e.g., regulatory changes).
3. **Strategy Development** – Develop a climate resilience strategy that aligns with the overall business risk strategy. This strategy should outline specific actions to mitigate identified risks, such as infrastructure upgrades, operational changes, and investment in new technologies.
4. **Implementation** – Implement the strategy through targeted investments and operational adjustments. This may involve upgrading infrastructure to withstand extreme weather, adopting cleaner technologies, and enhancing emergency response plans.
5. **Monitoring and Reporting** – Establish a system for ongoing monitoring and reporting of climate risks and mitigation efforts. This ensures that the strategy remains effective and can be adjusted as needed.

Global Reporting Standards which can be used for addressing and reporting these changes have been linked in Annexe – 3 – Global Reporting Standards. Supplementary reading for Transition Risks can be found in Annexe 5 – Transition risks further reading.

Figure 11: Container ships waiting outside the port of Los Angeles, California, the United States, October, 2021

Examples
The **Port of Rotterdam**, one of the largest ports in the world, has been actively working on climate resilience and transition risks. The port has implemented a comprehensive climate adaptation strategy that includes measures to protect against sea level rise and extreme weather events. Additionally, the port is investing in sustainable energy projects, such as offshore wind farms and hydrogen production, to reduce its carbon footprint and transition to a low-carbon economy.
Houston faces multiple climate vulnerabilities, including flooding, drought, and extreme heat. The city has developed a pilot project to plan for climate resilience, combining resources from government and non-profit agencies. This project includes infrastructure upgrades, green infrastructure to manage stormwater, and community engagement to build resilience against climate impacts.
Massive supply chain disruptions were being felt across the United States as imports resumed from Covid-19 pandemic lows. As a result, the country's busiest ports, at **Los Angeles** and **Long Beach**, were unable to handle the volume of container ships, many of which had to wait offshore.

6. PRACTICAL MEASURES

Here are some practical measures that you can take to progress your climate resilience journey. Becoming climate resilient is a continuous process that requires regular review and adaptation as climate science advances and new solutions become available. Additionally, technological innovations not only help in adapting to climate change but also improve the overall efficiency and sustainability of port operations.

6.1. No-regret Options

- Conduct a thorough **risk assessment** to understand the potential impacts of climate change on port operations and infrastructure.

  You should start by conducting comprehensive risk assessments to understand how climate change might impact their operations and infrastructure. This involves the steps detailed in *Section 4.1 – Hazard and Risk insights and awareness*. The assessment should identify vulnerable assets, evaluate the potential economic impact of disruptions, and prioritise areas for intervention. This data-driven approach will help you to make informed decisions about where to allocate resources for maximum resilience.
- Develop and implement **emergency response plans** for extreme weather events.

  This is crucial for minimising the impact of an extreme weather event. These plans should outline specific actions to take before, during, and after events such as hurricanes, floods, and heatwaves. Organisations should establish clear communication channels, designate emergency response teams, and ensure that all stakeholders are aware of their roles and responsibilities. Regular drills and simulations can help test the effectiveness of these plans and ensure that everyone is prepared to act swiftly and efficiently in a crisis.
- Provide **training** to staff on climate change risks and emergency response procedures.

  This training should cover the basics of climate science, the specific risks faced by the port, and detailed emergency protocols. Staff should be equipped with the knowledge and skills to respond to various scenarios, from evacuations to securing cargo and infrastructure. Continuous education and refresher courses can help keep everyone up to date with the latest best practices and technologies, building a workforce with long-term resilience.
- Implement **energy-efficient** practices in port operations to reduce greenhouse gas emissions.

  This can include upgrading to energy-efficient lighting and machinery, optimising logistics to reduce fuel consumption, and investing in renewable energy sources like solar or wind power. Additionally, port operators can adopt green building standards for new constructions and retrofits and encourage the use of cleaner fuels for ships and vehicles. These measures not only help mitigate climate change but can also lead to cost savings and improved operational efficiency.

You can carry out these measures using your in-house experts or by appointing technical consultancy firms to provide support.

Case Studies
Port of Rotterdam, Netherlands: The port has developed strategies to anticipate higher water levels for all port areas. They are also part of the World Ports Climate Action Program (WPCAP) which focuses on areas like shore power, sustainable fuels, and green shipping corridors (*United Nations Conference on Trade and Development, 2022*).
Port of Long Beach, USA: In its Climate Adaptation and Coastal Resiliency Plan, the port notes that climate change and extreme storms are already impacting the Southern California coast (*Bertrand and Williams, 2022*).

6.2. Short to Medium-term Actions

The following actions may be required in the near future depending on when the identified risks are expected to be realised.

- It may be necessary to **upgrade infrastructure** so that the port remains operational during and after extreme weather events. This may include reinforcing quay walls, installing flood defences or elevating critical infrastructure and buildings to protect infrastructure and cargo from water inundation, and designing structures to withstand high winds and heavy rainfall.
- Implementing **green infrastructure solutions**, such as rain gardens and permeable pavements, can help to manage stormwater runoff and reduce flooding. Rain gardens can absorb and filter rainwater, reducing the burden on drainage systems. Permeable pavements allow water to seep through the surface, minimising surface runoff and preventing water accumulation. These solutions not only mitigate flooding but also improve water quality and enhance the appearance of the port.
- Investing in **renewable energy** sources, like solar or wind power can significantly reduce reliance on fossil fuels. Solar panels can be installed on rooftops and other available spaces. These renewable energy sources can power port operations, reducing greenhouse gas emissions and operational costs. Additionally, renewable can be used for charging electric vehicles and equipment, further enhancing sustainability.
- Adopting technologies such as **IoT sensors** for real-time monitoring of environmental conditions and infrastructure health can support proactive risk management. IoT sensors can provide real-time data on weather conditions, sea levels, and the structural integrity of port infrastructure. This information will enable you to make informed decisions, respond quickly to potential issues, and perform predictive maintenance. By leveraging IoT technology, you can enhance your resilience and operational efficiency.

Case Studies

Port of Hamburg, Germany: The port is involved in three European projects to promote the decarbonisation of ports. These projects focus on harnessing synergies in the electrification strategies of both (inland) ports and their neighbouring regions (*Matthewson*). The Port of Hamburg has implemented a sophisticated flood protection system that includes both static and mobile flood protection walls. They have also developed a comprehensive risk management system that includes regular risk assessments and adaptation measures (*Resilience Rising, 2022*).

Port of Los Angeles, USA: Sustainability efforts such as switching to fuels that produce fewer sulphur emissions, supplying land-generated electricity to ships docked at port (known as shore powering), reducing vessel speeds, and investing in energy efficiency contributed to emission reductions at the port (*Resilience Rising, 2022*).

Figure 12: Waves crashing against a container ship in Nakhodka, Russia (November, 2021)

6.3. Longer-term Adaptation

Longer-term risks may have more significant impacts and require greater planning and higher investment. Monitoring will enable these actions to be implemented at the most appropriate time, targeting investment where and when it is really needed.

- Development of a comprehensive **climate adaptation plan** that outlines long-term strategies for managing climate change risks. Implementation of a Decision Support System (DSS) can support the delivery of the plan. The DSS provides decision-makers with actionable insights for long-term infrastructure development as well as actions for minimising the potential disruptions caused by climate-induced events.
- Port operators should proactively **plan for sea-level rise** by elevating infrastructure, such as raising the height of docks and quay walls. Relocating critical assets like control rooms and power supplies to higher ground can also mitigate the risk of flooding. Innovative solutions, such as floating terminals, can adapt to changing water levels, ensuring continuous operation even during extreme conditions. These measures will help safeguard the port's functionality and protect valuable assets from rising sea levels.
- Incorporating **resilient design principles** into new infrastructure projects is essential for future-proofing ports against climate change. This involves using materials and construction techniques that can withstand extreme weather conditions, such as high winds, heavy rainfall, and temperature fluctuations. Designing flexible and modular structures allows for easier upgrades and repairs. Additionally, integrating green building standards and sustainable practices can enhance the overall resilience and environmental performance of the port.
- **Collaboration** is key to effective climate adaptation. Port operators should work closely with other ports and cargo terminals, government agencies, and research institutions to share knowledge, data, and best practices. By participating in networks and forums, you can stay informed about the latest advancements and leverage collective expertise to enhance your resilience efforts.

Figure 13: Barge shipping containers on the Rhein river, Germany

Case Studies

Port of Rotterdam, Netherlands: The port has developed strategies to anticipate higher water levels for all port areas. They are also part of the WPCAP which focuses on areas like shore power, sustainable fuels, and green shipping corridors (*United Nations Conference on Trade and Development, 2022*). The Port of Rotterdam, one of the world's busiest ports, has been a leader in climate adaptation. They have implemented a range of measures to deal with sea-level rise and increased precipitation, including the construction of the Maeslant Barrier, a storm surge barrier that is one of the largest moving structures on Earth (*Resilience Rising, 2022*).

Port Nador West Med, Morocco: The installation of surfacing, mechanical, and electrical equipment will be designed to withstand projected temperature extremes exceeding 40°C. Additionally, surface drainage systems will be installed to manage extreme rainfall and overtopping. Storage facilities will also be equipped to endure extreme temperatures and weather conditions. An Emergency Response Plan will be put in place to address extreme weather events, while a Coastal Erosion Monitoring Scheme will be implemented in the local area to provide early warnings of climate-related impacts. Furthermore, a Structured Asset Maintenance Programme will be established to ensure ongoing resilience (*United Nations Framework Convention on Climate Change (UNFCCC)*).

Additionally, the EBRD is enhancing the climate resilience of ports along Morocco's Atlantic coastline by providing a €40 million loan to Agence Nationale des Ports (ANP) (*Zgheib, 2022*). The GEF Special Climate Change Fund has awarded a USD 6 million grant resources to co-finance this innovative investment. The project preparation involves understanding the institutional context, priorities for the development of the Moroccan ports sector, and identification of priority climate change risks (*European Bank for Reconstruction and Development, 2020*).

Port of Baltimore, USA: At the Port of Baltimore, cargo increased 10 percent between 2012 and 2016, but overall emissions dropped 19 percent, largely due to the modernisation of cargo handling equipment, the replacement of older short-distance haulage trucks (heavy-duty trucks that transport cargo containers), and operational changes (*Bertrand and Williams, 2022*).

7. ADDITIONAL INFORMATION AND SUPPORT

7.1. Reference Documents

Many countries have specific government regulations and frameworks to support infrastructure operators with climate change adaptation. Links to this information have been provided in Annexe 4.

7.1.1. PIANC

PIANC, the World Association for Waterborne Transport Infrastructure, produces a variety of technical documents and guidelines aimed at improving waterborne transport infrastructure. These documents include technical reports, guidelines, and recommendations that help shape industry standards and best practices. These documents are created by international experts and cover several key areas:

1. **Inland Navigation (InCom):** Focuses on the development and maintenance of inland waterways.
2. **Maritime Navigation (MarCom):** Deals with ports, harbours, and coastal infrastructure.
3. **Recreational Navigation (RecCom):** Covers facilities and infrastructure for recreational boating.
4. **Environmental Matters (EnviCom):** Addresses environmental issues, including climate change and sustainable practices.

PIANC has developed comprehensive guidelines for climate change adaptation. One of the key documents is the Climate Change Adaptation Planning for Ports and Inland Waterways (*EnviCom WG 178, 2020*). This guidance provides a structured approach to help these operators plan for and implement adaptation measures.

1. Identifying how climate change could affect assets, operations, and systems.
2. Gathering relevant climate-related data and using scenarios to understand potential future changes.
3. Analysing the vulnerability and risks to infrastructure.
4. Offering a portfolio of potential measures, including structural, operational, and institutional options.

Dedicated guidance specific for Maritime ports, inland ports and recreational/marinas are expected in the next few years with working groups formed in 2024. These separate reports will be based on Working Group 178 but more specific to each subsector. Technical papers have also been published to deal with uncertainty – Managing Climate Change Uncertainties in Selecting, Designing and Evaluating Options for Resilient Navigation Infrastructure and Costs and the business case for adaptation – Climate Change Costs to Ports and Waterways: Scoping the Business Case Assessment for Investment in Adaptation

7.1.2. Other Guidelines

- European Commission: The European Commission has developed detailed technical guidance on climate-proofing infrastructure, which is relevant for environmental impact assessments and EU-funded projects.

  International Association of Ports and Harbors (IAPH): IAPH has developed various guidelines and frameworks to help ports adapt to climate change. Their World Ports Sustainability Program includes resources on climate resilience and adaptation.
- International Maritime Organization (IMO): IMO has published several documents focusing on the impacts of climate change on maritime transport and strategies for adaptation. Their Guidelines on the Incorporation of Climate Change Considerations into Maritime Policies are widely used.
- Organisation for Economic Co-operation and Development (OECD): OECD has published numerous reports and guidelines on climate change adaptation, focusing on infrastructure resilience and sustainable development.

- United Nations Framework Convention on Climate Change (UNFCCC): UNFCCC provides extensive resources and guidelines on climate change adaptation, including specific measures for coastal and marine infrastructure.

7.2. Specialist Consultancy

Specialist consultancies offer a range of tailored solutions and services which can help with understanding of climate change risks and development of solutions to mitigate the impacts and improve resilience. Examples of how consultancy services can help include:

Climate Risk Assessment Evaluating the vulnerabilities and risks posed by climate change to port infrastructure.	**Hazard Data and Adaptation Know-How** Providing data on climate hazards and developing adaptation strategies for ports.	**Sustainable Solutions** Implementing nature-based solutions, decarbonization strategies, and infrastructure resilience measures.
Adaptation Planning Developing strategies to enhance resilience, such as flood defences and nature-based solutions.	**Nature-Based Solutions** Implementing sustainable and resilient infrastructure solutions like flood defences and climate-smart forecasting.	**Coastal Protection Projects** Designing and implementing projects to protect coastal areas from sea level rise and extreme weather events.
Decarbonization Strategies Implementing measures to reduce carbon emissions and improve sustainability.	**Climate Response Framework** Assessing climate risks and vulnerabilities across port operations.	**Sustainable Development** Integrating climate resilience into port development projects.

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ANNEXE 2 – ACCESSING CLIMATE DATA

IPCC AR6 Sea Level Projection Tool: This tool provides projections of sea level rise based on the latest IPCC Sixth Assessment Report (AR6). It allows users to explore different scenarios and understand potential impacts on coastal regions. https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

NASA Climate Models: NASA's Global Climate Modeling (GCM) project develops and uses climate models to simulate and understand climate change. These models help predict future climate conditions and assess the impacts of various factors on the Earth's climate. https://www.giss.nasa.gov/projects/gcm/

NASA Sea Level Portal: The NASA Sea Level Change Portal provides comprehensive information on sea level rise, including data, research, and tools to understand and address the impacts of rising sea levels. https://sealevel.nasa.gov/

Earth System Grid Federation (ESGF): ESGF is a collaborative effort to develop a software infrastructure for the management, dissemination, and analysis of climate data. It supports a wide range of climate research activities and provides access to a vast repository of climate data. https://esgf.llnl.gov/

ClimateSet: ClimateSet is a large-scale climate model dataset designed for machine learning tasks. It includes inputs and outputs from 36 climate models from the CMIP6 and Input4MIPs archives, supporting tasks like climate model emulation, downscaling, and prediction. ClimateSet on GitHub

Global Ensemble of Ocean Wave Climate Projections: This dataset, produced through the Coordinated Ocean Wave Climate Project (COWCLIP) phase 2, represents the first coordinated multivariate ensemble of 21st Century global wind-wave climate projections. It includes statistics of significant wave height, mean wave period, and mean wave direction. Global Ensemble of Ocean Wave Climate Projections

CliMT (Climate Modelling and Diagnostics Toolkit): CliMT is a Python-based toolkit for building Earth system models. It provides state-of-the-art components and an intuitive interface for creating and diagnosing climate models. CliMT on GitHub

GSW-Python: GSW-Python is a Python implementation of the Thermodynamic Equation of Seawater 2010 (TEOS-10). It provides a fast and efficient way to perform oceanographic calculations. GSW-Python on PyPI

WAVEWATCH III: WAVEWATCH III is a community wave modelling framework that includes the latest advancements in wind-wave modelling and dynamics. It is developed by NOAA/NCEP and is used for wave forecasting and hindcasting. WAVEWATCH III on NOAA

UMWM (University of Miami's Wave Model): UMWM is a third-generation spectral ocean wave model developed by the University of Miami. It solves the wave energy balance equation on a curvilinear grid and is used for simulating global swell, coastal waves, and more. UMWM on GitHub

World Resources Institute – Climate Data Platforms: The World Resources Institute provides an interactive visual matrix of more than 100 major climate data platforms, categorized by topic and geographic level/scale. This tool helps users find relevant climate data for various needs. Overview of 100+ Climate Data Platforms

ClimRR Climate Risk and Resilience Portal (ClimRR): This portal provides future climate data to help plan for and adapt to our changing world. It models over 60 climate variables to provide sophisticated, free dynamically downscaled projections for the United States. ClimRR Climate Risk and Resilience Portal

CAIT Climate Data Explorer: This interactive climate data platform provides free access to comprehensive, reliable, and comparable greenhouse gas emissions data sets. It also provides other climate-relevant and socio-economic data, enabling analysis on a wide range of climate-related data questions. CAIT Climate Data Explorer

Tools for Understanding Climate Data – U.S. National Park Service: This resource provides a partial list of online tools that provide comprehensive information and data to help people identify climate threats and vulnerabilities, as well as reduce their risks from the impacts of climate variability and change. Tools for Understanding Climate Data - U.S. National Park Service

Climate Data Analysis Tools & Methods | Climate Data Guide: This guide provides a list of climate data analysis tools and methods. Climate Data Analysis Tools & Methods

The Weather and Climate Toolkit | NOAA Climate.gov: This toolkit from NOAA's National Climatic Data Center makes it easier for staff at government agencies, educators, and private sector analysts to sift through and visualize gigabytes of weather and climate data. The Weather and Climate Toolkit

United Kingdom: UK Climate Projections (UKCP18): The UK Climate Projections (UKCP18) provide the most up-to-date assessment of how the climate of the UK may change over the 21st century. UK Climate Projections (UKCP18)

Germany: Climate Data Center (CDC) of the German Weather Service: The Climate Data Center (CDC) of the German Weather Service provides climate projections for Germany and Europe. Climate Data Center (CDC)

United States: National Climate Assessment (NCA): The National Climate Assessment (NCA) provides climate projections for the United States based on the latest scientific understanding of how climate is changing. National Climate Assessment (NCA)

Australia: Australian Climate Change Science Program (ACCSP): The Australian Climate Change Science Program (ACCSP) provides climate projections for Australia. Australian Climate Change Science Program (ACCSP)

Canada: Canadian Centre for Climate Modelling and Analysis (CCCma): The Canadian Centre for Climate Modelling and Analysis (CCCma) provides climate projections for Canada. Canadian Centre for Climate Modelling and Analysis (CCCma)

Japan: Japan Meteorological Agency (JMA): The Japan Meteorological Agency (JMA) provides climate projections for Japan. Japan Meteorological Agency (JMA)

ANNEXE 3 – GLOBAL REPORTING STANDARDS

These frameworks and standards complement each other, providing a comprehensive approach to sustainability reporting, helping organizations manage and disclose their climate-related risks and opportunities effectively. Organizations often use multiple frameworks to meet diverse stakeholder needs and regulatory requirements. All frameworks emphasize the importance of transparency and accountability in managing climate risks.

Framework	Summary Description
TCFD	Focuses on climate-related financial disclosures.
CSRD	Mandatory in the EU, covers comprehensive sustainability reporting.
GRI	Covers a broad range of ESG topics, widely used globally.
SASB	Industry-specific, focuses on financially material sustainability information.
ISSB	Aims to create a unified global standard, incorporating TCFD and SASB elements.

Task Force on Climate-related Financial Disclosures (TCFD)

The TCFD was established by the Financial Stability Board (FSB) in 2015 to develop a set of recommendations for voluntary climate-related financial disclosures. TCFD is now transferred/embedded in the International Sustainability Standards Board (ISSB) under the International Financial Reporting Standards (IFRS). These recommendations help companies provide clear, comprehensive, and high-quality information on the impacts of climate change. The TCFD framework focuses on four key areas:

1. **Governance:** Disclosing the organization's governance around climate-related risks and opportunities.
2. **Strategy:** Disclosing the actual and potential impacts of climate-related risks and opportunities on the organization's businesses, strategy, and financial planning.
3. **Risk Management:** Disclosing how the organization identifies, assesses, and manages climate-related risks.
4. **Metrics and Targets:** Disclosing the metrics and targets used to assess and manage relevant climate-related risks and opportunities.

Key Difference: TCFD is specifically focused on climate-related financial disclosures, aiming to provide investors with consistent and comparable information.

Global Reporting Initiative (GRI)

The GRI Standards are the most widely used standards for sustainability reporting. They enable organizations to understand and communicate their impacts on issues such as climate change, human rights, and corruption. The GRI Standards are structured into three series:

1. **Universal Standards:** Apply to all organizations and include foundational disclosures.
2. **Sector Standards:** Provide specific guidance for different sectors.
3. **Topic Standards:** Cover specific sustainability topics like emissions, waste, and labour practices.

Key Difference: GRI is comprehensive, covering a wide range of ESG issues beyond just climate-related financial risks.

Sustainability Accounting Standards Board (SASB)

SASB Standards are designed to help businesses identify, manage, and communicate financially material sustainability information to investors. These standards are industry-specific and focus on the sustainability issues most likely to impact financial performance.

Key Difference: SASB is industry-specific and focuses on financially material sustainability information, making it highly relevant for investors.

Corporate Sustainability Reporting Directive (CSRD)

The CSRD is a European Union directive that mandates comprehensive sustainability reporting for companies operating in the EU. It aims to improve the quality and consistency of sustainability information disclosed by companies, making it easier for investors and other stakeholders to assess their sustainability performance.

Key Difference: CSRD is mandatory for companies in the EU and covers a broad range of sustainability topics, ensuring high-quality and consistent reporting.

International Sustainability Standards Board (ISSB)

The ISSB, established by the International Financial Reporting Standards (IFRS) Foundation, aims to develop a global baseline of sustainability-related disclosure standards. These standards are intended to meet the information needs of investors and other capital market participants.

Key Difference: ISSB aims to create a unified global standard for sustainability disclosures, incorporating elements from TCFD and SASB to provide comprehensive guidance

ANNEXE 4 – REGULATIONS AND POLICY GUIDELINES

United Kingdom

- **Climate Change Act 2008:** This foundational legislation requires the UK to reduce greenhouse gas emissions and adapt to climate change. It mandates the production of a UK Climate Change Risk Assessment (CCRA) every five years, which identifies the risks and opportunities from climate change.
- **National Adaptation Programme:** DEFRA leads the development of the NAP, which outlines actions to address the risks identified in the CCRA. The third NAP (NAP3) covers the period from 2023 to 2028 and includes specific measures for infrastructure, including ports. Third National Adaptation Programme (NAP3) - GOV.UK (www.gov.uk)
- **Adaptation Reporting Power (ARP):** Under the ARP, DEFRA invites infrastructure providers, including port authorities, to report on their preparedness for climate change. This helps ensure that essential services and infrastructure are resilient to climate impacts. Climate change adaptation: policy information - GOV.UK (www.gov.uk)

United States

- **National Climate Assessment:** This comprehensive report provides guidelines and assessments to help port authorities understand and plan for climate impacts. It is a key resource for climate adaptation planning. Fifth National Climate Assessment (globalchange.gov)
- **Federal Emergency Management Agency (FEMA):** FEMA offers resources and funding for resilience and adaptation projects, including those for ports and coastal infrastructure. FEMA Resources for Climate Resilience

European Union

- **EU Adaptation Strategy:** This strategy encourages member states to develop national adaptation plans, including specific measures for ports and coastal infrastructure. It aims to enhance resilience across the EU. EU Adaptation Strategy - European Commission (europa.eu)
- **European Maritime Safety Agency (EMSA):** EMSA provides guidelines and support for climate resilience in maritime transport, helping ports adapt to changing climate conditions. Reducing GHG emissions – EMSA – European Maritime Safety Agency (europa.eu)

Australia

- **National Climate Resilience and Adaptation Strategy:** This strategy outlines measures for enhancing the resilience of critical infrastructure, including ports. It provides a framework for adaptation planning and implementation. Strategic objective 4: Responding to climate change | Australian Maritime Safety Authority (amsa.gov.au)
- **Australian Maritime Safety Authority (AMSA):** AMSA offers guidelines and resources for climate adaptation in the maritime sector, ensuring that ports can effectively respond to climate risks.

Canada

- **Pan-Canadian Framework on Clean Growth and Climate Change:** This framework includes specific measures for adapting port infrastructure to climate impacts, promoting resilience and sustainability. Pan-Canadian Framework on Clean Growth and Climate Change - Canada.ca
- **Transport Canada:** Provides guidelines and funding for climate resilience projects in the transport sector, supporting ports in their adaptation efforts. Information archivée dans le Web | Information Archived on the Web (publications.gc.ca)

Japan

- **Climate Change Adaptation Act:** This act requires port authorities to develop and implement adaptation plans to address climate risks. It ensures that ports are prepared for the impacts of climate change. 001579732.pdf (mlit.go.jp)
- **Ministry of Land, Infrastructure, Transport and Tourism (MLIT):** MLIT offers support and guidelines for climate adaptation in the maritime sector, helping ports enhance their resilience. Ministry of Land, Infrastructure, Transport and Tourism (mlit.go.jp)

ANNEXE 5 – TRANSITION RISKS FURTHER READING

WSP - How Ports Should Address Climate Change Risks
Marsh - Ports & Terminals: Risk Challenges and Solutions
Zurich - Navigating Climate Risks
EESI - Climate Change Mitigation and Adaptation at U.S. Ports
PIANC - Climate Resilience Guide for Ports
IDB Invest - Climate Risk and Ports: A Practical Guide on Strengthening Resilience
Springer - Climate Change Adaptation Planning for Ports and Inland Waterways
BSR - Improving the Environmental Performance of Ports and Terminals
Manifest Climate - Global Climate Disclosure Requirements Comparison
WTW - Climate Reporting: Comparing Disclosure Regimes with TCFD
Manifest Climate - How Do the CSRD and TCFD Compare?

About the Publishers of the Guidelines

TT Club

TT Club is the established market-leading independent provider of mutual insurance and related risk management services to the international transport and logistics industry. Its mission is to make the industry safer, more secure and more sustainable. Established in 1968, TT Club currently services more than 1400 Members – container owners, operators, ports, terminals and logistics companies, working across maritime, road, rail and air. The Club is renowned for its high-quality service, in-depth industry knowledge and enduring Member loyalty. Its average annual customer retention rate is consistently over 95%, with some Members having chosen to insure with the Club for over 50 years.

Haskoning

Haskoning is an independent and employee owned company dating from 1881 integrating engineering, design, consultancy, software and technology to deliver more added value for clients. Through our mission Enhancing Society Together, we take responsibility for having a positive impact on the world and contribute to UN Sustainable Development Goals. We constantly challenge ourselves and others to develop sustainable solutions to local and global issues related to the built environment and the industry. Backed by the expertise of around 6,800 colleagues working from offices in more than 25 countries across the world, we are helping clients with challenges ranging from climate change and digital transformation to changing customer demands and the energy transition. haskoning.com

ICHCA International

Established in 1952, ICHCA International is an independent, not-for-profit organisation dedicated to improving the safety, productivity and efficiency of cargo handling and movement worldwide. ICHCA's privileged NGO status enables it to represent its members, and the cargo handling industry at large, in front of national and international agencies and regulatory bodies, while its Technical Panel provides best practice advice and develops publications on a wide range of practical cargo handling issues.Operating through a series of national and regional chapters, including ICHCA Australia, ICHCA Japan and plus Correspondence and Working Groups, ICHCA provides a focal point for informing, educating, lobbying and networking to improve knowledge and best practice across the cargo handling chain. ichca.com

GLOSSARY

AI Artificial Intelligence
AGV Automated Guided Vehicle
ANP Agence Nationale des Ports
Acute Risk These are risks driven by specific, short-term weather events or hazards, such as heatwaves, floods, wildfires, and storms
Adaptation Adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities
Adaptive Capacity The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences
Anthropogenic Resulting from or produced by human activities, often used in the context of emissions that are produced because of human activities
BCR Benefit Cost Ratio
Carbon Footprint The total amount of greenhouse gases emitted by an individual, organization, event, or product, expressed as carbon dioxide equivalent
CAD Canadian Dollar
CDP Carbon Disclosure Project
Chronic Risk These are risks driven by longer-term shifts in climate patterns, such as rising sea levels and increasing average temperatures
Climate The average weather conditions in a region over a long period, typically 30 years or more
Climate Change A change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer
Climate Model A mathematical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions, and feedback processes
CO2 Carbon Dioxide
CSRD Corporate Sustainability Reporting Directive
DSS Decision Support System
Decarbonization The process of reducing carbon dioxide emissions through the use of low carbon power sources, achieving a lower output of greenhouse gases into the atmosphere
Direct measurements Measurements taken by instruments on satellites, aircraft, ships, buoys, and ground-based stations. These instruments measure various aspects of the climate system, including temperature, precipitation, wind speed and direction, and atmospheric composition.
EBRD European Bank for Reconstruction and Development
ECI University of Oxford's Environmental Change Institute
ECT Europe Container Terminals
EDF Environmental Defense Fund – A United States based non-profit environmental advocacy group
ESG Environmental, Social, and Governance
EV Electric Vehicles
Exposure ISO14091 defines exposure as the "presence of people, livelihoods, species or ecosystems, environmental functions, services, resources, infrastructure, or economic, social, or cultural assets in places that could be adversely affected" by climate change.

GEF Global Environment Facility – A partnership of 184 countries, international institutions, civil society organizations, and the private sector that addresses global environmental issues. The GEF provides funding to support projects related to biodiversity, climate change, international waters, land degradation, and chemicals and waste.

GHG Greenhouse Gas

GISS Goddard Institute for Space Studies

Greenhouse Gases (GHGs) Gases in the Earth's atmosphere that trap heat, such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases

GRI Global Reporting Initiative

HHLA Hamburger Hafen und Logistik AG

HHM Hafen Hamburg Marketing

Hazard The potential occurrence of climate-related physical events or trends that may cause damage and loss

IADB Inter-American Development Bank

IAPH International Association of Ports and Harbors

IMO International Maritime Organization

IPCC Intergovernmental Panel on Climate Change

Indirect proxies These are derived from physical, chemical, and biological materials preserved within the geologic record. Examples include ice cores, tree rings, and sediment cores. These proxies provide a historical record of climate conditions, allowing scientists to reconstruct past climates and understand how our climate has changed over time.

IoT Internet of things – a network of physical objects embedded with sensors, software, and network connectivity, allowing them to collect and share data.

ISSB International Sustainability Standards Board

LAL Lightning Activity Level

Mitigation Efforts to reduce or prevent the emission of greenhouse gases, aiming to limit the magnitude or rate of long-term climate change

NASA National Aeronautics and Space Administration

OECD Organisation for Economic Co-operation and Development

Physical Risk This encompasses both acute and chronic risks, referring to the potential for adverse impacts due to climate-related physical events or trends

PPP Public Private Partnership

RCP Representative Concentration Pathways

Resilience The capacity of social, economic, and environmental systems to cope with a hazardous event or trend, responding or reorganizing in ways that maintain their essential function, identity, and structure

Risk The potential for adverse consequences for human or ecological systems, recognizing the interaction between hazards, exposure, and vulnerability

SSP Shared Socioeconomic Pathways

SASB Sustainability Accounting Standards Board

SBTi Science Based Targets initiative

Sensitivity The degree to which a system or species is affected, either adversely or beneficially, by climate variability or change

TCFD Task Force on Climate related Financial Disclosures

Transition Risk These are risks related to the transition to a lower-carbon economy, which can include policy changes, technological advancements, and shifts in market preferences

UNFCC United Nations Framework Convention on Climate Change

USD United States Dollar

WPCAP World Ports Climate Action Program

Vulnerability The propensity or predisposition to be adversely affected

Weather The state of the atmosphere at a particular place and time, including temperature, humidity, precipitation, wind, and visibility