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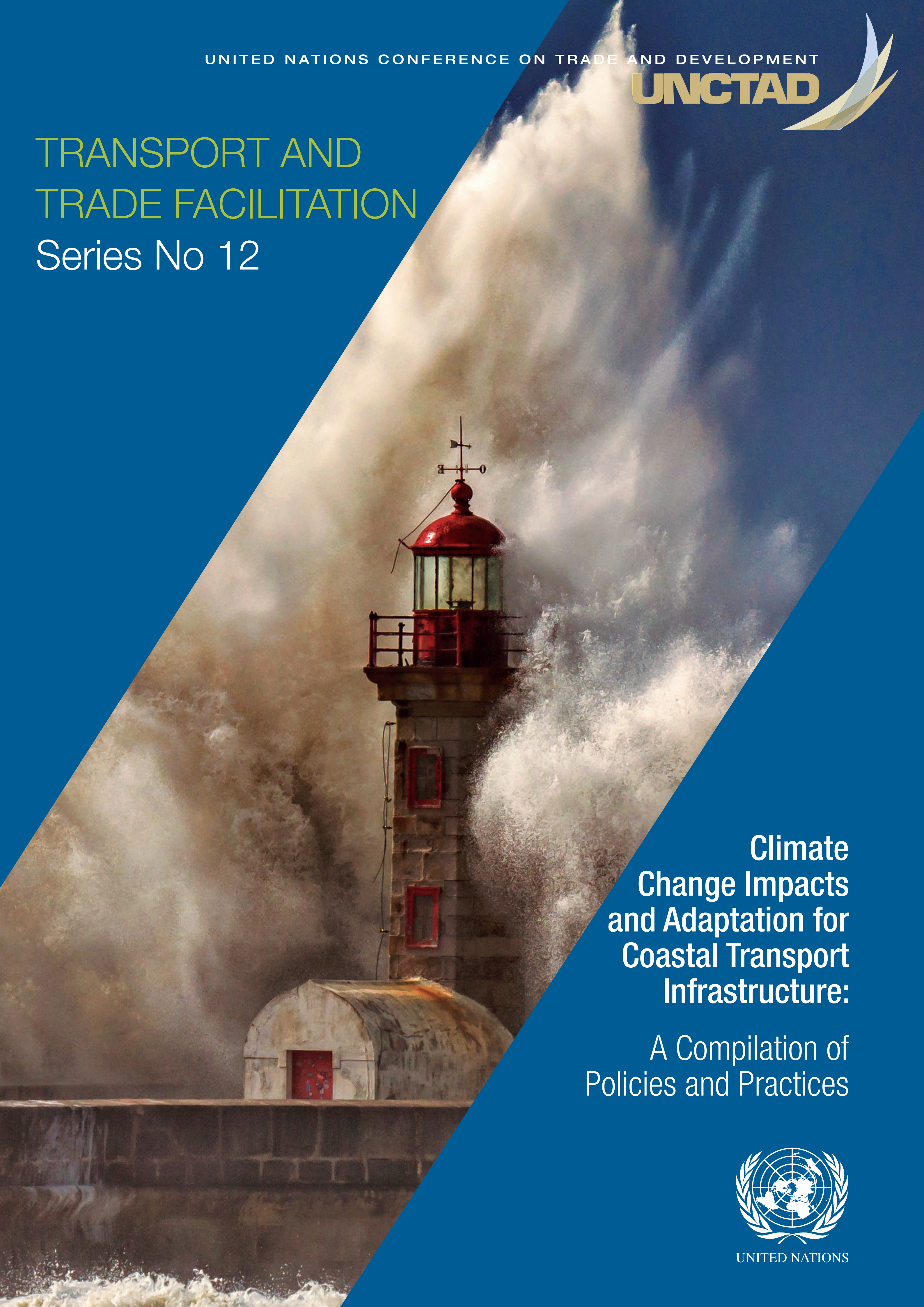

Climate Change Impacts and Adaptation for Coastal Transport Infrastructure:

A Compilation of Policies and Practices

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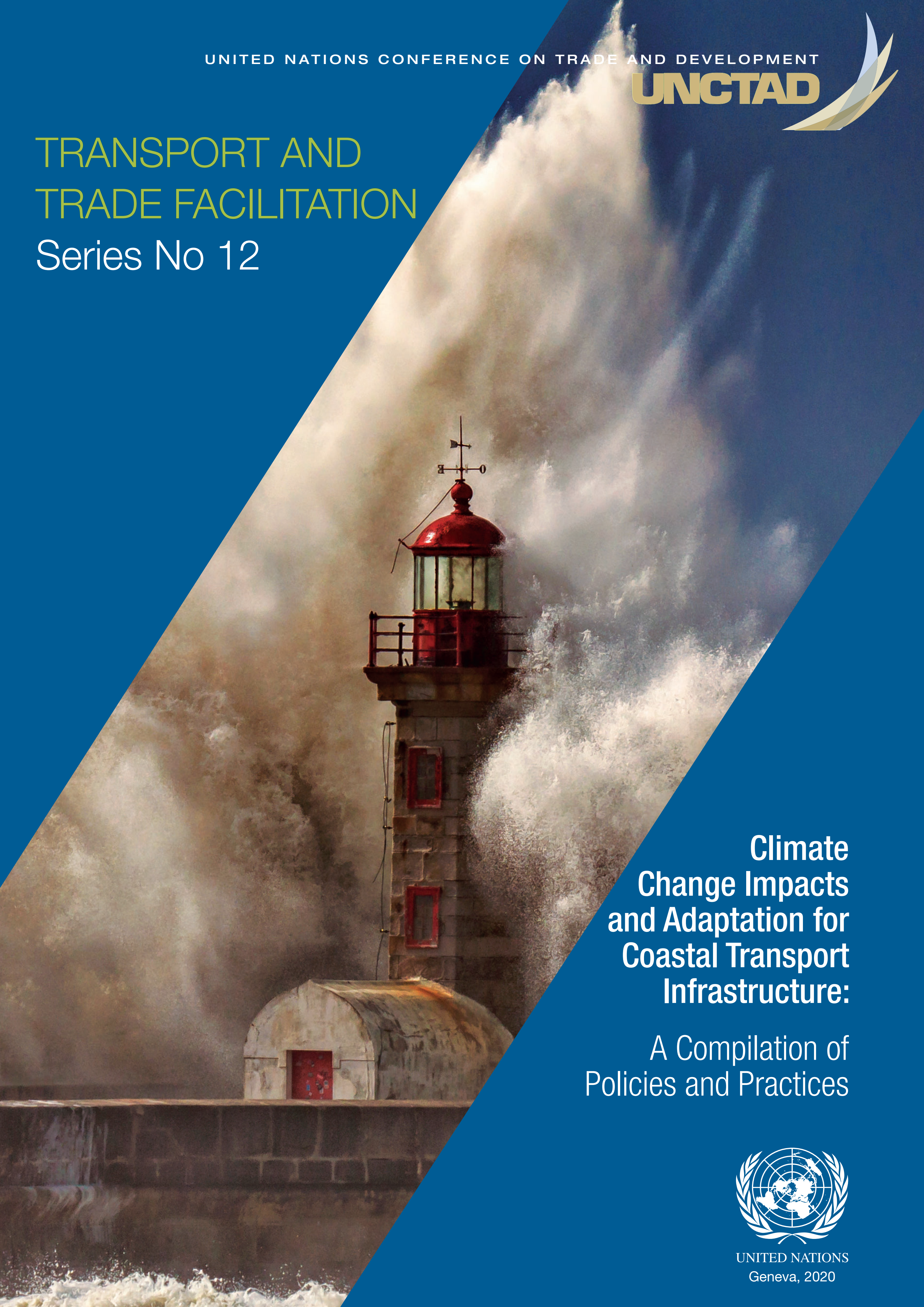

Climate Change Impacts and Adaptation for Coastal Transport Infrastructure:

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UNITED NATIONS
Geneva, 2020

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This publication has not been formally edited.

United Nations publication issued by the United Nations Conference on Trade and Development.

UNCTAD/DTL/TLB/2019/1

ISBN: 978-92-1-112970-0
eISBN: 978-92-1-004890-3
Sales No.: E.20.II.D.10

Acknowledgments

This report was prepared by Regina Asariotis, Lenka Kruckova and Viktoria Mohos Naray, Policy and Legislation Section, Trade Logistics Branch, Division on Technology and Logistics of UNCTAD. To the extent possible updates to reflect information available as of November 2019 have been included. The UNCTAD secretariat gratefully acknowledges the contribution of all experts, collaborators and stakeholders that have participated in and informed UNCTAD's related research and analysis, expert meetings and technical assistance work over the past ten years, on which this compilation draws.

For further information about UNCTAD's related work, please contact the UNCTAD secretariat's Policy and Legislation Section at policy.legislation@unctad.org or consult the website at https://unctad.org/ttl/legal and at https://SIDSport-ClimateAdapt.unctad.org.

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Executive Summary

Ports are critical infrastructure assets that serve as catalysts of economic growth and development and are key-nodes in the network of closely interconnected global supply-chains. At the same time, ports and other coastal transport infrastructure are exposed to the risk of climate change impacts, particularly in view of their location in coastal zones, low-lying areas and deltas. Given the strategic role of ports and of other key coastal transport infrastructure as part of the global trading system, and the potential for climate-related delays and disruptions across global supply chains, enhancing their climate resilience is a matter of strategic economic importance. In view of the long service life of transport infrastructure, and the potentially major consequences of inaction, effective adaptation and resilience building requires re-thinking of established approaches and practices early. A good understanding of risks and vulnerabilities is required for the development of well-designed adaptation measures that minimize the adverse effects of climatic factors. For the purposes of risk-assessment and with a view to developing effective adaptation measures, dissemination of more tailored data and information is important, as are targeted case studies and effective multi-disciplinary and multi-stakeholder collaboration at all levels. Legal and regulatory approaches, as well as policies and plans are going to be key to efforts at facilitating effective risk and vulnerability assessments and providing a supportive framework for adaptation action at all levels. Guidance, standards, best practices, methodologies and other tools in support of adaptation are urgently required, and targeted capacity building is going to be critical, especially for the most vulnerable countries.

Against this background, the present compilation presents examples of legal, regulatory and policy approaches, as well as of reports, studies and guidance to support climate risk, vulnerability and impact assessment, and the development of effective adaptation response measures. By way of context, the document also provides a brief overview of climate change impacts on coastal transportation, and of recent trends and projections regarding some key climate drivers of relevance to coastal zones, as well as of approaches to risk-assessment and adaptation. The included material has been selected and presented with a view to informing, guiding and inspiring policy makers, national authorities, transport infrastructure planners and managers, and other interested stakeholders in their efforts to advance climate change adaptation for coastal transport infrastructure and increase levels of preparedness. Main findings include the following.

Ports and other coastal transport infrastructure (i.e. coastal roads, railways, and airports) will be particularly affected by climate variability and change (CV & C). Projected increases in the mean and extreme sea levels will cause permanent and/or recurring marine inundation of seaports, coastal airports and other transport infrastructure in many regions, with the coastal transport infrastructure of small island developing States (SIDS) being particularly affected. Heavy rainfall (downpours) and fluvial and pluvial flooding can damage the structural integrity and affect operations of coastal transport infrastructure; regions where the flooding risk is already high will face severe problems more frequently in the future. Increases in mean temperatures and the frequency/duration of heat waves will pose substantial challenges, such as damages to port paved areas and navigational equipment, buckling of airport runways, aircraft payload restrictions, road asphalt rutting, bridge damages, rail track buckling and speed restrictions, higher energy consumption for cooling and health/safety issues for personnel and passengers. At the same time, although global warming can create new opportunities for international maritime networks/trade due to the opening up of new Arctic shipping routes, there will be significant engineering challenges due to the projected increases in extreme sea levels and coastal erosion along the Arctic coastlines and the thawing permafrost. Extreme winds and waves can be also catastrophic, as they can cause coastal erosion, port/coastal defence overtopping and flooding, infrastructure failures and operational disruptions.

Approaches to adaptation of coastal transport infrastructure will differ depending on the type of hazard: (a) episodic hazards due to extreme events and (b) slow-onset hazards, such as permanent facility flooding by sea level rise (SLR) or the effects of permafrost thawing. These different types of hazards require different responses and technological considerations. The former require risk reduction solutions including coastal protection works, whereas the latter requires long-term risk retention and resilience building; this in turn will require effective regulatory response measures that integrate/adapt the existing regulatory and policy frameworks which include national adaptation plans, various disaster risk reduction instruments and coastal zone planning policies.

Successful adaptation strategies need to be underpinned by strong legal and regulatory frameworks, that can help to reduce exposure and/or vulnerability to climate-related risks of coastal transport infrastructure. Given that ports form complex systems and large ports are usually linked to coastal urban agglomerates, coastal planning regulation can play a particularly important role as a facilitator of climate change adaptation through mainstreaming climate change considerations. Legal and regulatory tools may further provide economic incentives to fund climate change adaptation efforts, promote the transfer of adaptation technologies and contribute to the availability of accurate climate data and tools. At the same time, it is of major importance that legal and regulatory approaches do not – even inadvertently – foster ‘maladaptation’ that may limit or lock-in future adaptation options. Legal and regulatory instruments presented in this report are, by no means, exhaustive but illustrate a range of approaches that may contribute to climate adaptation efforts for coastal transport infrastructure.

At national and regional level, countries are increasingly developing policies and plans with a view to facilitating climate change adaptation. Public authorities play a pivotal role by providing the appropriate policy frameworks with a view to promoting climate resilient coastal transport infrastructure. Efforts might target a range of policy areas, including: (i) Improving risk assessment processes to support informed and evidence-based decision making; (ii) awareness raising and capacity building; (iii) screening and factoring climate risks into public investments; (iv) enabling infrastructure resilience through policy and regulation; (v) encouraging climate risk disclosure; and (vi) revealing interdependencies and supporting the design of appropriate integrated public policies.

A number of coastal transport facilities and networks have started initiating measures to address the implications of climate change. Often, however, these actions tend to focus more on climate mitigation rather than on increasing levels of preparedness to respond to the impacts of climate change and the development of adaptation action. Examples of climate change adaptation practices at facility level are therefore less common. Nevertheless, there are transport facilities/networks that have started building their climatic resilience and address the possible impacts they are likely to face (mostly in the near future). It appears that most efforts have been focusing on ‘hard’ adaptation measures, rather than on ‘soft’ adaptation responses, such as e.g. the development of ‘fit-for-purpose’ emergency management plans and processes, or appropriate changes in port operations and management.

1. Background and scope

Ports are critical infrastructure assets that serve as catalysts of economic growth and development. With 80 per cent of the volume of global merchandise trade carried by sea, ports are key nodes in the network of closely interconnected global supply-chains and at the heart of international trade and globalization. At the same time, ports and other coastal transport infrastructure, are exposed to the risk of climate change impacts, particularly in view of their location in coastal zones, low-lying areas and deltas. Rising mean sea levels, increased frequency and intensity of extreme storm surges and waves, precipitation, droughts and/or river floods and increased mean temperatures as well as extreme temperature variability constitute some of the climatic changes that pose serious threats to ports and other coastal transport infrastructure and services (UNCTAD, 2011a), with broader implications for international trade and for the development prospects of the most vulnerable nations, particularly the least developed countries and small island developing States.

Direct threats include accelerated coastal erosion, port and coastal road inundation/submersion, increased runoff and siltation requiring increased dredging, water supply problems, access restrictions to docks and marinas, deterioration of the condition and problems with the structural integrity of road pavements, bridges and railway tracks. In addition to causing damage to infrastructure and equipment, climate change impacts may also result in delay and disruption and lead to extensive economic and trade-related losses. Indirect impacts of climate change on ports include those arising from climate-driven changes to demand for transportation through for example, changes in the population concentration/distribution, as well as through changes in production, trade and consumption patterns. Associated risks, vulnerabilities and costs may be considerable, in particular for ports and other coastal transport infrastructure in developing regions with low adaptive capacity, and in small island developing States (SIDS).

Given the strategic role of seaports and of other key coastal transport infrastructure as part of the global trading system, and the potential for climate-related delays and disruptions across global supply chains, enhancing their climate resilience is a matter of strategic economic importance. Effective adaptation action for key coastal transport infrastructure assets will also be critical to achieving progress on a number of the Sustainable Development Goals and targets (e.g. 1.5, 9.1,[1] 9.a, 11.b, 13.1, 13.2 and 13.3, 14) as well as to implementation of the Addis Ababa Action Agenda on Financing for Development (AAAA), the SAMOA Pathway, and the Paris Agreement.

UNCTAD has been working on the implications of climate change for transportation since 2008 (see https://unctad.org/ttl/legal), with particular focus on impacts and adaptation needs of seaports and other coastal transport infrastructure. Relevant research and analytical work, including peer-reviewed publications, as well as the outcome of a series of expert meetings and technical cooperation activities have significantly helped to raise awareness and advance the international debate,[2] and benefit from strong support of Member States.[3] Lessons learnt as part of UNCTAD's work over the past 10 years indicate that multifaceted approaches to adaptation and resilience building for coastal infrastructure assets will be required to effectively address the challenge. These include mainstreaming climate

[1] See also https://sdgpulse.unctad.org/transport-infrastructure/.
[2] UNCTAD's work has informed, among others, IPCC Reports (2014; 2018; 2019), the Climate Change Policy Framework for Jamaica (2015); the National Adaptation Plan to Climate Change for Brazil (Vol.2) (2016) and the recent Climate Action Pathway for Transport and Resilience (https://unfccc.int/climate-action/marrakech-partnership/reporting-and-tracking/climate_action_pathways).
[3] See Maafikiano (TD/519/Add.2), paras. 55 (f),(k),(l).

change considerations into coastal transport infrastructure planning/operations as well as pursuing policy coherence among transport, trade, tourism and overall sustainable development decision-making. Innovative and mixed adaptation responses (regulation, management and technical measures) will be needed, including 'soft' and 'hard' adaptation measures.

In view of the long service life of transport infrastructure, and the potentially major consequences of inaction, effective adaptation and resilience building requires rethinking established approaches and practices early. Moreover, a good understanding of risks and vulnerabilities is required for the development of well-designed adaptation measures that minimize the adverse effects of climatic factors. This, however, constitutes a major challenge. The potential adverse impacts of climate variability and change may be wide-ranging, but they vary considerably by physical setting, climate forcing and mode of transport, as well as other factors. Thus, for instance, ports in river deltas face different challenges from open-sea ports; and extreme events and flooding may affect coastal transport infrastructure in some parts of the world, whereas melting permafrost could become a major problem in others. Technical risk assessment of coastal transport infrastructure under climate change will be required to inform effective adaptation action and avoid maladaptation.

However, there are at present still important knowledge gaps regarding the specific nature and extent of exposure that individual coastal transport facilities may be facing, with important repercussions for levels of preparedness. This is illustrated, among others, by the findings of an UNCTAD port industry-survey on climate change impacts and adaptation (Asariotis, et al., 2017), designed in collaboration with global port industry associations and other experts. The survey revealed important gaps in terms of relevant information available to seaports of all sizes and across regions, with implications for effective climate risk assessment and adaptation planning. Preliminary results of a more recent survey, conducted in 2019 by industry organizations IAPH and PIANC, confirm the key findings of the UNCTAD survey and illustrate the increasing number of extreme weather events affecting seaports and operations over recent years.[4]

For the purposes of risk-assessment and with a view to developing effective adaptation measures, dissemination of more tailored data and information is important, as are targeted case studies and effective multi-disciplinary and multi-stakeholder collaboration at all levels (see also Becker et al., 2018). Legal and regulatory approaches, as well as policies and plans are going to be key to efforts at facilitating effective risk and vulnerability assessments, and providing a supportive framework for adaptation action at all levels. Guidance, standards, best practices, methodologies and other tools in support of adaptation are urgently required, and targeted capacity building is going to be critical, especially for the most vulnerable countries. This includes SIDS, which depend on their ports and coastal airports for food and energy needs, external trade and – crucially – tourism, which typically accounts for a major share of GDP.

Against the above background, this compilation of policies and practices has been prepared to contribute to bridging a knowledge gap with regards to climate change impacts and adaptation for coastal transport infrastructure. The compilation presents examples of legal, regulatory and policy approaches, as well as of reports, studies and guidance to support climate risk, vulnerability and impact assessment, and the development of effective adaptation response measures. Practices addressed in the document relate to a total of over 35 countries covering five continents, as well as practices that are considered of global nature.

[4] Personal communication, Jan Brooke, PIANC.

Chapter 2 provides important contextual information, namely a brief overview of: (i) the varied impacts of climate variability and change (CV&C) on coastal transport infrastructure; (ii) recent trends and projections regarding some key climate drivers of relevance to coastal zones; as well as (iii) approaches to risk-assessment and adaptation. This information is intended to assist readers further in their understanding of the extent of the challenge and of the urgent need for appropriate adaptation response measures. Chapter 3 presents examples of international, regional and national legal and regulatory approaches that are relevant for climate change impact assessment and adaptation for coastal transport infrastructure, while Chapter 4 presents policies or plans that have been developed at regional or national levels. Chapter 5 presents a selection of relevant reports, studies and guidance, illustrating approaches that may be of assistance in the development of appropriate climate change adaptation plans and measures, particularly at facility level.

The compilation provides an overview of each example listed and refers to the original source documents as well as other related material providing further information. For the purpose of the present compilation, 'practices' should be understood in a broad sense, implying not only activities at airport and seaport level, but also research/academic work on risk and vulnerability assessments, as well as case studies, reports, and standards and guidance material. The compilation does not seek to classify or rate practices. Further, regulatory and policy approaches, as well as studies, reports, and guidance presented in this compilation, are to be considered as select illustrative examples only, as the document is not intended to provide an exhaustive overview of existing practices on climate change adaptation for coastal transport infrastructure.

Thus, the material included in this compilation has been selected and presented with a view to informing, guiding and inspiring policy makers, national authorities, transport infrastructure planners and managers, and other interested stakeholders, in their efforts to advance the important issue of climate change adaptation for coastal transport infrastructure and increase levels of preparedness.

2. Climate change impacts and adaptation for coastal transport infrastructure

2.1 Climate variability and change (CV&C): Impacts

Global climate is, beyond doubt, changing with the major forcing being the increase in the atmospheric concentrations of green house gases (GHGs), which absorb large parts of the heat reflected back from the Earth's surface and, thus, increase the Earth's heat storage (IPCC, 2013). Fossil fuel emissions have been increasing steadily since the 1950s and, with the exception of the most mild future RCP climate scenario[5], are projected to continue growing at least until 2050. Fossil CO2 emissions from energy use and industry grew 2 per cent in 2018, reaching a record 37.5 GtCO2 per year. There is no sign of GHG emissions peaking in the next few years, with every year of postponed peaking suggesting that deeper/faster cuts will be required in the future. By 2030, emissions would need to be 25 per cent and 55 per cent lower than in 2018 to put the world on the least-cost pathway to limiting global warming to below 2˚C and 1.5°C, respectively (UNEP, 2019). Transportation accounts for a significant fraction (about 25 per cent) of global (GHG) emissions[6] and, at the same time, faces severe challenges as a result of climate variability and change (CV & C)[7] (UNECE, 2019).

Coastal transport infrastructure consists of complex systems and multimodal nodes, and will be particularly affected. Seaports are most critical coastal transportation assets. They are points of convergence between maritime and inland transportation, providing access to global markets for all countries. In addition to being gateways to (international) trade, they create employment, generate wealth, contribute to national gross domestic product (GDP) and promote nearby urban/industrial agglomerations. In the case of large seaports, which are mostly integrated within large coastal urban agglomerates, CV & C will directly impact large populations and socio-economic activities (IPCC, 2019).

While ports are at the heart of international trade and globalization, they are also exposed to various hazards induced by CV & C.[8] (Table 2.1). Due to their location at the open coast or low-lying estuaries and deltas, ports are particularly affected by rising sea levels and storm surges, waves and winds, as well as riverine and pluvial flooding (e.g. Becker et al., 2013). Given the concentration of populations and services and the size/value of infrastructure in port areas as well as the vital role of ports in the international supply chains, CV & C impacts on ports and their hinterland transportation links can have broad ramifications for a range of economic sectors. Thus, port infrastructure damages and/or operational disruptions and delays may adversely affect trade, energy and food supply and tourism. By the same token, it should be also noted that the transport industry is a demand-driven industry. Thus, CV & C impacts on other sectors of the economy (e.g. commodities and tourism) may indirectly

[5] Climate projections are made on the basis of the IPCC Representative Concentration Pathways-RCP scenarios, for which the CO2 equivalent concentrations of GHGs for 2100 are set as: RCP 8.5, 1370 ppm; RCP 6.0 850 ppm CO2-equivalent; RCP 4.5, 650 ppm CO2-equivalent; and RCP 2.6, peaking at 490 ppm CO2-equivalent.

[6] Fuel combustion emits directly Carbon dioxide (CO2), Carbon monoxide (CO), volatile organic compounds, Sulfur and Nitrogen oxides (SOx and NOx) and particulates. At seaports, road freight vehicle loading/unloading increase pollution, particularly as vehicles pollute more during the first few kms of their journey (UNECE, 2015).

[7] Climate Variability and Change (CV & C) refers to the variability and sustained change of climatic factors relative to a reference period, e.g. the first period with accurate records (1850s-1860s), or periods with widespread and comparable observations (e.g. 1986-2005 and/or 1980-2014).

[8] It is noteworthy that for the transportation industry and the broader society, economy and the environment, changes in climatic extremes can be more relevant than slow onset climatic changes (IPCC SREX, 2012).

affect transportation through changes in the demand for transportation (UNECE, 2015; UNCTAD, 2017).

Seaports and other coastal transport infrastructure (i.e. coastal roads, railways, and airports) will be particularly affected by CV & C. Increases in the mean and extreme sea level will cause permanent and/or recurring marine inundation of seaports, coastal airports and other transport infrastructure, with the northwestern European, northern American Pacific and the southeastern Asian coasts as well as the coasts of the small island developing States (SIDS) being particularly affected (e.g. Vousdoukas et al., 2018; Monioudi et al., 2018; Giardino et al., 2018).

Coastal inundation from extreme events can render transportation systems unusable for the event duration and damage terminals, freight villages, storage areas and cargo and disrupt supply chains for longer periods of time (UNECE, 2015). Impacts could include disruptions to operations and damages to port infrastructure and vessels, as well as to hinterland connections. A recent study has found that over 60 per cent of the EU seaports may be inundated by 2100 under a mean sea leve rise (SLR) of 1 m and extreme sea levels (ESLs) of about 3 m (Christodoulou and Demirel, 2018). Many seaports in Greece (169), the United Kingdom (165) and Denmark (90) will be affected by 2080, with the overall number of EU seaports facing inundation (852) expected to increase by 50 per cent relative to 2030. However, a port industry survey carried out by UNCTAD has indicated significant gaps in the information/data necessary to assess inundation risks, and low levels of preparedness across global ports (Asariotis et al., 2017).

Heavy rainfall (downpours), fluvial and pluvial flooding can damage coastal transport infrastructure and affect port operations due to poor visibility and decreased manoeuvrability of locks and vessels caused by suddenly increased water levels/speeds. Extreme precipitation can cause flash floods that can damage the structural integrity and affect operations of the connecting inland roads and railroads and terminals as well as inland waterway connections (USDOT, 2012; Palko, 2017). Regions where the flooding risk is already high (Koks et al., 2019) will face severe problems more frequently in the future. Downpours may also result in more rain-related accidents due to road/track damages, reduced traction and poor visibility, and traffic delays and disruptions (Hambly et al., 2012; Palko, 2017).

The safety, efficiency and reliability of coastal railroads will be compromised. There could be various damages, such as: track and line side equipment failure, flood scours at bridges and embankments, culvert washouts, flooding of below-grade tunnels, obstructions of railway tracks, bridges and culverts, and landslides/mudslides. There could also be problems with the safety of personnel/passengers and the accessibility of the rolling stock and maintenance depots. In the United Kingdom of Great Britain and Northern Ireland, costs related to extreme precipitation/floods and other extreme events, which had been estimated as about £ 50 million a year in 2010, might increase to £ 500 million per year by the 2040s (Dora, 2011). Inland waterways (IWW) can also be affected by both floods and droughts. Riverine (fluvial) floods can have major impacts such as the suspension of navigation, damages to port facilities, banks and flood protection works (UNECE, 2013), silting, and changes in the river morphology (PIANC, 2008). IWWs can also be affected by low water levels that can inhibit access by heavier vessels during droughts; these are now considered a greater hazard for European IWWs than floods (Christodoulou and Demirel, 2018).

Increases in mean temperatures and the frequency/duration of heat waves will pose substantial challenges to coastal transport infrastructure and operations, including to the safety/health of passengers and personnel. They can cause deterioration of port paved areas and navigational equipment, buckling of airport runways and aircraft payload restrictions, road asphalt rutting, bridge damages, rail track buckling and speed restrictions, higher energy consumption for cooling and health/safety issues for personnel and passengers (Monioudi et al., 2018; UNECE, 2019).

At the same time, global warming can create some opportunities for international maritime networks/trade due to opening up of new Arctic shipping routes. However, there will be also challenges due to (i) the projected increases in extreme sea levels and coastal erosion for the northern coastlines of Canada, the Russian Federation and the United States of America (Vousdoukas et al., 2018); and (ii) increasing engineering challenges in the development/maintenance of the Arctic transport infrastructure due to thawing permafrost (e.g. Shuur et al., 2015; Palko, 2017). Permafrost thawing causes ground subsidence, slope instability, drainage issues and cracking which affects the structural integrity and load-carrying capacity of transportation infrastructure and induces high maintenance costs and usage restrictions (Karl et al., 2009; UNECE, 2013). Such problems are expected to worsen under the projected increases in the extent/depth of permafrost thaw (EEA, 2015). Increased ground freeze-thaw cycles can also damage coastal transportation infrastructure. In Canada, for example, freeze-thaw cycles changes have caused damages to airport runways/taxiways and roads (Palko, 2017).

Extreme winds and waves can be also catastrophic, as they can cause coastal erosion, port and coastal defence overtopping, and flooding of the coastal transportation infrastructure. Extreme winds can result in infrastructure failures and operational interruptions through wind-generated debris, vehicle and railcar blow-overs, rail track and road obstructions from e.g. fallen power lines/trees, grounding of aircraft and inability to operate port equipment (e.g. cranes). (PIARC, 2012; UNECE, 2019).

Costs and economic losses arising from damage to infrastructure, as well as from operational disruptions and delay across closely interconnected global supply chains may be extensive. This is illustrated by some of the studies that have provided some cost estimates. A study by Lenton et al. (2009), which included tipping points in the climatic forcing, estimated that, by 2050, asset exposure to flooding in 136 port megacities will be close to 28 trillion US$. Hoshino et al (2016) estimated inundation levels and potential costs under the combined mean sea level rise and typhoon storm surges for the Tokyo Bay area and found that costs could be crippling (up to US$ 690 billion in today's values). A recent study indicates that, by 2100, global flood damages due to sea level rise (and related extreme events) might amount to up to US$ 27 trillion per year – or about 2.8 per cent of 2100 global GDP (Jevrejeva et al., 2018).

In areas affected by tropical cyclones and related storm surges and waves, damages to the coastal infrastructure and associated losses can be staggering. In 2017, total damages of the Caribbean hurricane season were estimated as US$ 320 billion (WMO 2018), with Dominica's damages/losses assessed to be in excess of 200 per cent of its Gross Domestic Product (GDP) (Gov. Dominica, 2017). The total cost of impacts/effects of the 2019 Hurricane Dorian on the Bahamas has been estimated at US$ 3.4 billion, with hundreds dead/missing, and impacts on the economy that will last for years (IDB, 2019). A large fraction of these damages/losses often arise as a result of impacts on transport infrastructure. For example, Hurricane Sandy caused a week-long shut-down of large US container port in 2012, with overall damages/losses estimated at US$ 30 – 50 billion (EQECAT Inc., 2012).

Table 2.1 Major impacts on coastal transportation infrastructure and operations from changing climatic factors and hazards. Lists are not exhaustive. For details, see also Asariotis et al. (2017) and UNECE (2019)

Factor/hazard	*Seaports*	*Coastal Airports*	*Coastal roads, railways and IWWs*
Sea level: Mean sea level rise (SLR)	Increased risk of permanent inundation of facilities making seaports inoperable without major upgrades (port elevation, coastal protection); changes in port access; effects on key transit points (e.g. the Kiel Canal); major insurance issues	Inundation of runways and other pavements requiring major upgrades; major insurance issues	Increased inundation and erosion damages for coastal road and rail networks; potential changes in IWW water levels; insurance issues
Increased extreme sea levels (ESLs); changes in wave energy/direction	Increasing frequency/depth of infrastructure inundation; chronic flooding and damages to port facilities; increased losses due to operational delays; increased costs of port protection; navigation channel sedimentation; higher dredging requirements; insurance issues	Increasing frequency and depth of inundation, resulting in damage to runways and buildings; flight cancellations and delays; insurance issues	Structural damages to coastal roads; pavement damages due to inundation and/or wave attack; temporary inundation that can render the roads unusable resulting in costly delays and traffic diversions; Structural damages to coastal railways, embankments and earthworks; restrictions/disruption of rail operations
Precipitation: Changes in mean values and/or in the intensity, type and frequency of extreme events causing riverine and pluvial flooding or droughts	Infrastructure inundation and damages; poor maneuverability of locks and vessels due to suddenly increased water level/speed; poor visibility from increasing fogs	Flooding of airport runways and taxiways; damage to airport structures/equipment; decreased traction on runways; increased de-icing for runways and aircraft in snowstorms	Inundation, damages/wash-outs of roads and bridges; landslides; bridge scouring; earthwork and equipment failure; poor visibility causing accidents; reduced vehicle traction; drainage system/tunnel issues; rail embankment, earthwork and culvert damages; delays; changes in demand; under droughts, navigational restrictions in IWWs due to diminished river water levels
Temperature: Higher mean temperature; heat waves; droughts; changes in warm and cool days	Deterioration of paved areas; inoperable cranes; navigational equipment and cargo damages; higher energy consumption for cooling; health/safety issues for personnel and passengers	Pavement deterioration and buckling of runways and taxiways; higher energy consumption for cooling; payload restrictions- reduced lift; runway extensions; health/safety issues; lower heating costs	Asphalt rutting; thermal damage to bridges; rail track buckling and rolling stock failures; rail speed restrictions; increased landslides; asset lifetime reduction; increased needs for cooling (passenger and freight); health and safety issues; shorter summer construction and maintenance windows and increased costs; changes in demand; water level changes with water affecting inland waterways
Reduced arctic snow cover and ice	New arctic shipping routes, longer seasons and lower fuel costs; reductions in snow/ice removal costs; but arctic seaports will face increasing sea storm hazards	Longer construction and maintenance periods; reductions in snow/ice removal costs	Longer construction/maintenance periods; reductions in snow/ice removal costs; reduced integrity of winter ice roads; potential gains in arctic river navigability
Permafrost degradation and thawing	Ground subsidence, slope instability and drainage issues, affecting the structural integrity	Deterioration of the infrastructure structural integrity	Increased deteroration of the structural integrity and load-carrying capacity of road, rail and IWW infrastructure
Wind: Changes in frequency and intensity of exteme events	Damage to terminals and navigation equipmentl; problems in vessel navigation and berthing with ports; problems with crane operations above certain wind speeds	Damages to terminals and aircraft from debris; cancellations/delays due to high winds with cross wind components	Damages to road/rail fences; increased accident risks, damages to road structures, signage and traffic signals; debris, obstructions for roads/rail tracks by fallen power lines/trees and other debris; bridge closures; overvoltage; rail car blow-overs; operational disruptions

The most affected infrastructure sectors by Hurricanes Irma and Maria in the British Virgin Islands were roads, airports and ports, with related estimated damages/losses of US$ 252 million or about 55 per cent of the country's GDP (UNECLAC, 2018); the associated disruptions in Miami and Atlanta airports affected about US$ 245 million worth of air cargo per day and resulted in revenue losses of US $75 – 85 million per day (IATA, 2017).

2.2 Climate variability and change (CV&C): Trends and projections

In this Section, a brief overview of the observed trends and projections of those climatic changes that can impact on coastal transportation infrastructure is presented.

Sea level rise and waves

A major effect of the global warming is the mean sea level rise (SLR)[9]. Since 1860, the global sea level has increased by about 0.2 m, with a discernible acceleration in the last decades, for which satellite and tide gauge observations suggest a global average SLR of 3.3 ± 0.25 cm per decade (Hansen et al., 2016). SLR has recently accelerated further to more than 4.0 cm per decade (WMO, 2019), a trend that has been mainly attributed to continental ice melting (Rignot et al., 2019). There is considerable regional (spatial) variability, with some regions showing higher SLR than others (IPCC, 2019). Sea level rise will continue for centuries beyond 2100 (Jevrejeva et al., 2012).

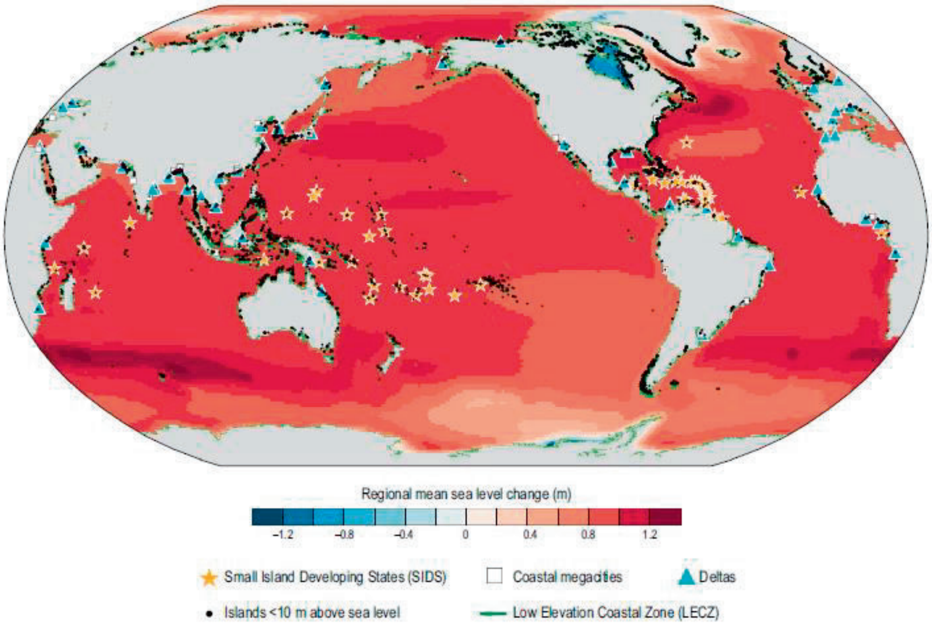
Model projections of the future mean sea levels are constrained by uncertainties in the ocean thermal response to the increasing global warming and the behaviour of the large continental ice sheets of Greenland and Antarctica (Hansen et al., 2016; Cheng et al., 2019; Rignot et al., 2019). In any case, high spatial variability is projected (Fig 2.1). SLR projections are continuously upgraded/revised upwards. In the IPCC AR5 report, mean sea level rise for 2100 was projected to be between 0.26 and 0.98 m relative to the mean of the 1986 - 2005 period, depending on the climatic scenario (IPCC, 2013). In the latest IPCC report (2019), however, these projections have been revised upwards to 0.29 and 1.10 m, respectively (IPCC, 2019). It is noteworthy that the IPCC has consistently provided conservative estimates, with other published projections often being considerably higher (Asariotis et al., 2017).

Coastal transport infrastructure/operations can also be severely impacted by waves and the extreme sea levels (ESLs). Camus et al. (2017) have provided global multi-model projections for the wave conditions under CV & C that show future increases in the annual mean significant wave height[10] in the Southern and the eastern Pacific Oceans and decreases in the north Atlantic, the north-western Pacific and the Indian Oceans, with the magnitude of the increases being about four times higher than those of the decreases. Generally, significant increases (up to 30 per cent) have been projected for the extreme coastal wave energy fluxes, an important seaport design parameter, for most southern temperate coasts as well as for the northeastern Pacific and the Baltic Sea coasts, with wave direction changes also predicted for some regions (Mentaschi et al., 2017).

[9] SLR is caused by the combination of (Hanna et al., 2013): (i) ocean thermal expansion due to the increase of the ocean heat content; (ii) ocean water mass increases from the melting of the continental Greenland and Antarctic ice sheets, glaciers and ice caps; (iii) isostatic adjustment; and (iv) changes in land water storage.

[10] Annual significant wave height (Hs) is the mean of the highest one third of the waves recorded each year.

Figure 2.1 Global distribution of low-lying islands and coasts particularly at risk from sea level rise. Source: IPCC, 2019, Cross-Chapter Box 9: Integrative Cross-Chapter Box on Low-lying Islands and Coasts

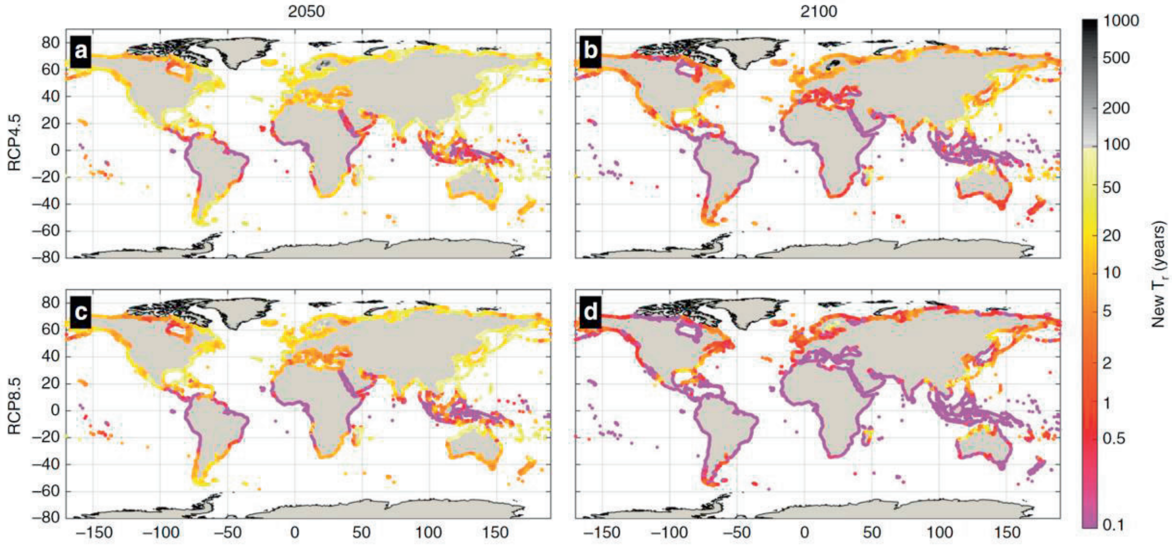


The gradual (slow onset) mean sea level (SLR) will combine with the future extreme tides, storm surges and waves and generate extreme sea level (ESL) events that can have devastating coastal impacts. Extreme sea levels are set to increase almost everywhere (Losada, et al., 2013; IPCC, 2019). ESL events of certain magnitude that currently have a low recurrence frequency in a location will become more frequent in the future (Vousdoukas et al., 2018). As the recurrence frequency/return period[11] of extreme sea levels (and associated waves) form fundamental parameters of the design of coastal defences for coastal (transport) infrastructure, the impacts and choice/design of effective adaptation options should be considered on the basis of future projections of the return periods of ESLs of certain magnitude.

By 2050, recent projections (Vousdoukas et al., 2018) suggest that at the global level, the mean return period of the baseline extreme sea level (the average for the period 1980 - 2014) will be occurring about every 20 and 30 year respectively, with the largest changes expected for the African, South American and the Mediterranean coasts (Fig. 2.2). The changes will be much greater by 2100, when many coasts will experience extreme sea levels having the baseline 1-100 year event magnitude many times every year under RCP8.

[11] The return period of an extreme event is a probabilistic measure. It shows how many times an event of a certain magnitude will appear in a time period. Infrastructure is (commonly) designed to be relatively resilient to events with a magnitude that can appear once in 100 years (the 1-100 year event).

Figure 2.2 Future frequency of the present day 1 in a 100 years ESL. Colors show the return period of the present day 100-year ESL under RCP4.5 and RCP8.5 in 2050(a,c) and 2100 (b,d), based on the median values. Note that the color scale is not linear (Vousdoukas et al., 2018).



Precipitation

Global land rainfall data show an increasing trend, especially in middle and high latitudes (Schneider et al., 2017). Precipitation shows a high natural variability as it can be strongly influenced by e.g. the El Niño-Southern Oscillation (ENSO). It is expected to change in a complex manner, with increases in precipitation projected for some regions and droughts for others (IPCC, 2013; 2018). Widespread droughts have been projected for most of southwestern North America for the mid to late twenty-first century, whereas, by comparison, Central Europe, the Mediterranean and parts of North America are projected to show shorter and lighter droughts (IPCC, 2018).

Increases in the frequency/intensity of downpours has been observed in many regions. Hazards connected to heavy precipitation events like slope failures and landslides have also increased in mountainous areas (Karl et al., 2009). Downpours are projected to be more intense over most of the mid-latitude and wet tropical regions (IPCC, 2013; 2018). High resolution climate models indicate that extreme seasonal rainfalls could also intensify under climate change. In the United Kingdom, for instance, although summers will become drier overall, heavy summer downpours (i.e. more than 30 mm rainfall in an hour) could increase approximately five-fold (MetOffice, 2014). River flooding caused by sustained, above average, precipitation and/or strong downpours is already a severe and widespread hazard for transportation infrastructure (Koks et al., 2019); under climate change, the flood hazards and damages are projected to increase in many regions (e.g. Alfieri et al., 2018).

Temperature

Globally-averaged, near-surface atmospheric temperature has increased by almost 1.1 °C since the pre-industrial times (IPCC, 2019). Ocean temperatures also show significant increases in heat content (Dieng et al., 2017) that has resulted (amongst others) in their thermal (steric) expansion. The last 5 year period has been the warmest in record, with observations being consistent with a steady trend in global warming superimposed on random, short-term variability (WMO, 2018). Temperature does not, and will not, change uniformly. Temperatures have risen faster close to the poles. The mean near surface atmospheric temperature is projected to increase by 1.0 – 3.7 °C (mean estimates) until the end of the century, depending on the GHG concentration scenario. Oceans will also warm, with most changes projected to occur in the upper ocean (IPCC, 2013).

Although there are uncertainties concerning the future development of the Greenland and Antarctic ice sheets, global warming is expected to affect negatively their mass balance (IPCC, 2019). The snow cover extent has decreased since the 1950s across the northern hemisphere which contains about 98 per cent of the global snow cover. Arctic sea ice is in decline with further decreases projected for the future, which will however show considerable inter-annual variability. Minimum Arctic sea ice extent has declined by about 40 per cent since 1979, with the greatest ice minima having occurred in the last decade (NOAA, 2017). By 2081 – 2100, reductions in sea ice extent up to about 34 and 94 per cent are projected for February and September, respectively, relative to the 1986- 2005 average (IPCC, 2013; 2019).

There has also been a reduction in the thickness of the northern hemisphere permafrost by 0.32 m since 1930 (IPCC, 2013), causing thawing and ground instability. Accelerated permafrost thawing is projected for the future, due to rising temperatures and changes in the snow cover; permafrost extent is expected to decrease by up to 80 per cent by the end of the century, depending on the emissions scenario (IPCC, 2013; 2019). Permafrost thawing will severely challenge the construction and maintenance of transport infrastructure and could constrain the development of transport networks that could take advantage of the new Arctic shipping routes (UNECE, 2019).

With regard to extreme temperature events, observations show increases in the frequency and intensity of heat waves (e.g. IPCC, 2013; WMO, 2018), with most models projecting further increases in the occurrence of very hot summers and heat waves during the century (Coumou and Robinson, 2013; IPCC, 2018). Greater changes in hot (seasonal) extremes are expected for the subtropics and the mid-latitude regions, whereas the frequency of cold events will decrease in all regions.

The combination of extreme heat with high relative humidity may have severe implications for the health and safety of personnel/passengers in most modes of transport. Recent projections (Mora et al., 2017) indicate very substantial increases in the number of days per year exceeding a 'deadly temperature and humidity threshold' by 2100, which will be particularly severe under the RCP8.5 emission scenario. While currently nearly one-third of the world's population is regularly exposed to climatic conditions surpassing this deadly threshold, by 2100, almost three-quarters of the world's human population could be exposed to deadly climatic conditions under high future emissions (RCP 8.5); the situation is projected to be particularly severe in the tropics and sub-tropics.

Windstorms

The annual incidence of storms has not changed with time (WMO, 2018). However, as severe tropical and extra-tropical storms, are fed by the increasing upper ocean heat content, it is expected that storm intensity will increase under climate change (e.g. Emanuel, 2005; Trenberth et al., 2018; WMO, 2018). Tropical and extra-tropical storms are usually associated with extreme winds, rainfall and coastal flooding that can have severe impacts on coastal transport infrastructure (e.g. Becker et al., 2013). It should be noted that storms can induce combined damages, such as those from fluvial/pluvial and marine flooding and high wind damages (Koks et al., 2019; IPCC, 2019).

2.3 Climate risk assessment and adaptation for coastal transport infrastructure

In the light of recent projections and given the potential for a broad range of impacts, all stakeholders involved in coastal transport infrastructure planning, development and operations will need to take into account the effects of climate variability and change as part of their decision-making processes. Collaboration and participation of a broad range of actors will be of particular importance, both in relation to the assessment of impacts and in the planning, development and implementation of effective adaptation measures. While many coastal transport assets are owned/operated by private actors, public authorities retain a pivotal role in providing the right regulatory and policy framework to facilitate an enabling environment that promotes climate change adaptation for coastal transport networks and assets. Other institutions, such as financial institutions and the insurance industry, also have an important role to play.

Approaches to adaptation of coastal transport infrastructure will differ depending on the type of hazard: (a) episodic hazards due to extreme events and (b) slow-onset hazards, such as permanent facility flooding by SLR or the effects of permafrost thawing. These different types of hazards require different responses and technological considerations. The former requires risk reduction solutions including coastal protection works, whereas the latter requires long-term risk retention and resilience building; this in turn will require effective regulatory response measures that integrate/adapt the existing regulatory and policy frameworks which include national adaptation plans, various disaster risk reduction instruments and coastal zone planning policies.

Efficient adaptation and resilience building for coastal transport infrastructure and operations depends on the assessment of the risks posed by climate variability and change. Assessments are determined by the spatio-temporal scale and resolution and the available information (UNECE, 2019; Koks et al., 2019). Global and/or continental-scale assessments can inform the development of global and/or multi-national adaptation policies and regulation, whereas those at the national/regional scale can assist in the planning of national and regional adaptation policies and improve the efficiency of the allocation of the available human and economic resources. Finally, assessments at the local (facility) level are necessary to support on-the-ground decisionmaking and the design of requisite adaptation measures.

Risk assessments of coastal transport infrastructure consist of different constituent assessments. First, *assessments of the climatic hazards* induced by the changing climatic factors. Secondly, *assessments of the exposure* of the transport infrastructure/operations present in the hazard zones. Finally, *assessments of the vulnerabilities* that make transportation assets and systems susceptible to damages and losses from coastal hazards; these in turn are controlled by the availability of technolologies and materials for the requisite coastal protection and/or asset elevation, the human and financial resources and the effectiveness of governance, regulation and management (Hinkel et al., 2014; Wong et al., 2014).

In recent years, various approaches to risk assessments have appeared, which are based on significant developments in relevant observation technologies and tools (e.g. Yamazaki et al., 2017; Giuliani et al., 2017), and improved, integrated models to project future hazards and risks (Vousdoukas et al., 2016; 2018; Alfieri et al., 2017; Rueda et al., 2017; Paprotny et al., 2018; Bove, G., et al., 2020). On the basis of such risk assessments, the probability of a damaging climatic event and the severity of its impacts can be determined. The urgency of the adaptation responses can then be defined as the ratio between the time needed to plan/implement effective responses over the time available (Lenton et al., 2019).

Climate change adaptation of coastal transport infrastructure may involve the construction of new resilient infrastructure, in addition to measures to enhance the resilience of existing infrastructure, involving both ‘soft’ and ‘hard’ adaptation measures. This requires a shift in the planning paradigm that can address various challenges. These include, among others: (i) lack of awareness of climate-change impacts as well as of localized climate information, especially in small transportation assets; (ii) mismatches between the time-frames for facility planning, the infrastructure lifetimes and the climatic factor projections which are characterised by inherent uncertainties; (iii) lack of adequate funding; iv) not fit-for-purpose regulation with sometimes competing priorities; (v) constraints relating to research and technology; and (vi) lack of technical expertise and human capacity (UNCTAD, 2011b).

There is no single approach to climate change adaptation planning due to the diverse, complex and context-dependent nature of adaptation (IPCC, 2014). A variety of tools and approaches are already being employed, including the widespread use of engineering and technological options. In addition, there is an increasing recognition of the need for social, institutional and ecosystem-based adaptation mechanisms for the purposes of climate change adaptation in general. Legal/regulatory approaches have an important role to play to create the right enabling environment. Standards, guidance, and methodological tools for organizations are also of key importance. Examples presented in this document may support and inspire adaptive action for the coastal transport sector worldwide.

3. Examples of legal and regulatory approaches relevant for climate change impacts and adaptation for coastal transport infrastructure

Successful adaptation strategies need to be underpinned by strong legal and regulatory frameworks. Whilst there are many legal fields that will be impacted by the need to adapt to climate change, this Chapter presents select examples of international, regional and national legal and regulatory instruments that may be considered relevant for the assessment of climate change impacts/risks and the development of adaptation measures for coastal transport infrastructure.

Regulation may play a role in helping to reduce exposure or vulnerability to climate-related risks of coastal transport infrastructure, as it can assist in preventing or minimizing the negative impacts of slow onset events in addition to preventing, mitigating and recovering from extreme weather-related disasters. Strengthening disaster risk resilience of coastal transport infrastructure is of key importance where legal and regulatory instruments may drive pro-active initiatives. Given that ports form complex systems and large ports are usually linked to coastal urban agglomerates, planning frameworks can play a particular role as facilitators of climate change adaptation (e.g. mainstreaming climate change adaptation, requiring climate risk-assessments etc.), in addition to natural resource management schemes and biodiversity conservation structures (e.g. eco-system-based adaptation etc.). Legal and regulatory tools may further provide an economic incentive to fund climate change adaptation efforts, promote the transfer of adaptation technologies and contribute to the availability of accurate and indispensable climate data at local level as well. They are also key in ensuring accountability, public participation and non-discrimination in adaptation-related decision-making processes.

At the same time, it is of major importance that legal and regulatory approaches do not – even inadvertently – foster 'maladaptation' that may limit or lock-in future adaptation options. The inherent uncertainty with regards to climate change adaptation coupled with the long-term time frame of related investment decisions, may pose particular challenges. Legal and regulatory frameworks, therefore, need to allow for reversible and flexible adaptation response options and, at the same time, account for potentially irreversible changes.

As ports are generally associated with a range of environmental effects, the first Section of the Chapter describes how the international community has dealt with various aspects of environmental law that may be relevant for climate change impacts and adaptation for coastal transport infrastructure. These international conventions are not specifically designed to address climate change impacts but may be important in the development of climate change adaptation-related actions, in addition to providing important environmental safeguards at domestic level in ratifying countries. The second Section of the Chapter presents some legal instruments at regional and national levels, using examples from around the world that showcase potential approaches to address the diverse aspects of climate change impact/risk assessments and adaptation for coastal transport infrastructure.

Legal and regulatory instruments presented in this chapter are to be considered as illustrative examples only. They are by no means exhaustive but illustrate a range of approaches that may contribute to climate change adaptation efforts for coastal transport infrastructure. Further information on legal and regulatory sources of relevance in this context may also be found in the database of the Grantham Research Institute on Climate Change and the Environment: 'Climate Change Laws of the World'.

3.1 International Conventions

There are various international conventions that may be of relevance for climate change impacts/risks assessment and adaptation for coastal transport infrastructure (Table 3.1). The world's oceans are governed by the UN Convention on the Law of the Sea, 1982 which, *inter alia*, sets out provisions of general relevance to the protection of the marine environment. Climate change is specifically addressed in the UN Framework Convention on Climate Change (UNFCCC), 1992 and its 1997 Kyoto Protocol, as well as the Paris Agreement, 2015.[12] In addition, there are several international instruments that address a range of environmental aspects potentially affecting climate change adaptation efforts for coastal transport infrastructure. These include, *inter alia*, the Convention on Biological Diversity, 1992; the Espoo Convention on Environmental Impact Assessment in a Transboundary Context, 1991; the Ramsar Convention on Wetlands, 1971; the Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental, 1991; and the Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean, 1995.

Table 3.1 Examples of International Conventions of relevance to climate change impacts and adaptation for coastal transport infrastructure

Treaty	Objectives	Comments
UNFCCC 1992* (Entry into force: 21/03/1994)	The ultimate objective is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.	The United Nations Framework Convention on Climate Change (UNFCCC) provides the foundation for climate change action at international level. It calls on the developed countries and Annex I Parties to take measures on climate change mitigation by cutting their anthropogenic emissions of greenhouse gases (GHG) and enhancing sinks and reservoirs. The Convention acknowledges the vulnerability of all countries to the effects of climate change and lays the ground for climate adaptation efforts at the international level. The Convention also establishes a financial mechanism for developing countries to assist them in their actions; and requires Parties to e.g. develop a national inventory of greenhouse gas emissions, report on mitigation policies and measures, cooperate in preparing for climate change adaptation and adopt programmes containing measures on climate change mitigation and adaptation. Parties carry out climate adaptation related activities in several work streams, work programmes and in specialized groups and committees. These include: National adaptation programmes of action (NAPAs); National Adaptation Plans; Adaptation Committee; Least Developed Countries Expert Group (LEG); Nairobi work programme (NWP); and Technical Examination Process on Adaptation.
Kyoto Protocol 1997** (Entry into force: 16/02/2005)		The Kyoto Protocol is an international agreement negotiated under the auspices of the UNFCCC, which commits Annex I Parties to setting binding emission reduction targets. It also establishes different mechanisms to enable States to achieve their targets: i) clean development mechanism (investment in emission reduction or removal enhancement projects in (mostly) developing countries); ii) emissions trading mechanism (acquiring emission units from other countries to meet domestic targets); iii) joint implementation (take part in emission-reduction or removal in another country).

[12] It should be noted that efforts at reducing GHG emissions from international shipping are dealt with under the auspices of the International Maritime Organization (IMO). For an overview of latest developments, see UNCTAD, Review of Maritime Transport, 2019, Ch. 4.

Paris Agreement 2015*** (Entry into force 4/11/2016)		During the first commitment period, 37 industrialized countries and the European Community committed to reducing GHG emissions to an average of five per cent against 1990 levels. During the second commitment period, Parties committed to reducing GHG emissions by at least 18 per cent below 1990 levels in the eight-year period from 2013 to 2020. GHG reduction efforts from international shipping and aviation are not covered by the Kyoto Protocol. The Paris Agreement specifies a long-term temperature goal to keep the global temperature rise below 2°C above pre-industrial levels and pursue efforts to limit the increase to 1.5°C. It requires all Parties to put forward their best efforts through nationally determined contributions (NDCs) and to strengthen these efforts in the years ahead. In addition: - The Paris Agreement aims to strengthen the global climate change response by increasing the ability of all to adapt to adverse impacts of climate change and foster climate resilience. It defines a global goal on adaptation: i) to enhance adaptive capacity and resilience; ii) to reduce vulnerability, with a view to contributing to sustainable development; and ensuring an adequate adaptation response in the context of the goal of holding average global warming well below 2 degrees C and pursuing efforts to hold it below 1.5 degrees C. - The Agreement requires all Parties to engage in adaptation planning and implementation through e.g. national adaptation plans, vulnerability assessments, monitoring and evaluation, and economic diversification. - All Parties should communicate their priorities, plans, actions, and support needs through adaptation communications, which shall be recorded in a public registry and are subject to collective review mechanisms.
		*United Nations Framework Convention on Climate Change Status (as of November 2019): Signatories: 165. Parties: 197 **Kyoto Protocol to the United Nations Framework Convention on Climate Change Status (as of November 2019): Signatories: 83. Parties: 192 ***Paris Agreement Status (as of November 2019): Signatories: 195. Parties: 187 For further information: http://treaties.un.org/Pages/ParticipationStatus.aspx
United Nations Convention on the Law of the Sea 1982* (Entry into force: 16/11/1994)	Comprehensive global legal regime for the marine environment.	The United Nations Convention on the Law of the Sea lays down a comprehensive regime of law for the world's oceans and seas establishing rules governing all uses of the oceans and their resources. - It contains provisions applicable to the marine environment, and therefore of relevance for coastal transport infrastructure, in particular the obligation to preserve and protect the marine environment and conducting marine scientific research. - It establishes/delimits Maritime Zones; details rights and responsibilities of the Coastal State with regard to exploring, exploiting, conserving and managing the natural resources, the establishment of offshore installations and structures, marine scientific research and the environmental protection and preservation of marine environment; prescribes transboundary obligations; provides for a global framework to manage the seas and oceans and establishes guidelines and/or procedures for economic and commercial activities, scientific research and the settlement of disputes; and prescribes a general obligation to protect and preserve the marine environment. - Contracting Parties shall take measures to prevent, reduce and control all type of pollution of the marine environment, prevent accidents and deal with emergencies.
		*United Nations Convention on the Law of the Sea Status (as of November 2019): Signatories: 157. Parties: 168 For further information: http://treaties.un.org/Pages/ParticipationStatus.aspx

Convention on Biological Diversity 1992* (Entry into force: 29/12/1993)	Conservation of biological diversity; sustainable use of its components; and fair and equitable benefit sharing of genetic resources.	The Convention on Biological Diversity establishes a global legal regime for the conservation of biological diversity. There are important inter-linkages between climate change and biodiversity, as climate change impacts may negatively affect biodiversity. At the same time, biodiversity, through the ecosystem services, may also contribute to climate-change mitigation and adaptation efforts. Ecosystem-based adaptation uses biodiversity and ecosystem services in an overall adaptation strategy. Consequently, conserving and sustainably managing biodiversity is critical to addressing climate change. Contracting Parties of the Convention shall (among others): ensure that activities within their jurisdiction/control do not cause damage to the environment of other States; develop national conservation strategies, plans or programmes; identify/monitor components of biological diversity that are important for conservation; establish a system of protected areas; regulate/manage biological resources important for biodiversity conservation; promote environmentally sound and sustainable development; rehabilitate/restore degraded ecosystems; prevent the introduction of, control or eradicate alien species that threaten ecosystems, habitats or species; integrate considerations of biological resource conservation and sustainable use into national decision-making; establish/maintain programmes for relevant scientific and technical education and training; promote/encourage research contributing to conservation; introduce appropriate procedures requiring environmental impact assessment for proposed (coastal) projects.
		*Convention on Biological Diversity Status (as of November 2019): Signatories: 168. Parties: 196 For further information: http://treaties.un.org/Pages/ParticipationStatus.aspx
Espoo Convention on Environmental Impact Assessment in a Transboundary Context 1991*(UNECE) (Entry into force: 10/09/1997) Espoo Protocol on Strategic Environmental Assessment 2003(UNECE) (Entry into force: 11/07/2010)	To assess environmental impacts in a transboundary context. To assess early transboundary SEAs.	The Espoo Convention on Environmental Impact Assessment in a Transboundary Context sets out obligations for environmental impact assessments (EIAs) of certain activities at the planning stage. - It also prescribes a general State Party obligation to notify/consult with other states on all major projects that can have significant adverse transboundary impacts as well as prescribes post-project monitoring requirements. - Whilst negotiated under the auspices of United Nations Economic Commission for Europe (UNECE), the Sofia Amendment 2001 (entered into force in 2014) allows non-UNECE, UN member States to join the Convention. *"Strategic environment assessment can be an effective tool for climate change adaptation and mitigation, by introducing climate change considerations into development planning"*. The Espoo Convention on Environmental Impact Assessment in a Transboundary Context has been supplemented by a Protocol on Strategic Environmental Assessment (SEA): - The protocol requires its Parties to evaluate the environmental consequences of their official draft plans and programmes and prescribes integration of EIAs into plans/programmes at the earliest stage. - It further provides for Strategic Environmental Assessments (SEAs) and for extensive public participation in the governmental decision-making in numerous development sectors. - Although negotiated under the auspices of UNECE, the Protocol is open for accession to all UN members.
		*Convention on Environmental Impact Assessment in a Transboundary Context Status (as of November 2019): Signatories: 30. Parties: 45 For further information: http://treaties.un.org/Pages/ParticipationStatus.aspx
RAMSAR 1971 Convention* (Entry into force: 21/12/1975)	Framework for national action and international cooperation for the conservation	The Convention on Wetlands (Ramsar, Iran, 1971) is an inter-governmental treaty with the following mission: - "The conservation and wise use of all wetlands through local and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world".

	and wise use of wetlands and their resources.	- To this end, contracting Parties have the following obligations (among others): designate wetlands (riparian, coastal and marine with water depths > 6 m at low tide) on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology for inclusion in a *List of Wetlands of International Importance*; formulate/implement wetland conservation planning; establish nature reserves in wetlands; encourage relevant research and information exchange; consult with each other about implementing obligations, especially in the case of shared wetlands. - Wetlands have an important role to play in climate adaptation, as wetlands make communities more resilient to the impacts of climate change. They provide buffers against sea level rise and storm surges, and reduce the impacts of floods, droughts and cyclones. Therefore, preserving wetlands are of particular importance for enhancing the resilience of coastal transport infrastructure.
		*Convention on Wetlands Number of Contracting Parties (as of November 2019): 171 For further information: https://www.ramsar.org/sites/default/files/documents/library/annotated_contracting_parties_list_e.pdf
Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters 1998* (UNECE) (Entry into force: 08/10/2009)	To guarantee the rights of access to information, public participation in decision-making, and access to justice in environmental matters.	The UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters provides a framework for fostering transparency in climate change-related decision-making at international level. The Convention adopts a rights-based approach. The following three legal rights are at the core of the Convention: - Right of access to environmental information - Right to participate in decision making in environmental matters - Right of access to justice in environmental matters. The Convention: - *"Links government accountability and environmental protection"* - *"Focuses on interactions between the public and public authorities in a democratic context"* - *"Establishes that sustainable development can be achieved only through the involvement of all stakeholders"* - *"Acknowledges that we owe an obligation to future generations"* - *"Links environmental rights and human rights*". Whilst the Convention was negotiated in the UNECE region, it is open for accession by all UN Member States.
		*Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters Number of Signatories (as of November 2019): 39. Parties: 47 For further information: https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-13&chapter=27&clang=_en#1
Barcelona Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean 1995*	Promotion of environmental protection and integration in the Mediterranean	The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention, as amended in 1995) is a key instrument for the protection of the environment in the Mediterranean region. Obligations of contracting Parties in protecting the environment as defined by the Convention include: - Application of the pre-cautionary principle - Application of the polluter pays principle - Undertaking environmental impact assessments for activities that are likely to cause significant adverse impact on the marine environment. In 2008 a Protocol was developed to provide a common framework for the Contracting Parties to promote and implement integrated coastal zone management. The Protocol

(Entry into force: 09/07/2004) **Protocol on Integrated Coastal Zone Management**** (Entry into force: 24/03/2011)		addresses the following key themes: i) objectives and general principles of integrated coastal zone management; ii) elements and instruments for integrated coastal zone management; as well as iii) risks affecting the coastal zone, including natural hazards, coastal erosion and responses to natural disasters; and iv) international cooperation. Inter alia, Art. 8 envisages a 100m set-back zone "*as from the highest winter waterline … where construction is not allowed*" subject to very limited exceptions, "*taking into account … the areas directly and negatively affected by climate change and natural risks*".
		***** Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean Number of Contracting Parties (as of November 2019): 22 For further information: http://wedocs.unep.org/bitstream/handle/20.500.11822/7096/Consolidated_BC95_Eng.pdf?sequence=1&isAllowed=y * * Protocol to the Barcelona Convention on Integrated Coastal Zone Management Number of Signatories (as of November 2019): 15. Parties: 12 For further information: https://web.unep.org/unepmap/8-iczm-protocol

<u>Sources and additional information</u>:

- *United Nations Framework Convention on Climate Change*, available at: https://unfccc.int/
- United Nations Framework Convention on Climate Change (UNFCCC), *What do adaptation to climate change and climate resilience mean?* Available at: https://unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean
- *United Nations Convention on the Law of the Sea*, available at: http://www.un.org/depts/los/convention_agreements/texts/unclos/UNCLOS-TOC.htm
- *Convention on Biological Diversity*, available at: https://www.cbd.int/convention/text/
- *Climate Change and Biodiversity*, available at: https://www.cbd.int/climate/
- *Espoo Convention on Environmental Impact Assessment in a Transboundary Context Convention 1991*, available at: https://www.unece.org/env/eia/eia.html
- *Climate change and the Protocol on Strategic Environment Assessment (SEA),* available at: http://www.unece.org/fileadmin//DAM/env/eia/about/climate.html
- *The Ramsar Convention and its mission*, available at: https://www.ramsar.org/about/the-ramsar-convention-and-its-mission
- *An Introduction to the Ramsar Convention on Wetlands*, 7th ed. (previously The Ramsar Convention Manual). Ramsar Convention Secretariat, Gland, Switzerland, available at: https://www.ramsar.org/sites/default/files/documents/library/handbook1_5ed_introductiontoconvention_final_e.pdf
- *Wetlands and Climate Change*, available at: https://www.ramsar.org/news/wetlands-and-climate-change
- The full text of the *UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters* (Aarhus Convention) is available at: https://www.unece.org/env/pp/treatytext.html
- *The Aarhus Convention: An Implementation Guide* (second edition), Published: June 2014, available at: http://www.unece.org/index.php?id=35869&L=0
- *Mediterranean Action Plan / Barcelona Convention – Overview*, available at: https://web.unep.org/unepmap/resources/info-kit

3.2 Legal and regulatory approaches at regional and national level

Whilst adaptation to climate change in general has been receiving growing attention from regulators at the international, regional and national level, climate change impacts and adaptation for coastal transport infrastructure has been somewhat less at the forefront of legal and regulatory efforts so far. Mainstreaming climate change adaptation requirements into relevant domestic legislation may be employed to facilitate the process. Whilst several areas of law and regulation could be targeted (e.g. laws regarding marine and coastal management, nature conservation, water resource management etc.) with a view to enhancing the climate resilience of coastal transport infrastructure, laws dealing with the built environment, building standards and spatial planning regulations are key instruments. In that context, modifying technical requirements to account for climate change in coastal transport infrastructure-related regulations as well as requiring the assessment of climate-related impacts by seaports and airports may be encouraged by regulators.

This Section highlights some legislative approaches from around the world that may be of relevance for climate change impact/risk assessment and adaptation efforts for coastal transport infrastructure. An interesting example is offered by the European Union (Directive 2014/52/EU) that requires mandatory consideration of climate change in environmental impact assessments with potential major consequences at national level planning regulations affecting seaports and airports in 28 countries. In addition, this Section presents further domestic examples that may stimulate reflection on legislative action in relation to climate change adaptation for coastal transport infrastructure: i) Requiring climate risk disclosure by port authorities (United Kingdom); and ii) Requiring current and future impacts of climate change to be taken into account by state agencies in relation to infrastructure in addition to fostering collaboration between the scientific community and infrastructure projects with a view to integrate scientific data on projected climate change impacts into state infrastructure engineering (United States).

Directive 2014/52/EU amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment

Country/Region: European Union

Date: 2014

✓ Mandatory consideration of climate change in Environmental Impact Assessments in the European Union

✓ Applies to transport infrastructure, such as ports and airports

The European Union's (EU) *Directive 2014/52/EU* is a legislative instrument on environmental impact assessments (EIA). All EU Member States are required to give effect to the Directive through appropriate domestic legislation. This Directive, amending the initial EIA Directive (consolidated in 2011), is in force since 2014 and had to be transposed into national legislation in EU Member States by May 2017. It was adopted in the light of emerging challenges faced by the EU in various areas, including climate change, with the intent to simplify EIAs "*without weakening existing environmental safeguards*" contained in the initial Directive. The instrument applies to a variety of public and private projects, including construction of transport infrastructure, such as airports and ports. As a result of the 2014 amendment to the EIA Directive, climate change and disaster prevention are better reflected in the EIA process within the European Union.

The EIA Directive establishes a procedure to assess the impacts of projects on humans and the environment before a permit is granted for those projects that are likely to have a significant effect on the environment. An EIA must identify, describe and assess the significant effects of a project on various factors, including on "*climate*" (Article 3.1.c). Annexes I and II detail the projects that are subject to an assessment or a screening procedure in accordance with specific requirements set out in the Directive.

In particular, the 2014 amendment to the EIA Directive also specifically requires an assessment of the impact of climate change on projects and the *"vulnerability of the project to climate change*". The revised Annex III of the Directive lays down the "*selection criteria*" to determine whether the projects listed in Annex II should be subject to an EIA. The selection criteria include the characteristics and the location of the project as well as the type and characteristics of the potential impact. According to the Directive, in considering the characteristics of a project to assess whether it should be subject to an EIA, particular regard must be given to the "*risk of major accidents and/or disasters which are relevant to the project concerned, including those caused by climate change, in accordance with scientific knowledge*". In relation to the location of the project, the new EIA Directive further lays down that when assessing the environmental sensitivity of geographical areas likely to be affected by projects, attention must be paid to "*coastal zones and the marine environment*". In case an EIA is required for a project, an environmental impact assessment report must be submitted. This report should include specific information identified in the Directive, including a "*description of the likely significant effects of the project on the environment resulting from, inter alia: the impact of the project on climate and the vulnerability of the project to climate change*." (Annex IV). The amended Directive requires that "*the description of the likely significant effects on the factors should cover the direct effects and any indirect, secondary, cumulative, transboundary, short-term, medium-term and long-term, permanent and temporary, positive and negative effects of the project*" (Annex IV).

<u>**Sources and additional information**</u>:

- *Directive 2014/52/EU of the European Parliament and of the Council of 16 April 2014 amending Directive 2011/92/EU on the assessment of the effects of certain public and private projects on the environment*. Official Journal of the European Union L 124/1, 25.4.2014, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014L0052&from=EN
- *Directive 2011/92/EU of the European Parliament and of the Council of 13 December 2011 on the assessment of the effects of certain public and private projects on the environment*. Official Journal of the European Union L 26/1, 28.1.2012, available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32011L0092
- European Commission, Environment> Environmental Impact Assessments> Review of the EIA Directive, http://ec.europa.eu/environment/eia/review.htm
- *An EU Strategy on adaptation to climate change*, COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS/* COM/2013/0216 final */, http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52013DC0216
- REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL on the implementation of the EU Strategy on adaptation to climate change, COM/2018/738 final, available at: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:738:FIN
- COMMISSION STAFF WORKING DOCUMENT, 2018, *Evaluation of the EU Strategy on adaptation to climate change, Accompanying the document*, available at:https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018SC0461&from=EN

UK Climate Change Act 2008

Country/Region: United Kingdom of Great Britain and Northern Ireland, Europe

Date: 2008

✓Legally binding framework for climate change mitigation and adaptation

✓ Climate change adaptation reporting by harbour authorities

The *UK Climate Change Act*, in force since 2008, provides a national legal framework to achieve long-term goals on greenhouse gas emission reduction and to ensure that steps are taken to adapt to the impacts of climate change. It attributes important duties to the Secretary of State to reduce greenhouse gas emissions and empowers the Government to require different bodies, including seaports and airports, to report on their progress on adapting to climate change (referred to as the 'Adaptation Reporting Power').

More specifically, the Act (Section 1) sets a legally binding domestic greenhouse gas emission reduction target for 2050 (net carbon account to be at least 80 per cent lower than the 1990 baseline). It also introduces emission trading schemes (Part 3) and a system of carbon budgeting (Section 4-10). A Committee on Climate Change (CCC) is also established by the Act with advisory and reporting functions (Part 2). It advises namely on carbon budgets and on other areas, including issues related to emissions from international aviation and shipping.

The Part 4 of the Act further contains a section on climate change adaptation, whereby it requires the Government to assess and report every five years to Parliament on the risks of the current and predicted impact of climate change (Section 56). The CCC's advice must be taken into account before the report is submitted to the Parliament (Section 57). The Act further requires the Secretary of State to develop a programme for adaptation to climate change setting out the objectives along with the Government's proposals and policies for meeting those objectives (Section 58). On that basis, the UK National Adaptation Programme was published in 2013. The CCC is to assess the progress made towards implementing the programme.

In addition, through the Adaptation Reporting Power, the Secretary of State "*may direct*" statutory undertakers or bodies with functions of a public nature (referred to as 'reporting authorities') to prepare a report containing "*an assessment of the current and predicted impact of climate change in relation to the authority's functions*", "a *statement of the authority's proposals and policies for adapting to climate change in the exercise of its functions and the time-scales for introducing those proposals and policies*", and an assessment of progress (Section 62). Compliance with Secretary of State's directions is obligatory (Section 63: "*A reporting authority must comply with any directions under section 62*").

The first reporting round targeted 91 organizations, including strategic airport operators and harbour authorities. According to the UK Government, "*the primary aims of the first round of the Adaptation Reporting Power were to ensure that the organisations selected understood the risks climate change poses to their activities and were making the necessary plans to respond to climate change*". During this round, nine responses were received from Ports and Ports Associations in the UK. Similarly, nine airports from England, Scotland and Wales, the Civil Aviation Authority (CAA) and National Air Traffic Services (NATS) submitted Adaptation Reports in 2011. A second round of reporting was initiated in 2013, whereby first round reporting organizations were invited to provide progress updates, and a small group of new organizations were invited to report for the first time. Examples of reports are provided in Chapter 4 of this compilation. The Government will invite airports and selected commercial ports for the third round of reporting (2019-2021) on a voluntary basis.

Sources and additional information:

- United Kingdom, *Climate Change Act 2008*, c. 27, available at: https://www.legislation.gov.uk/ukpga/2008/27/contents
- GOV.UK, Collection >*Climate change adaptation reporting: second round reports*, available at: https://www.gov.uk/government/collections/climate-change-adaptation-reporting-second-round-reports
- Department of Environment, Food and Rural Affairs, *Second round of reporting under the Adaptation Reporting Power: List of organizations which were invited to participate in the second round*, 2014, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/432804/arp-2round-org-list.pdf
- Department of Environment, Food and Rural Affairs, *Adapting to Climate Change: helping key sectors to adapt to climate change*, Government Report for the Adaptation Reporting Power, March 2012, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69518/pb13740gov-summary-adapt-reports.pdf
- Committee on Climate Change, *UK Climate Change Risk Assessment 2017, Synthesis report: priorities for the next five years*, 2016, available at: https://www.theccc.org.uk/wp-content/uploads/2016/07/UK-CCRA-2017-Synthesis-Report-Committee-on-Climate-Change.pdf
- Department of Environment, Food and Rural Affairs,*The National Adaptation Programme and the third strategy for climate adaptation reporting,Making the country resilient to a changing climate,* July 2018, available at: https://www.gov.uk/government/publications/climate-change-second-national-adaptation-programme-2018-to-2023

Public Resources Code, State of California, 2016

Country/Region: United States of America, North America

Date: 2016

✓ Climate change impacts to be considered for state infrastructure

✓Integration of scientific data concerning projected climate change impacts into state infrastructure engineering

Assembly Bill No. 2800, authored by State of California Assembly member Bill Quirk and signed by Governor Brown in 2016, modified Section 71155 of the *Public Resources Code (PART 3.7. Climate Change and Climate Adaptation [71150 - 71155])* of the State of California (Added by Stats. 2016, Ch. 580, Sec. 2. (AB 2800)). The modification became effective on 1 January 2017.

In its introductory part, the Bill refers to the climate change impacts in California noting "*The impacts of climate change are already being felt in California and include record-breaking drought, wildfires, flooding, sea level rise, coastal erosion, and heat waves. These impacts are projected to worsen with a future punctuated by what are now considered extreme weather events*." Further, the Bill states that "*…. Infrastructure project planning and design must incorporate design standards and specifications for climate change impacts.* "

As a result, the amended Public Resources Code requires all state agencies to "*take into account the current and future impacts of climate change when planning, designing, building, operating, maintaining and investing in state infrastructure*". In addition, the Code calls on the agency to establish, a 'Climate-Safe Infrastructure Working Group 'to examine *"how to integrate scientific data concerning projected climate change impacts into state infrastructure engineering, including oversight, investment, design, and construction"*.

The working group is foreseen to have a diverse member composition (engineers, scientists, architects etc.). It is tasked to consider and investigate, at a minimum, the following issues:

- *"The current informational and institutional barriers to integrating projected climate change impacts into state infrastructure design.*
- *The critical information that engineers responsible for infrastructure design and construction need to address climate change impacts.*
- *How to select an appropriate engineering design for a range of future climate scenarios as related to infrastructure planning and investment*."

The Code requires the working group to make recommendations to the Legislature of the State of California including recommendations for the following: i) Integrating scientific knowledge of projected climate change impacts into state infrastructure design; ii) Addressing critical information gaps identified by the working group; iii) A platform or process to facilitate communication between climate scientists and infrastructure engineers.

Sources and additional information:

- State of California, *Public Resources Code – PRC DIVISION 34. ENVIRONMENTAL PROTECTION* [71000 - 71424] Heading of Division 34 amended by Stats. 1994, Ch. 1112, Sec. 2.) PART 3.7. Climate Change and Climate Adaptation [71150 - 71155] (Part 3.7 added by Stats. 2015, Ch. 603, Sec. 2.), available at: https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=71155.&lawCode=PRC
- AB 2800 (Quirk) *Climate-Safe Infrastructure Working Group* Schedule and Meeting material, available at:http://resources.ca.gov/climate/climate-safe-infrastructure-working-group/
- A Report of the Climate-Safe Infrastructure Working Group to the California State Legislature and the Strategic Growth Council, *Paying it Forward: The Path Toward Climate-Safe Infrastructure in California,* September 2018, available at: http://resources.ca.gov/docs/climate/ab2800/AB2800_Climate-SafeInfrastructure_FinalWithAppendices.pdf
- California Natural Resources Agency, *Safeguarding California Plan: 2018 update, California's Climate Adaptation Strategy, Transportation*, p.116-125, January 2018,available at: http://resources.ca.gov/climate/safeguarding/
- *California Adaptation Forum*, available at:http://www.californiaadaptationforum.org/2018/04/18/climate-safe-infrastructure-building-resilience-to-climate-change/

4. Examples of policies and plans relevant for climate change impacts and adaptation for coastal transport infrastructure

At national and regional level, countries are increasingly developing policies and plans with a view to facilitating climate change adaptation. Public authorities play a pivotal role by providing the appropriate policy framework with a view to promoting climate resilient coastal transport infrastructure. Governments efforts to facilitate climate-resilient infrastructure might target a range of policy areas, including: i) Improving risk assessment and information to support informed and evidence-based decision making by ensuring available and accessible data on projected climate variability and change; ii) Awareness raising and capacity building of relevant decision makers; iii) Screening and factoring climate risks into public investments; iv) Enabling infrastructure resilience through policy and regulation by removing policy or regulatory distortions, or adding regulatory requirements to consider climate risks; v) Encouraging climate risk disclosure; and vi) Revealing interdependencies and supporting the design of appropriate public policy (Vallejo et al., 2017).

This Chapter presents select examples of regional and national climate change policy instruments and plans that are considered relevant for coastal transport infrastructure adaptation efforts. Policy instruments highlighted in this Chapter offer a remarkable diversity: some foresee mainstreaming adaptation into policies, including transport-related policies, some provide guidance for climate change adaptation of coastal infrastructure or explicitly apply to climate change adaptation of coastal transport infrastructure, others set institutional arrangements to address climate change responses in various sectors, including transport etc. These examples are intended to illustrate relevant regional and national efforts rather than to provide a comprehensive overview of policies regulating climate change impact/risk assessments and adaptation for coastal transport infrastructure.

Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas 2016

Country/Region: Mediterranean

Date: 2016

✓ Climate change resilience

✓Cross-border approach: 21 Mediterranean countries

✓Transport sector addressed

In the light of the significant challenges that climate change poses to the Mediterranean countries, and in response to calls for developing a regional approach for climate change adaptation, the *Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas* was developed under the auspices of United Nations Environment Programme (UNEP) Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean (Barcelona Convention) and endorsed by the 19th meeting of the Contracting Parties in 2016. The Framework reflects a cross-border collaborative and coordinated approach to climate change adaptation with a view to enhancing resilience to climate change of coastal and marine environments in the Mediterranean region.

The main objective of the Framework is to:

> *"Set a regional strategic approach to increase the resilience of the Mediterranean marine and coastal natural and socioeconomic systems to the impacts of climate change, assisting policy makers and stakeholders at all levels across the Mediterranean in the development and*

implementation of coherent and effective policies and measures by identifying strategic objectives, strategic directions and priorities that:

- *Promote the right enabling environment for mainstreaming adaptation in national and local planning;*
- *Promote and exchange best practices and low-regret measures;*
- *Promote leveraging of necessary funding; and*
- *Exchange and access best available data, knowledge, assessments and tools on adaptation."*

The Framework covers the Mediterranean Sea and the coastal zones of the 21 countries that border it for the period of 2016–2025. The Framework stresses the fact that the region's climate is already changing. It further provides projections for the future and an overview of expected climate change-related risks, such as risks to human settlements, industry and infrastructure. In that context, the Framework notes that port infrastructure, but also coastal roads, railways, and airports, are expected to be at risk mainly due to temporary and permanent flooding arising from sea-level rise, high winds and storm surges.

The Framework is structured around four strategic objectives. These strategic objectives further specify strategic directions and suggested priorities for their realisation (Table 4.1). Transport is referred to in the context of the strategic objective on better-informed decisions-making and data availability (Strategic objective 4) as part of the list of priorities for consideration in relation to "*understanding of the vulnerability of natural and socioeconomic systems and sectors and of possible impacts*".

Table 4.1 Strategic Objectives, Strategic Directions and Priorities of the Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas

Strategic Objective 1: Appropriate institutional and policy framework, increased awareness and stakeholder engagement, and enhanced capacity building and cooperation	**Strategic Directions:** 1.1. Enhancing awareness and engagement of key stakeholders on climate adaptation 1.2. Promoting adequate institutional and policy frameworks 1.3. Promoting a regional approach on Disaster Risk Management 1.4. Improving implementation and effectiveness of adaptation policies through monitoring and reviewing progress 1.5. Integrating climate adaptation into local plans for the protection and management of areas of special interest
Strategic Objective 2: Development of best practices (including low regret measures) for effective and sustainable adaptation to climate change impacts	Strategic Directions: 2.1. Identifying adaptation needs and best practices 2.2. Mainstreaming, exchanging and adopting best practices
Strategic Objective 3: Access to existing and emerging finance mechanisms relevant to climate change adaptation, including international and domestic instruments	Strategic Directions: 3.1. Prioritizing public spending relative to climate adaptation and mobilizing national sources of climate finance 3.2. Accessing international financing 3.3. Building alliances with the banking and insurance sectors
Strategic Objective 4: Better informed decision-making through research and	Strategic Directions: 4.1. Understanding of the vulnerability of natural and socioeconomic systems and sectors and of possible impacts *[priorities for consideration*

scientific cooperation and availability and use of reliable data, information and tools	*include vulnerability and interactions of socioeconomic systems and sectors such as tourism and transport]* 4.2. Building capacities for and promoting the use of vulnerability and risk assessment at regional to local levels 4.3. Strengthening Science-policy interface and accessibility of related knowledge 4.4. Developing Regional climate information at a resolution suitable for adaptation planning

Sources and additional information:

- *Regional Climate Change Adaptation Framework for the Mediterranean Marine and Coastal Areas*, 2016, available at: https://wedocs.unep.org/rest/bitstreams/8384/retrieve
- *Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean* (Barcelona Convention), available at: https://wedocs.unep.org/bitstream/handle/20.500.11822/7096/Consolidated_BC95_Eng.pdf?sequence=1&isAllowed=y
- United Nations Environment Programme (UNEP) *Mediterranean Action Plan* (MAP), available at: http://web.unep.org/unepmap/

Transport Climate Change Sectoral Adaptation Plan of Ireland, 2019

Country/Region: Ireland, Europe

Date: 2019

✓Transport specific climate change adaptation plan

✓Threshold analysis for the transport sector

✓Explicit mention of port infrastructure

Sectoral adaptation planning in Ireland is based on the Climate Action and Low Carbon Development Act 2015. The *Transport Climate Change Sectoral Adaptation Plan*is the first Sectoral Adaptation Plan for the transport sector elaborated on the above mentioned statutory basis. The Adaptation Plan was published in 2019 and developed in line with the Sectoral Planning Guidelines for Climate Change Adaptation, building on the document entitled Developing Resilience to Climate Change in the Irish Transport Sector (2017).The Adaptation Plan "*sets out the priority climate concerns for the transport sector, presents the links between climate impacts and risks to infrastructure, outlines the next steps required to close knowledge gaps and complete a robust assessment of sectoral adaptive capacity*".

The Adaptation Plan states that climate change poses significant challenges to the transport sector which has faced an unprecedented level of destruction to infrastructure and disruption to services caused by extreme weather events, such as Storm Ophelia in 2017, Storm Emma in 2018. First, the Adaptation Plan describes Ireland's transport infrastructure networks before identifying projected climate 'trends' (slowly changing variables) and climate 'shocks' (extreme weather events) followed by presenting a qualitative risk analysis for the transport sector. The methodology contained in the UK Climate Change Risk Assessment (2017) was used to identify and determine sectoral risks. This methodology considers the future likelihood and magnitude of each projected climate impact (considered against identified vulnerability in transport infrastructure and services) to establish climate risk. The analysis led to the identification of the following key climate risks for the transport sector:

- High Climate Risk: Projected increase in precipitation extremes, flooding, high winds, increased storm intensity and projected rises in sea level;
- Moderate Climate Risk: Projected increase in coastal erosion and temperature extremes;
- Low Climate Risk: Projected changes to humidity levels or phenological factors.

The coastal zone is considered as a critical environment by the Adaptation Plan as multiple critical infrastructure networks and hubs are in close proximity to the coast. In that context, the national port infrastructure is described as especially sensitive to storm surge and SLR, with potential for severe impacts including damage to port infrastructure, damage to vessels, disruption to navigations and implications for passenger safety. In relation to storms (high winds) and storm surge, Storm Ophelia, that made landfall over Ireland as an extra-tropical storm on 16th October 2017, is cited in the Adaptation Plan as an example: The storm led to the suspension of all public transport services and cancellation of all ferry sailings to the UK on 16 October. Ireland's airports remained open throughout the Storm but experienced flight disruption, including cancelled and delayed flights.

A thresholds analysis approach was used to identify future sectoral consequences of high-priority and moderate-priority climate risks for the transport sector. In that respect, the Adaptation Plan refers to an on-going analysis to help identity the geospatial distribution of climate impacts in Ireland in addition to presenting a suite of maps illustrating projected downscaled high and moderate climate change impacts in the country. In relation to assessing the resilience of the transport system, the Adaptation Plan showcases a data collection exercise focusing on costs incurred as a result of extreme weather events; the frequency and severity of such weather events, and their associated risks. An example of the data gathered by stakeholders following Storm Ali (18-20 September 2018) is presented that caused, among others, delays incurred by vessels waiting to berth and commence operations in addition to flight disruptions.

An entire chapter is dedicated to the adaptation action plan with "*the overarching goal of transport adaptation planning is to ensure that the sector can fulfil its continuing economic, social and environmental objectives by ensuring that transport infrastructure is safeguarded from the impacts of climate change."* The following "*implementation objectives*" are included in the action plan:

1. *"Improve understanding of the impacts of climate change on transport infrastructure, including cross-sectoral cascading impacts, and close knowledge gaps;*
2. *Assist transport stakeholders in identifying and prioritising climate risks to existing and planned infrastructural assets and enabling them to implement adaptation measures accordingly; and*
3. *Ensure that resilience to weather extremes and longer-term adaptation needs are considered in investment programmes for planned future transport infrastructure".*

Implementation is envisaged via "soft", policy type of adaptation actions by the Adaptation Plan. To this end, several adaptation actions are presented with regards to each of the above-mentioned implementation objectives, along with identifying lead organisations and other stakeholders, timeline and cross-sectoral linkages.

The *Transport Climate Change Sectoral Adaptation Plan* of 2019 built on the document entitled *Developing Resilience to Climate Change in the Irish Transport Sector* prepared by the Minister for Transport, Tourism and Sport of Ireland. This document, published in 2017, *"outlines initial research and analysis on the likely effects of climate change on the Irish transport sector and proposes actions to develop climate resilience within the sector*." In terms of port infrastructure, the following key impacts are identified by the document entitled *Developing Resilience to Climate Change in the Irish Transport Sector*:

- Damages to port infrastructure, navigations and safety equipment;
- Damages to vessels while in port and impacts on safety of passengers while embarking, in transit, and disembarking;
- Storm activity can also cause issues in relation to the channels leading into ports becoming blocked with large amounts of sand silt and other materials driven by storm activity;
- Changes in sea level will have impacts on dredging requirements at ports, positive or negative depending on local circumstances, and implications for natural scouring capability at estuarial ports.

High and medium priority impacts identified for seaports are summarized in Table 4.2.

Table 4.2 High and medium priority impacts of climate change vulnerabilities identified for ports. Developing Resilience to Climate Change in the Irish Transport Sector

	High priority impacts	Medium priority impacts
Ports	- Sea level rise and increased occurrence of coastal storms will put port infrastructure at risk - Damages to port infrastructure from freezing weather events - Service disruption - Changing patterns of siltation	Passenger and staff comfort

Current measures by transport providers on enhancing climate resilience are also highlighted in the document. The following examples of current measures by ports are included:

- Dublin Port Company: It publishes an annual sustainability report to track and record progress on the port's economic, environmental and social responsibilities. The Port Company is certified in Port Environmental Review System and ISO 14001 Environmental Management System
- Port of Cork and the City of Cork: Rising sea level and fluvial flooding are considered as priority issues. Infrastructure planning and design is based on risk assessment and strategic planning. Special attention is paid to maintaining the road access to the port under extreme weather conditions. Emergency planning procedures are in place, including monitoring of ship movements and crane operations in extreme conditions.
- Shannon Foynes Port Company: In relation to weather events, the Company is engaged with the local communities, including initiating a text alert messaging system to advise of future events.
- Drogheda Port: The port is currently developing a project focused on small to medium sized Atlantic ports in Europe to identify the impact on the existing infrastructure of ports and identify future infrastructural requirements to protect port operations.

Sources and additional information:

- *Climate Action and Low Carbon Development Act 2015*, Number 46 of 2015, available at: http://www.irishstatutebook.ie/eli/2015/act/46/enacted/en/html
- *Sectoral Adaptation Plan for Transport Infrastructure, 2019,* Department of Transport, Tourism and Sport, available at: https://www.gov.ie/en/publication/a2444e-sectoral-adaptation-plan-for-transport-infrastructure/
- *Adaptation Planning: Developing Resilience to Climate Change in the Irish Transport Sector,* 2017, available at: https://www.gov.ie/en/publication/1dbbbd-adaptation-planning-developing-resilience-to-climate-change-in-the-i/

- *National Adaptation Framework, Planning for a Climate Resilient Ireland,* Department of Communications, Climate Action & Environment, January 2018, available at: https://www.dccae.gov.ie/en-ie/climate-action/topics/adapting-to-climate-change/national-adaptation-framework/Pages/default.aspx
- *Climate Action Plan 2019*, Department of Communications, Climate Action & Environment, available at: https://www.gov.ie/en/publication/ccb2e0-the-climate-action-plan-2019/
- *UK Climate Change Risk Assessment 2017 Evidence Report,* available at: https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/

National Climate Change Adaptation Plan of France 2011, 2018

Country/Region: France, Europe

Date: 2011, 2018

✓Cross-cutting national climate change adaptation plan

✓Mainstreaming climate change adaptation

✓Enhancing the resilience of transport networks

The first *National Climate Change Adaptation Plan* of France was adopted in 2011 on the basis of Programme law 2009-967 of 3 August 2009, which foresees *"the preparation of a National Adaptation Plan for a variety of areas of activity by 2011*". The first Plan covers a five-year period between 2011 and 2015. It is cross-cutting and addresses twenty sectors, including transport. The second National Climate Change Adaptation Plan was adopted in 2018 for the period of 2018-2022. Both National Climate Change Adaptation Plans were elaborated based on a national consultation process involving a wide-range of stakeholders.

After describing climate scenarios for France in the 21st century, the first Plan defines guiding principles, before outlining twenty thematic ´*National Climate Change Adaptation Plan Action Sheets*´ in line with the themes raised during the national consultation process. Each ´*Action Sheet*´ contains a ´*key measure*' in addition to prescribing corresponding actions, responsible and partner stakeholders with a view to climate change adaptation. A cross-cutting action sheet foresees systematically mainstreaming climate change "*in delegated public service contracts and public service contracts let by the government*". Concrete actions include in that respect: a) Define climate change reference scenarios; b) Systematically mainstream climate change in delegated public service contracts let by the government; c) Mainstream climate change projections in risk assessments over the life expectancy of classified installations; d) Facilitate thinking in order to define the notion of acceptable risk; e) Increase research into adaptation in the context of Future Investments.

The first Plan includes a dedicated *Action Sheet* on ´*infrastructures and transport system*´ with the key measure to "*Review and adapt technical standards for the construction, maintenance and operation of transport networks (infrastructures and equipment) in continental France and overseas territories*." The following concrete actions are foreseen in that context:

1. Review and adapt technical standards for construction, maintenance and operation of transport networks (infrastructures and equipment) in continental France and French overseas territories;

2. Study the impact of climate change on transport demand and the consequences for reshaping transport provision;
3. Define a harmonised methodology to diagnose the vulnerability of infrastructures and land, sea and airport transport systems;
4. Establish a statement of vulnerability for land, sea and air transport networks in continental France and in French overseas territories and prepare appropriate and phased response strategies to local and global climate change issues. The last action covers vulnerability studies for ports and airports as well.

The revision of the first Plan along with the commitments enshrined in the Paris Agreement led to the adoption of the second *National Climate Change Adaptation Plan* in 2018. This second Plan incorporates a long term vision up to 2050 and addresses 58 actions to protect the country from the impacts of extreme climate-induced events. Transport infrastructure is mentioned among priority sectors - supplying essential services to the population - with a view to climate change adaptation. Transport-related actions include the following:

- Continue adapting technical and normative standards for the operation, maintenance and construction of transport infrastructure and equipment;
- Continue the risk and vulnerability assessments of transport infrastructure;
- Elaborate a study on the impacts of changing international trade routes, including impacts on entry points, flow and nature of products entering into France;
- Analyse the consequences of voluntary restrictions of transport in times of crisis.

Sources and additional information:

- *Adaptation de la France au changement climatique,* Ministère de la Transition écologique et solidaire, avalable : https://www.ecologique-solidaire.gouv.fr/adaptation-france-au-changement-climatique#e2
- *French National Climate Change Impact Adaptation Plan 2011 – 2015[English translation],* Ministry of Ecology, Sustainable Development, Transport and Housing, available at: https://www.ecologique-solidaire.gouv.fr/sites/default/files/ONERC_PNACC_Eng_part_1.pdf
- *French National Climate Change Impact Adaptation Plan 2011 – 2015 ANNEXE II Detailed action sheets[English translation],*Ministry of Ecology, Sustainable Development, Transport and Housing, available at: https://www.ecologique-solidaire.gouv.fr/sites/default/files/ONERC_PNACC_Eng_part_2.pdf
- *Plan national d'adaptation au changement climatique 2018-2022,* Ministère de la Transition écologique et solidaire, avalable : https://www.ecologique-solidaire.gouv.fr/sites/default/files/2018.12.20_PNACC2.pdf
- *Plan national d'adaptation au changement climatique 2018-2022, Fiches de la composante « Prévention et résilience »,* Ministère de la Transition écologique et solidaire, available at : https://www.ecologique-solidaire.gouv.fr/sites/default/files/ONERC_Concertation_PNACC2_Fiches%20recommandations%20Prevention%20resilience.pdf

Climate Change Policy Framework for Jamaica 2015

Country/Region: Jamaica, Caribbean

Date: 2015

✓Cross-cutting, multi-sectoral approach to climate change mitigation and adaptation

✓Explicit mention of coastal transport infrastructure

✓Climate mainstreaming

The *Climate Change Policy Framework for Jamaica* is a landmark policy in the Caribbean region, which outlines the objectives, principles and strategies to be adopted by Jamaica to respond to climate change. In place since September 2015, it was developed using as a basis *Vision 2030 Jamaica – National Development Plan*, and *Jamaica's Second National Communication on Climate Change to the UNFCCC*. It is intended to support *Vision 2030* by reducing the risks posed by climate change to Jamaica's sectors and development goals.

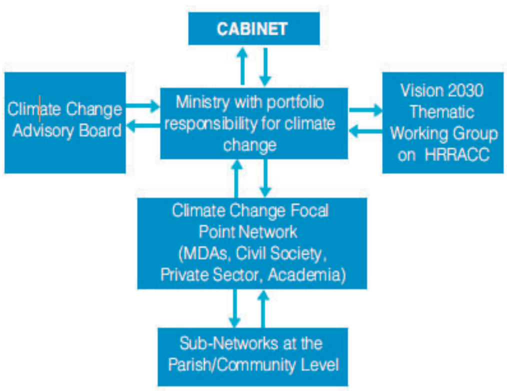
The Framework explicitly acknowledges the need to address climate change adaptation. It aims to "*mainstream climate change considerations into national policies and all types and levels of development planning and to build capacity to implement climate change adaptation and mitigation activities*". It further aims to "*create a sustainable institutional mechanism to facilitate the development, co-ordination and implementation of policies, sectoral plans, programmes, strategies and legislation to address the impacts of climate change*". Mobilizing climate financing for climate adaptation and mitigation initiatives, along with encouraging the private sector to embrace climate change imperatives, are also among its objectives.

The Framework is cross-sectoral and provides guidance to all Government Ministries, Departments and Agencies, civil society, the private sector as well as the general public. Based on the Framework, relevant sectors are to develop individual plans addressing climate change adaptation and mitigation, taking into account set principles. The main sectors for the development of climate change strategies and action plans include transportation, tourism, coastal resources and response management, among others.

With respect to impacts on coastal transportation infrastructure, the Framework highlights the potential damage to coastal infrastructure, including seaports and airports, due to extreme and slow onset events. In addition, trade-related implications of climate change are noted with concern, including import/export delays, loss and damage to goods and other challenges in global supply chains caused by interruptions in operations at seaports and airports.

The Framework further recognizes the need to ensure coordination among sectors to ensure an effective response to climate change, outlining the necessary institutional arrangements (Fig. 4.1).

Figure 4.1 Institutional arrangements set out in the Climate Change Policy Framework for Jamaica 2015



Of particular importance are the climate change "focal points", which are to be appointed in all ministries, selected departments and agencies, with representation from civil society groups and the private sector. The Framework stipulates that "*focal points will be responsible for coordinating the development and implementations of their respective sectoral strategies and actions with respect to climate change, and the mainstreaming of climate change considerations into their respective policies, plans and programmes*."

Sources and additional information:

- Government of Jamaica, *Climate Change Policy Framework for Jamaica*, 2015, available at:https://sidsport-climateadapt.unctad.org/wp-content/uploads/2018/05/Climate-Change-Policy-Framework-FINAL-2015.pdf
- Oral Khan (Lt. Cl.), Ministry of Economic Growth and Job Creation, Jamaica, *Climate Change Policy Framework for Jamaica: Jamaica's NDCs Under the Paris Agreement* [PowerPoint presentation], UNCTAD National Workshop Jamaica, 30 May – 1 June 2017, "Climate Change Impacts and Adaptation for Coastal Transport Infrastructure in Caribbean SIDS", Kingston, Jamaica, available at: https://sidsport-climateadapt.unctad.org/wp-content/uploads/2018/03/OKhan_MEGJC_JAMWorkshop_p04_en.pdf

National Climate Change Policy for Grenada, Carriacou and Petit Martinique 2017

Country/Region: Grenada, Carriacou and Petit Martinique, Caribbean

Date: 2017

✓Assessment of vulnerability of critical transport infrastructure

✓Coastal transport infrastructure identified as at-risk due to climate change

✓Climate change adaptation as cross-cutting policy

The *National Climate Change Policy for Grenada, Carriacou and Petit Martinique* was enacted in November 2017. The Policy covers the period of 2017–2021. Following the description of both global and regional context, the document outlines climate change impacts in Grenada in addition to emphasising its vulnerability. In that context, key coastal infrastructure is identified as at risk due to rising sea levels, noting that those will be inundated by a 1 metre (3 feet) sea level rise affecting 73 per cent of all major tourism resorts as well as 40 per cent of all seaport lands. Sections of the coastline close to the Point Salines International Airport are further identified as other at-risk area.

Building climate resilience in priority thematic areas, including coastal zone management, is a key policy objective for 2017–2021, in addition to facilitating *"climate smart (low carbon, climate resilient) infrastructure location, planning, design and maintenance".*

Policy objectives are to be achieved through the pursuit of 13 inter-related strategies. In that context, climate change adaptation is foreseen to be of cross-cutting nature by the Policy, as it is to be integrated into the *"National Sustainable Development Plan 2030 formulation and implementation, priority sectoral corporate plans, the Public Sector Investment Programme (PSIP) budget and approval process, and environmental impact assessments."* Assessing the vulnerability of critical infrastructure assets, including airports, are further explicitly included in the above-mentioned inter-related strategies as follows:

- *"Assess vulnerability of critical infrastructure assets (e.g. Dumfries, Maurice Bishop, and Pearls airports).*
- *Provide training and mentoring to enable building code and enforcement of the Physical Development Plan.*
- *Provide guidance and incentives for climate smart development and update policies and plans to ensure land and infrastructure development is climate smart."*

Among the specific outcomes to be achieved during the 2017–2021 period, the Policy foresees the integration of climate variability and change into policies and guidelines for physical planning and development.

The Policy's objectives, strategies and outcomes in relation to adaptation are mainly implemented by the *National Climate Change Adaptation Plan (2017–2021) for Grenada, Carriacou and Petite Martinique. "Resilient infrastructure"* is included as "*Programme of Action 7"* of the *National Climate Change Adaptation Plan* with the objective to "*increase resilience of selected infrastructure to climate change, including increasingly extreme weather events through location, planning, design and maintenance*." The Plan notes that coastal infrastructure has greater exposure to sea level rise, storm surge and coastal flooding events and refers to airports and seaports as important infrastructures. In that context, the Plan considers the Maurice Bishop International Airport (MBIA) to be the most '*at risk*' airport within the CARICOM region, as it is predisposed to serious threats from sea-level rise. Therefore, detailed vulnerability assessments are needed not only for MBIA, but also Pearls (abandoned airfield) and Dumfries (new location in Carriacou) and Lauriston (the existing airport in Carriacou). Data acquisition to facilitate proper planning and management are further identified as needs by the Plan.

Table 4.3 presents the objectives and corresponding, relevant priority actions as identified by the National Climate Change Adaptation Plan in relation to "*Resilient infrastructure"*:

Table 4.3 Objectives and Priority Actions, Programme of Action 7:Resilient infrastructure and sustainable land management, National Climate Change Adaptation Plan (2017-2021) for Grenada, Carriacou and Petite Martinique (excerpt)

Objective	Priority Action
Objective 1 Improve policy, legal, regulatory and institutional framework for resilient infrastructure	- Integrate climate change considerations into the updated airport master plan.
Objective 2 Identify infrastructure at risk of being damaged or lost due to impacts of climate change	- Conduct a detailed Climate Change Vulnerability assessment for all three airports (Dumfries, Maurice Bishop, Pearls), including parking areas (sea-level rise, erosion, increased temperatures and impact on runway, flooding etc.) and implementation of first erosion control measures where required - Assess climate change vulnerability of existing tourism sites; identify potentially new sites; assess vulnerability of other relevant tourism infrastructure/develop recommendations for physical adaptation measures for tourism infrastructure such as, the port, resorts, road systems and bridges. Include the results in relevant tourism plans.
Objective 3 Improve the resilience of selected buildings and infrastructure and implement local area adaptation plans	- Design mitigation and implement construction works to stabilise areas prone to floods, rock falls, and landslides. - Improve resilience of most vulnerable bridges as identified in nation-wide bridge assessment.

Objective 4 Improve technical capacity for spatial data management, risk-modelling and climate-smart/green building approaches/standards	- Improve the use of data, GIS and remote sensing for climate change adaptation and prepare a plan of action for long-term sustainability for spatial data management. - Establish and improve capacity for risk modelling for SLR, storm surges, inland flooding and land slippage. - Improve data collection.

The Plan notes serious lack of available climate data and projections and, therefore, establishes adaptation actions in relation to "*Climate and sea-level rise data and projections*" (Programme of Action 9), to strengthen institutional arrangements for the collection, analysis and provision of climate-related data for use in decision-making. In that context, the establishment, equipment and maintenance of a national facility (National Meteorological Service) as main coordinator is foreseen by the Plan for collecting, collating, analysing and disseminating climate related data to all potential users, including the Maurice Bishop International Airport.

Sources and additional information:

- *National Climate Change Policy for Grenada, Carriacou and Petite Martinique* (2017–2021), November 2017, available at: https://www.gov.gd/egov/docs/other/Grenada-National-Climate-Change-Policy-2017].pdf
- *National Climate Change Adaptation Plan (2017–2021) for Grenada, Carriacou and Petite Martinique,* November 2017, available at: https://www.gov.gd/egov/docs/other/Grenada-National-Adaptation-Plan-2017.pdf

Climate Risks and Adaptation Practices for the Canadian Transport Sector 2016

Country/Region: Canada, North America

Date: 2016

✓Impacts of climate factors on marine and air transportation

✓ Case studies and climate change adaptation practices for marine and air transportation

The *Climate Risks and Adaptation Practices for the Canadian Transportation Sector 2016* report, co-led by Transport Canada and Natural Resources Canada, presents the current state of knowledge about climate risks to the Canadian transportation sector; and identifies existing or potential climate change adaptation practices. The report includes six regional chapters and one urban chapter, along with climate change adaptation approaches and case studies to highlight adaptation actions and practices.

With regards to Canada´s transportation system, the report notes that a total of 567 port facilities, 902 fishing harbours and 202 recreational harbours, are included in the Canadian port system with the Great Lakes/St. Lawrence Seaway System serving 15 major international ports and 50 regional ports that connect to 40 provincial/interstate highways and 30 rail lines. In relation to aviation, the report refers to 26 National Airport System (NAS) airports that handled around 90 per cent of total air passenger traffic in 2014 with 1.1 million tonnes of freight unloaded at Canadian airports.

The document describes the observed and projected changes to Canada´s climate and hydrology affecting the transportation system. These include temperature, precipitation, permafrost, relative sea level, sea, lake and river ice, inland water levels, and extreme weather events. Mode-specific impacts are defined for both air and marine transport. Examples of direct impacts on marine transportation from various climate factors include: a) Flooding and/or damage to port facilities; b) Increased or reduced access to ports, dredging requirements; c) Hazards to vessel navigation – storms and wind events (waves); d) Hazards to vessel navigation – detached sea ice; e) Longer or shorter shipping season; f) New navigation opportunities.

Regional chapters further outline specific climate risks and impacts for six Canadian regions, in addition to presenting adaptation practices and case studies for all modes, including marine and air transportation. In general, engineering and technological solutions, as well as policy, planning, management, and maintenance approaches are cited as adaptation options for the transportation infrastructure. Specific, marine transportation-related regional case studies described in the report covering climate risks and climate change adaptation practices include the following, among others:

- Artic region and the Northwest Passage;
- Climate change vulnerability of the Manitoba-Nunavut supply chain, whereby a study was carried out to analyse the engineering vulnerability of the Port of Churchill, the Thompson Freight Services Hub, and the Rankin Inlet Airport;
- Water levels, ice removal and adaptive management concerning the St. Lawrence Seaway, an important international marine shipping route spanning 3,700 km over many jurisdictions;
- Planning for future extreme weather conditions at Halifax Harbour;
- Climate change adaptation at Port Saint John.

Sources and additional information:

- Palko, K. and Lemmen, D.S. (Eds.). (2017), *Climate risks and adaptation practices for the Canadian transportation sector 2016.* Ottawa, ON: Government of Canada, available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/ClimatRisk-E-ACCESSIBLE.pdf
- Lemmen, D.S., Warren, F.J., James, T.S. and Mercer Clarke, C.S.L. editors (2016): *Canada's Marine Coasts in a Changing Climate*; Government of Canada, Ottawa, ON, 274p, available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2016/Coastal_Assessment_FullReport.pdf
- Elizabeth Smalley, Transport Canada, *Transportation and Adaptation: a Canadian Perspective, [presentation],* UNCTAD Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future, 16 to 17 April 2019, available at: https://unctad.org/meetings/en/Presentation/dtltlbpls-AhEM2019_p13_ELIZABETH%20SMALLEY%20_en.pdf

U.S. Department of Transportation Climate Adaptation Plan 2014

Country/Region: United States of America, North America

Date: 2014

✓Implements US Executive Order No. 13653 for the transport sector

✓ Addresses vulnerability to climate change impacts of coastal transport systems

Adopted by the U.S. Department of Transportation (DOT) in 2014, the *DOT Climate Adaptation Plan* describes how the Department intends to move towards integrating considerations of climate change adaptation and resiliency into its policies, programs, and operations. U.S. DOT and its modal agencies oversee the safe operation of the transportation system in the country, including 5'000 public-use airports and 300 coastal, Great Lakes, and inland waterways ports.

U.S. DOT was required to submit this plan pursuant to Executive Orders No. 13514 on federal leadership in environmental, energy and economic performance, and No. 13653 on "Preparing the United States for the Impacts of Climate Change" (signed by former President Barack Obama but rescinded in March 2017). The document is an update of the 2012 Plan, and includes new requirements arising from Executive Order No. 13653 that required all Federal agencies to take specific steps to prepare to climate change impacts and support climate change resilience efforts with the aim of preparing the United States for the impacts of climate change by undertaking actions to enhance climate preparedness and resilience.

The U.S. DOT Climate Adaptation Plan identifies and assesses climate change related impacts on the Agency's activities. The various potential impacts include reduced shipping access to dock and shore equipment and navigation aids. It further outlines the actions the Agency has already put in place, and briefly addresses its response to significant climate change risk. The U.S. DOT Plan further stipulates that the following adaptation and resiliency strategies may be considered by transportation planners and system operators in addressing the impact of climate change: i) Climate-conscious land-use planning; ii) Planning for new infrastructure; iii) Hardening of existing infrastructure; iv) Relocation or abandonment of at-risk infrastructure; v) Adding redundancy to reduce impacts to the system; and vi) Provisions for rapid recovery.

It also highlights transportation-related vulnerably to different potential impacts of climate variability, change and severe weather events, such as temperature increase and sea level rise. Coastal transport infrastructure is specifically referred to in this context. Notably, operational disruptions due to higher temperatures, and infrastructure deterioration and damage to shore side equipment and navigational aids due to rising sea level are examples of possible impacts identified. The U.S. DOT Plan further mentions the greater challenges that arise due to a combination of factors, such as damage and destruction of coastal roadways, bridges and airports caused by storm surge, with exacerbated effects due to sea level rise.

The U.S. DOT Plan also informs on how the agencies will consider the need to improve climate change adaptation and resilience and highlights U.S. DOT accomplishments in 2012 and 2013. Planned future goals are also outlined. With respect to maritime transportation, the U.S. DOT Plan states that the Maritime Administration intends to "*incorporate climate change adaptation considerations into internal reviews, particularly port infrastructure projects, shipyard grand application evaluations, and Agency facility modifications […]*". Stakeholder outreach to support adoption of climate change considerations is also mentioned among the future goals of the Maritime Administration.

Source and additional information:

- U.S Department of Transportation, *Climate Adaptation Plan 2014: Ensuring Transportation Infrastructure and System Resilience*, 2014, available at: https://www.transportation.gov/sites/dot.gov/files/docs/2014-%20DOT-Climate-Adaptation-Plan.pdf

Climate Change Adaptation Plan of Japan 2018

Country/Region: Japan, Asia

Date: 2018

- ✓ Climate change adaptation measures for coastal areas
- ✓ Mainstreaming climate change adaptation

On the basis of the recent Climate Change Adaptation Act (2018) that requires the Government of Japan to establish a plan to promote a policy for climate change adaptation comprehensively and systematically, the *Climate Change Adaptation Plan of Japan* was adopted in November 2018. The Plan establishes "*Basic Direction of Climate Change Adaptation Policy in Japan*", including "*Key Strategies*", in addition to "*Basic Directions*" for sectoral measures, as well as "*Basic Policies for Promotion of Adaptation*" with the main objective to prevent and to reduce climate-related impacts. This Plan covers a 5-year period at the same time "*considering a long-term perspective until the end of the 21st century*"*.* Table 4.4 outlines "*Key Strategies*" that are foreseen by the Plan to minimize or avoid damage from the impacts of climate change.

Table 4.4 "Key Strategies" according to the Japanese Climate Change Adaptation Plan (2018)

Mainstreaming adaptation into government policies
Promotion of the Climate Change Adaptation based on scientific findings
Gathering information/knowledge from researchers and institutes and developing information infrastructure
Promotion of adaptation considering local background
Deepening understand of people and promoting adaptation action in each business sector
Contribution for capacity enhanced in the developing countries
Securing close relationship and collaboration among the relevant government agencies

According to the Plan, climate change adaptation efforts by the different sectors are to be based on "*Basic Directions for Measures in Each Sector*". The following sectors are covered in the Plan: agriculture, forest, forestry and fisheries; water environment, water resources; natural ecosystems; natural disasters, coastal areas; human health; industrial and economic activity, life of citizenry, urban life.

Adaptation measures are identified for storm surges and high waves in the framework for *"Basic Directions for Measures"* in relation to "*Natural Disasters, Coastal areas*". In that respect, the following projected risks are recognised: 1) Increase of coastal erosion due to long-term sea-level rise; 2) Storm surges and stronger waves as a result of increase of typhoon strength due to climate change; 3) Risk for damage to coastal protection facilities and breakwaters in harbours and fishing ports due to increase in wave height and storm surges. To address the projected risks, the following adaptation measures are mentioned: 1) Improvement of facilities for more robust structures and coastal disaster prevention forests; 2) Monitoring for weather and marine change / Impact assessment using simulations of projections for inundation due to storm surges and high waves; 3) Development of technologies for levees, measures against coastal erosion and so on. Further transportation-related adaptation measures are identified in the context of *"Basic Directions for Measures"* with regards to *"Life of Citizenry, Urban Life"*.

Sources and additional information:

- Japan, *Climate Change Adaptation Act*, Act No. 50 of 2018, available at: http://www.japaneselawtranslation.go.jp/law/detail/?id=3212&vm=04&re=01
- Ministry of Environment, *Outline of National Adaptation Plan*, November 2018, available at: https://www.env.go.jp/en/earth/cc/adaptation/mat02.pdf
- Government of Japan, Ministry of Environment, *Adaptation*, available at: https://www.env.go.jp/en/earth/cc/adaptation.html

Singapore's Climate Action Plan 2016

Country/Region: Singapore, Asia

Date: 2016

- ✓ New port and airport terminals to be built higher due to rising sea levels
- ✓ Climate change adaptation measures for coastal transport infrastructure

As an island State and a major port city, Singapore is particularly vulnerable to the impacts of climate change. Against this backdrop, *Singapore's Climate Action Plan, Take Action Today for a Sustainable Future* was adopted in 2016, that includes two complementary documents on Singapore's climate change mitigation and adaptation plans. The first document, "*Take Action Today, for a Carbon-Efficient Singapore*", contains information on how Singapore intends to reduce greenhouse gas emissions and increase energy efficiency. The second document, "*A Climate-Resilient Singapore, for a Sustainable Future*", explains how Singapore may be affected by climate change, and foresees the strategy to address these challenges.

Climate change adaptation efforts contained in the (second) document entitled "*A Climate-Resilient Singapore, for a Sustainable Future*" cover the following areas: 1) Protection of coastal areas, 2) Management of water supply and floods 3) Protection of biodiversity and greenery; 4) Strengthening of resilience in public health and food supply; 5) Protecting network infrastructure and buildings from climate change. In relation to network infrastructure, the following key risks are identified: Intense rainfall, sea level rise, temperature changes that could affect the operation of telecommunications, power, and transport infrastructure.

The document notes that Singapore is home to one of the world's busiest hub ports with more than 130,000 ships calling at the island-state and more than 30.9 million 20-foot equivalent units (TEUs) of containers passing through its ports annually. In order to incorporate further resilience requirements into the planning of new terminals, the document highlights that the latest sea level rise projections have been factored into the design of the new Tuas terminal and it will be built more than two metres (m) higher than the highest water level observed. Furthermore, the Changi Airport Terminal 5 will be built 5.5m above mean sea level, according to the document.

The 2018 version of the *Singapore's Climate Action Plan, Take Action Today for a Sustainable Future* contains a Case study entitled "*Building Our New Changi Airport Terminal 5 And Tuas Port Terminal At Higher Levels*". This Case study of the 2018 Plan stipulates that the new Tuas Port Terminal will be built more than 5 m higher than the mean sea level and the new Changi Airport Terminal 5 to be built 5.5 m above the mean sea level to ensure the continued resilience of port and airport services.

Sources and additional information:

- *Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future*, Ministry of the Environment and Water Resources | Ministry of National Development, Singapore, 2016, available at: https://www.nccs.gov.sg/docs/default-source/publications/a-climate-resilient-singapore-for-a-sustainable-future.pdf
- *Singapore's Climate Action Plan: A Climate-Resilient Singapore, For a Sustainable Future,* Sustainable Singapore, Climate Action, 2018
- Adapting to climate change, Singapore Government, National Climate Change Secretariat, Strategy Group Prime Minister's Office, available at: https://www.nccs.gov.sg/climate-change-and-singapore/adapting-to-climate-change

Republic of Nauru Framework for Climate Change Adaptation and Disaster Risk Reduction 2015

Country/Region: Nauru, Pacific

Date: 2015

✓Climate change adaptation linked to disaster risk reduction (DRR)

✓ Priority climate change adaptation and DRR activities for coastal infrastructure

The *Framework for Climate Change Adaptation and Disaster Risk Reduction* (RONAdapt) was adopted by the Government of Nauru (2015) with a view to responding to the risks to sustainable development posed by climate change and disasters. RONAdapt was developed with the aim of:

- Identifying "*immediate priorities relating to climate change adaptation (CCA) and disaster risk reduction (DRR) in order to clearly articulate these for all government ministries, state owned enterprises, the private sector, civil society, communities and development partners to engage with*"; and
- Providing a "*general framework for longer term planning and programming of CCA and DRR activities, including guidance on their mainstreaming in national and sectoral development policies. This includes setting out the key principles that are expected to guide CCA and DRR planning in Nauru, as well as clarity on the roles and responsibilities of different stakeholders*".

The Framework links climate change adaptation and disaster risk reduction. It addresses a variety of sectors (water, energy etc.) and specifically covers infrastructure and coastal protection. The document sets out the principles upon which planning should be based, including focusing on vulnerability in its holistic sense. It contains information on the national and international broader policy context for climate change adaptation and disaster risks reduction, provides key activities to be undertaken in the near-term by different ministries, and presents institutional arrangements for reducing vulnerability and risks associated with climate change and disasters.

The Framework notes that the majority of Nauru's housing and its economic infrastructure are located in the low-lying coastal strip, including airports and ports. Consequently, the Framework lists infrastructure and coastal protection as priority areas for climate change adaptation and disaster risk reduction. It also outlines corresponding "prioritised high-level strategies" for addressing climate change adaptation and disaster risk reduction in the sector that include: i) Reduce coastal risks to key infrastructure; and ii) Reduce flooding occurrence and intensity. Proposed activities to implement these strategies are summarized in Table 4.5. Seaports and airports are considered as critical assets to ensure supply of essential goods and services, as well as for the exportation of phosphate and dolomite. The Framework highlights the need to design and manage infrastructure with future conditions in mind, as vital infrastructure is threatened by sea level rise and associated coastal erosion, but also flooding, storm surges, or fires. Finally, the Framework outlines priority institutional actions with a view to institutional strengthening and mainstreaming.

Table 4.5 Priority infrastructure and coastal management actions contributing to CCA and DRR. Reproduced from the Framework for Climate Change Adaptation and Disaster Risk Reduction, Republic of Nauru (2015)

Infrastructure and coastal protection		
Strategy	**Activity**	**Lead**
Reduce coastal risks to key infrastructure	Conduct **coastal vulnerability assessment and mapping**, with strong focus on community involvement, to identify key infrastructure at risk from coastal hazards and identify options to reducing risks. Assessment of coastal activities and management practices, as well as biophysical coastal processes, as a platform for making informed coastal management decisions. Develop an **Integrated Coastal Zone Management Plan**, identifying priority areas for reinforcement/protection, adjustments in land management, and possible relocation needs for specific high-risk assets.	Department of Commerce, Industry and Environment
Reduce flooding occurrence and intensity	Develop and implement heavy rainfall and local **flooding contingency plans** Design and construction of **drainage infrastructure**, to reduce flood risks in critical location	Ministry of Finance Planning and Aid Division, National Disaster Risk Management Office

Source and additional information:

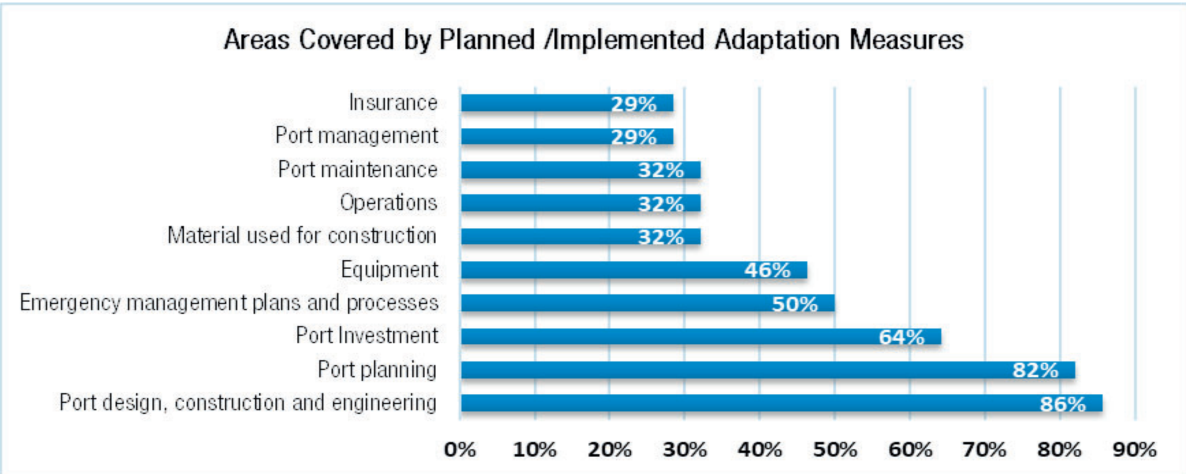
Republic of Nauru, *Framework for Climate Change Adaptation and Disaster Risk Reduction*, 2015, available at: https://nauru-data.sprep.org/group/nauru-department-commerce-industry-and-environment?sort_by=changed&f%5B0%5D=field_tags%3A55&f%5B1%5D=field_tags%3A57

5. Reports, studies and guidance on climate change impacts and adaptation for coastal transport infrastructure

A number of seaports and airports across regions have begun initiating measures to address the implications of climate change. Often, however, these actions tend to focus more on climate mitigation rather than on increasing levels of preparedness to respond to the impacts of climate change and the development of adaptation action. Examples of climate change adaptation practices at seaport and airport level are therefore less common. This is in line with the findings of a recent UNCTAD port-industry survey on the availability of weather and climate-related information as wells as on the level of preparedness and climate-resilience among ports, which indicate that there is a need to strengthen and accelerate efforts with a view to climate change adaptation for coastal transport infrastructure at facility levels (Asariotis et al., 2017).

Nevertheless, there are seaports and airports worldwide that have started building their resilience to climate change and address the possible impacts they are likely to face in the (near) future. 58 per cent of respondent ports to the UNCTAD port-industry survey confirmed the availability of existing or planned corporate adaptations strategies (Asariotis et al., 2017). When ports were asked to identify areas/aspects covered by implemented or planned adaptation measures, respondent ports indicated port engineering and planning as the most common fields where adaptation measures were implemented or planned (Fig. 5.1). It appears that respondents consider mostly 'hard' adaptation measures, rather than 'soft' adaptation responses involving e.g. the development of 'fit for purpose' emergency management plans and processes, or appropriate changes in port operations and management.

Figure 5.1 Areas covered by planned/implemented adaptation measures as revealed by the UNCTAD Port Industry Survey on Climate Change Impacts and Adaptation (Asariotis et al., 2017)



This Chapter presents a selection of reports and other studies on coastal transportation-related climate change adaptation efforts by seaports and coastal airports, as well as relevant guidance in support of the development of facility specific adaptation approaches. Examples selected are practical and/or conceptual nature and highlight the wide scope of initiatives that can contribute to assessing climate change impacts/risks and developing climate change adaptation measures for coastal transport infrastructure. Reports and studies presented cover either several coastal transport assets or showcase practices associated with individual coastal transport asset. Once again, the selection presented in this Chapter does not intend to be exhaustive. Reports and studies are to be considered as examples, to share relevant knowledge and enable further reflection on the topic. Relevant guidance, such as developed by industry organization PIANC and by UNCTAD, as well as the ISO Standard 14090 may be of assistance in the development of structured approaches to adaptation planning that may be used at facility level.

World Bank, Climate and Disaster Resilient Transport in Small Island Developing States: A Call for Action

Country/Region: SIDS

Date: 2017

✓Focus on transport in SIDS

✓ Policies and measures to enhance resilience

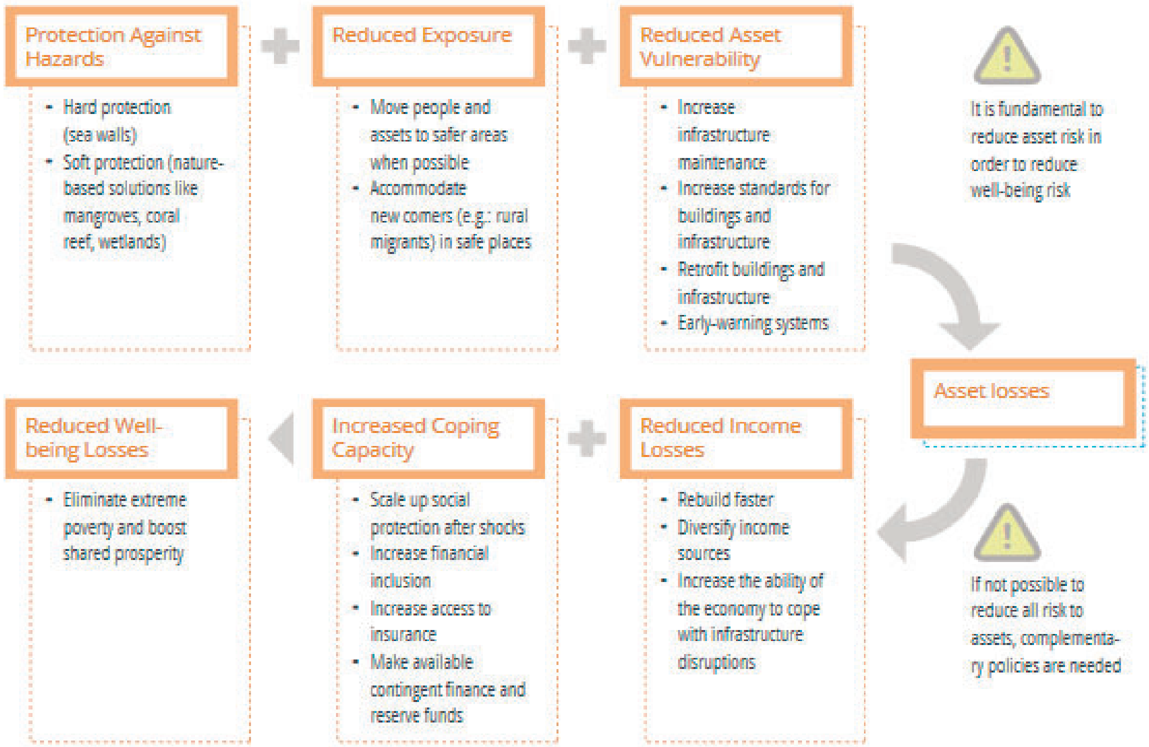
✓ Ports and airports

✓Worldwide case studies

Climate and Disaster Resilient Transport in Small Island Developing States: A Call for Action exposes the challenges and reality that SIDS are facing with respect to natural disasters and climate change impacts. Published by the World Bank in 2017, it is a report that aims to support the integration of climate and disaster risk considerations in transport infrastructure lifecycle management to enhance the resilience of transport systems. It provides an overview of the vulnerability of SIDS to natural disasters and climate change impacts and suggests possible actions on policies and measures to enhance resilience.

In that context, the following set of policies and measures are presented (Fig. 5.2) to limit the impact of disasters and climate change and so reduce losses in assets, income and well-being:

Figure 5.2 Policies and Measures to Reduce Asset, Income, and Well-being Losses from Natural Disasters, World Bank, Climate and Disaster Resilient Transport in Small Island Developing States: A Call for Action



The report further discusses the integration of climate change risks into transport asset management systems and proposes a path to address people, processes and technology elements of those systems through the following four components: (a) development of a country needs assessments and transition plans for integrating resilience into decision making; (b) deployment of selected solutions to enhance resilience of the transport sector; (c) capacity building and knowledge exchange among SIDS; and (d) fundraising and reassessing capital needs.

The report also presents 14 examples classified as 'best practices and case studies' to illustrate the possible practical ways to strengthen resilience of transport systems. The various examples showcase experiences in integrating climate change and disaster risks considerations in transport infrastructure lifecycle. The list of examples is reproduced in Table 5.1.

Table 5.1 Overview of case studies on resilient transport experiences in SIDS. Reproduced from World Bank, Climate and Disaster Resilient Transport in Small Island Developing States: A Call for Action

Systems Planning	Engineering & Design	Operations & Maintenance	Contingency Programming
Case Study 1 / Samoa: Enhanced Systems Planning to Better Prepare for and Respond to Natural Disasters and Climate Change Impacts	**Case Study 3 / Kiribati & Tuvalu:** Climate and Disaster Resilience Roads Using Geocell Concrete Pavements	**Case Study 6 / Dominica:** Development of a Risk-based Infrastructure Asset Management System	**Case Study 11 / Caribbean** Using the CERC in Limited Capacity Environments to Reduce Road Network Interruptions following a Disaster
Case Study 2 / Mozambique: Prioritization of Road Interventions under Flood Risks and Uncertainty	**Case Study 4 / Coral atolls of the Pacific Islands:** Local Materials for Climate Resilient Coastal Protection	**Case Study 7 / Saint Lucia:** Using Smartphone Apps to Increase Resilience of Road System	**Case Study 12 / Tonga:** Emergency Response System and Procurement Regulations
	Case Study 5 / Sri Lanka: Geosynthetic Reinforced Soils for Rapid and Low Cost Bridges	**Case Study 8 / Belize:** Information Management Systems for Enhanced Resilience of Transport Assets	
		Case Study 9 / Vietnam: Empowering Women to Manage Rural Road Maintenance: Lessons from Vietnam	
		Case Study 10 / Sao Tomé and Principe: Building Resilience Through Communities Involvement in Road Maintenance	
Case Study 13 / Tuvalu: Climate and Natural Disaster Resilient Airport			
Case Study 14 / Colombia: Climate Risk Assessment for Muelles el Bosque Port			

<u>**Source and additional information**</u>:

- World Bank, *Climate and disaster resilient transport in small island developing states: a call for action*. Washington, D.C.: World Bank Group, 2017, available at: http://documents.worldbank.org/curated/en/879491510323939763/Climate-and-disaster-resilient-transport-in-small-island-developing-states-a-call-for-action

Ng et al., Climate Change and Adaptation Planning for Ports

Country/Region: Global

Date: 2016

✓ Worldwide case studies

✓Theoretical and methodological frameworks

✓ Challenges and lessons learned

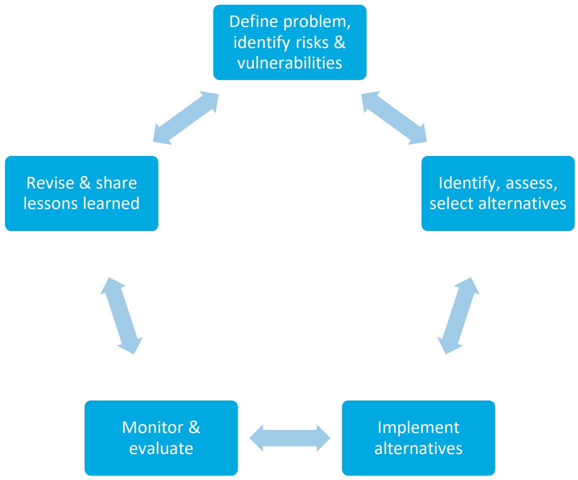
Climate Change and Adaptation Planning for Ports is an edited volume on the impacts of climate change on seaports. It aims to identify international practices, planning and appropriate policies to effectively adapt to, develop resilience, and benefit from, the impacts posed by climate change on transportation and supply chains. It contains methodologies and case studies from Asia, Europe, Latin America, North America and Oceania illustrating how climate change is impacting port infrastructure and how it is tackled by regionally defined adaptation solutions – while also highlighting challenges faced by ports.

The edited volume presents the following case studies (total of 13):

- ‘Climate change and adaptation strategies of Canadian ports and shipping – the case of the St. Lawrence-Great Lakes system’
- ‘Climate change and the adaptation planning of inland port and rail infrastructures in the province of Manitoba in Canada’
- ‘The impacts of Hurricane Sandy on the Port of New York and New Jersey – Lessons learned for port recovery and resilience’
- ‘Climate adaptation of German North Sea ports – The example of Bremerhaven’
- ‘Port planning and climate change – Evidence from Italy’
- ‘Adaptation to an increase in typhoon intensity and sea level rise by Japanese ports’
- ‘Modeling and evaluation of green port development – A case study on Tianjin Port’
- ‘Terminal Maritimo Muelles el Bosque, Cartagena, Colombia’ [13]
- ‘Climate change adaptation in the Panama Canal’
- ‘The impact of climate change on Australian ports and supply chains – The emergence of adaptation strategies’
- ‘A decision support toolkit for climate resilient seaports in the Pacific region’
- ‘Canada’s Arctic shipping challenge – Towards a twenty-first century Northwest Passage’
- ‘Arctic transportation and new global supply chain organizations – The Northern Sea Route in international economic geography’.

[13]More detailed information on this study can be found in the example ‘Climate Risk and Business: Ports – Terminal Marítimo Muelles el Bosque (Cartagena, Colombia)’.

Figure 5.3 The process of adaptation to climate change impacts (after Moser and Ekstrom, 2010), reproduced from Ng et al., 2016



In addition to the case studies, the edited volume discusses the roles of adaptation practitioners and institutions in ports' adaptation planning and introduces a model for risk assessments to help policymakers and industrial practitioner develop effective adaptation strategies, plans and actions. The last chapter of the book concludes with a contextualization of the cases, which are drawn upon to discuss all steps of a framework for adaptation, as presented in Figure 5.3.

Source and additional information:

- Adolf K. Y. Ng, Austin Becker, Stephen Cahoon, Schu-Ling Chen, Paul Earl and Zaili Yang (eds), *Climate Change and Adaptation Planning for Ports*, Routledge: New York, 2016.

PIANC Guidance on Climate Change Adaptation Planning for Ports and Inland Waterways

Country/Region: Global

Date: 2020

✓ Industry guidance on climate change adaptation for ports and inland waterways

✓ Methodological framework

✓ Portfolio of possible climate change adaptation measures

The World Association for Waterborne Transport Infrastructure, PIANC, the key non-profit organisation representing global waterborne transport infrastructure has been elaborating industry guidance on climate change adaptation planning for ports and inland waterways. The PIANC *Guidance on Climate Change Adaptation Planning for Ports and Inland Waterways* (published in 2020) contains a methodological framework and a portfolio of possible adaptation and resilience measures, developed through an extensive international engagement exercise.

The Guidance reflects a "*staged approach to identifying and assessing possible climate change adaptation measures for waterborne transport infrastructure*." In that context, the following stages and corresponding steps are identified (Table 5.2).

Table 5.2 Main stages of the PIANC methodology on climate change adaptation planning for ports and inland waterways, Retrieved from PIANC, Guidance on Climate Change Adaptation Planning for Ports and Inland Waterways

Stage		Step
Stage 1	Understand the context and objectives	- Scope the assessment and set high level goals - Understand critical infrastructure assets, operations and systems - Indicate susceptibility - Identify relevant stakeholders - Set adaptation objectives - Determine data needs and management
Stage 2	Understand climate-related impacts	- Identify relevant climate parameters and processes - Collate baseline information - Collate future projections - Understand future climate-related hazards based on scenarios
Stage 3	Understand vulnerabilities and risks	- Understand existing exposure of an asset, operation or system - Establish changes in susceptibility - Understand vulnerability of assets, operations or systems - Carry out risk analysis
Stage 4	Identify and implement measures	- Understand the implications of uncertainty - Refer to the portfolio of measures - Screen long-list of potential options - Detailed evaluation of shortlisted options - Agree on adaptation pathways - Determine implementation priorities and prepare strategy - Implement adaptation action

For each stage presented above, the detailed methodology sets out not only suggested tasks, but indicative steps for each task along with important considerations. In addition, the Guidance includes a portfolio of possible adaptation and resilience measures, presented as options for adapting or strengthening the resilience of navigation infrastructure assets, operations and systems. Whilst PIANC highlights that the portfolio is intended as a "*source of ideas and inspiration*" instead of a comprehensive list of possible solutions, reference can be made to detailed lists of physical (structures; systems; technologies; services), social (people; behaviour; operations; information) and institutional (governance; economics; regulation; policy) measures for each of the following predicted type of impact:

- Rainfall-related flooding
- Flooding due to overtopping
- High flow or changes in sea state
- Low flow or drought
- Changes in sediment regime
- Bed or bank erosion
- Reduced visibility
- Change in wind characteristics
- Extreme cold, ice or icing
- Extreme heat or humidity
- Ocean water acidity
- Salinity or salt water intrusion
- Vegetation growth
- Species migration or change in range
- Native species survivability
- Invasive, non-native species

Sources and additional information:

- *PIANC EnviCom WG 178 - 'Climate Change Adaptation Planning for Ports and Inland Waterways'*, available at: https://www.pianc.org/publications/envicom/wg178
- Jan Brooke, World Association for Waterborne Transport Infrastructure (PIANC), *Climate change adaptation guidance for ports and inland waterways [presentation],* UNCTAD Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future, 16 to 17 April 2019, available at: https://unctad.org/meetings/en/Presentation/dtltlbpls-AhEM2019_p04_JAN%20BROOKE_en.pdf
- PIANC, *Navigating a Changing Climate, Adaptation of Inland and Maritime Navigation Infrastructure*, available at: https://www.pianc.org/think-climate
- PIANC, *Climate change adaptation - Detailed Steps*, available at: https://www.pianc.org/climate-change-adaptation-detailed-steps
- PIANC, *Climate Change adaptation - Portfolio of measures*, available at: https://www.pianc.org/climate-change-adaptation-portfolio-of-measures
- *PIANC Permanent Task Group on Climate Change* (PTG CC), available at: https://www.pianc.org/permanent-task-group-on-climate-change

Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I and II

Country/Region: United States of America, North America

Date: 2008 – 2015

✓ Seminal study on climate change impacts on transportation

✓Vulnerability assessment tools

✓Evaluation of critical transportation components

The Gulf Coast Study is a comprehensive multi-phase research, which aimed to provide knowledge and tools to enable transportation planners and managers to better understand the risks, adaptation strategies, and trade-offs involved in planning, investment, design, and operational decisions. The study was conducted by the U.S. Department of Transportation to increase the understanding of climate change impacts on transportation infrastructure and to identify potential adaptation strategies. In addition to reports, the study also led to the development of vulnerability assessment tools.

Phase I of the study, which took place from 2003 to 2008, examined the impacts of climate change on transportation infrastructure at a regional scale, notably in the U.S. Central Gulf Coast between Galveston, Texas, and Mobile, Alabama. This region contains multimodal transportation infrastructure that is critical to regional and national transportation services. This first phase addressed the risks that the transportation system faces from climate change and what is needed to ensure its safety and resilience. Historical trends and future climate scenarios were used to establish a context for examining the potential effects of climate change on all major transportation modes within the region. The study assessed likely changes in temperature and precipitation patterns, sea level rise, and increasing severity and frequency of tropical storms, and then explored how these changes could impact transportation systems.

Phase II, completed in 2014, involved an assessment of risks to transportation in a selected location, focusing on Mobile, Alabama. This phase of the study sought to evaluate which transportation infrastructure components are critical to economic and societal function and assess the vulnerability of these components to weather events and long-term changes in climate. It evaluated the impacts on six transportation modes (highways, ports, airports, rail, transit, and pipelines) from projected changes in temperature and precipitation, sea level rise, and the storm surges and winds associated with more intense storms.

This second phase also led to the development of risk management tools to help transportation system planners, owners and operators determine which systems and assets to protect and how to do so. The vulnerability assessment tools consist of the following:

- An **asset sensitivity matrix** to help identify the sensitivity of different asset types to climate stressors – spread sheet tool that documents the sensitivity of roads, bridges, airports, ports, pipelines and rail to 11 climate impacts;
- A **guide to assessing criticality of assets** that discusses common challenges associated with assessing criticality, options for defining criticality and identifying scope, and the process of applying criteria and ranking assets;
- A **climate data processing tool**, which consists of a spread sheet tool that produces statistics relevant for transportation planners, using raw climate model outputs; and
- A **vulnerability assessment scoring tool** in the form of a spread sheet tool to help agencies screen for asset vulnerabilities and prioritize assets.

The methods and tools developed under phase II were intended to be replicable to other regions in the country. According to the U.S. DOT Federal Highway Administration, several departments of transportation and metropolitan planning organizations used pre-release versions of these tools in climate resilience pilot programs.

Sources and additional information:

- CCSP, *2008: Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research [Savonis, M. J., V.R. Burkett, and J.R. Potter (eds.)]. Department of Transportation, Washington, DC, 445 pp, available at: https://digital.library.unt.edu/ark:/67531/metadc12034/
- ICF International, *Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: The Gulf Coast Study, Phase 2.* Assessing Transportation System Vulnerability to Climate Change: Synthesis of Lessons Learned and Methods Applied. Final Report, Task 6. A report by ICF International. Department of Transportation, Washington, DC, 2014, 46p, available at: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/gulf_coast_study/phase2_task6/fhwahep15007.pdf
- Mike Savonis, 'Assessing Climate Change Vulnerability at the Port of Mobile, AL: Gulf Coast Phase 2' [PowerPoint presentation], Scoping Workshop on Sea Ports and Climate Change, March 5, 2013. Retrieved from: https://ec.europa.eu/assets/jrc/events/20130304-sea-ports/20130304-sea-ports-savonis.pdf
- U.S. Department of Transportation, Federal Highwater Administration, Office of Planning, Environment, & Realty > Environment > Sustainability > Resilience > Ongoing and Current Research > Gulf Coast Study, available at: https://www.fhwa.dot.gov/environment/sustainability/resilience/ongoing_and_current_research/gulf_coast_study/index.cfm

Enhancing the resilience of seaports to a changing climate report series

Country/Region: Australia

Date: 2013

✓Series of reports

✓Climate change adaptation guidelines for ports

✓ "Hybrid" climate change risk/vulnerability assessment

Enhancing the resilience of seaports to a changing climate report series synthesizes the research findings of the '*Climate Resilient Seaports*' project conducted between 2011 and 2012. The objective of the project was to better understand the vulnerability of critical seaport assets (structural and functional) in Australia and to develop new knowledge and methodologies for enhancing the resilience of seaports to future climate change. It sought to contribute to an emerging knowledge base relating to climate change and seaports, to test and refine assessment methodologies, and to develop tools to assist decision-making by port personnel.

The project consisted of a multi-disciplinary research conducted through four work packages, which lead to the development of five reports. Gladstone Ports Corporation, Sydney Port Corporation, and Port Kembla Corporation were selected as case studies for the project. These ports are located on the Eastern seaboard of Australia and are representative of two different climate zones: warm humid and temperate.

The five reports produced by the project collectively generated technical, policy and operational recommendations for enhancing the resilience of Australian seaports to a changing climate. They consist of the following:

1. **'Understanding future risks to ports in Australia'** (part of the first work package) is a research, which sought to better understand the future climate and non-climate risks that are likely to affect port operations in Australia. To this effect, a literature review was conducted, and an integrated assessment methodology was applied, whereby quantitative, qualitative and participatory approaches were used. Research activity for this package involved the sourcing, collaboration and interpretation of climate and non-climate data to inform the assessment activity for functional and infrastructural vulnerabilities; and the use of this information to scope potential adaptation options. The report documents the research and the findings.

   The following six components framed the integrated assessment of risks: i) Analysis of ports as systems; ii) Considering current (and past) weather/climate data; iii) Interpreting future climate projects; iv) Reconciling climate information with research needs (risk assessment and adaptation planning for functions, workforce and infrastructure); v) Compilation of climate information packs for each of the case study ports; and vi) Contextualizing with non-climate drivers.

2. **'Functional resilience of port environs in a changing climate – assets and operations'** (second work package): The objective of this component was to develop a research methodology that has the capacity to systematically assess the vulnerability of port assets, infrastructure and logistics operations within the port area. The study involved the development of an asset register; the investigation (and simulation) of possible impact of climate change related disruptions to container terminal operations through the development of an agent-based simulation tool; and an assessment of the adaptive capacity of the workforce to assess preparedness to manage

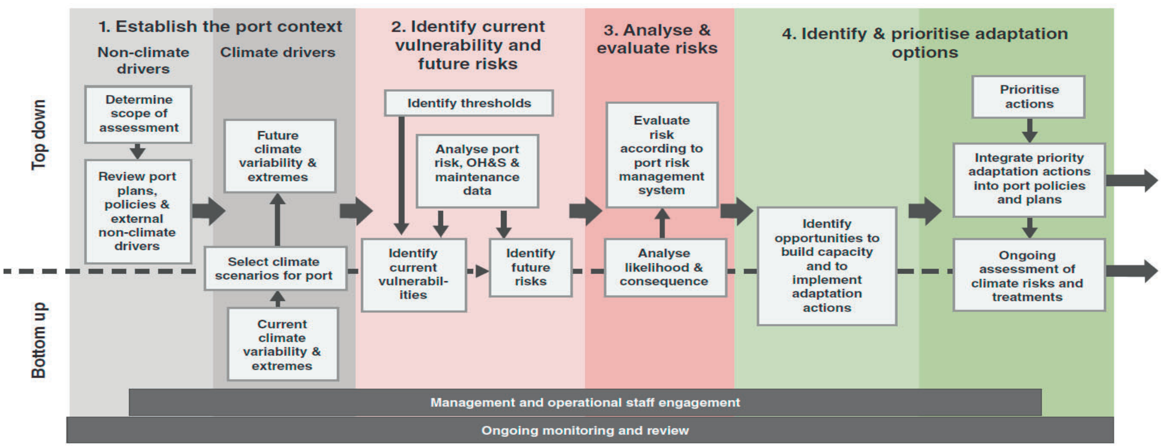
climatic shifts and extreme events. Two software tools were developed as part of this work package: a GIS-enabled Asset Register for Port Kembla Port Corporation and Container Terminal Operation Simulator for one particular terminal operating within the Sydney Port Corporation.

3. **'Structural resilience of core port infrastructure in a changing climate'** (third work package) concerned the longer-term deterioration rates of core port infrastructural assets under a changing climate. The research consisted of the following stages: identification of seaport structural assets; interpretation of climate data for the deterioration modelling; long-term deterioration modelling; generation of resilience matrices; development of a methodology for life-cycle cost analysis; and production of an online software tool for use by port engineers. The latter tool provides the progression of deterioration mechanisms affecting port structures.

4. **'Climate change adaptation guidelines for ports'**: It presents a framework intended to enable seaports to conduct "*hybrid climate change risk / vulnerability assessment*". Hybrid climate change risk/vulnerability assessment is defined in the report as the "*consideration of current day vulnerabilities to extreme weather events, integrated with an assessment of future climate risks*" (Fig. 5.4). This approach therefore seeks to guide port authorities in identifying such vulnerability and risks in a site-specific assessment, in order to help address concerns, which delay action on climate change adaptation. The document outlines key steps, divided by the following stages, involved as part of the assessment:

Stage 0	Getting started – Executive support
Stage 1	Establish the Port context
Stage 2	Identify current vulnerabilities and future risks
Stage 3	Analyse and evaluate risks
Stage 4	Identify and prioritise adaptation options
Stage 5	Monitoring and evaluation

Figure 5.4 Hybrid Vulnerability/Risk Assessment Process for Ports. Source: Scott, H, McEvoy, D, Chhetri, P, Basic, F, Mullett, J, Climate change adaptation guidelines for ports, Enhancing the resilience of seaports to a changing climate report series, National Climate Change Adaptation Research Facility, Gold Coast, 2013



The report contextualizes each step by using examples from studies and risk assessments from international seaports (UK, USA and Colombia) and three case study ports in Australia. In addition, it outlines the overarching process of various existing tools and guidelines available to assist ports with their assessment process.

5. Finally, the document **'Research synthesis and implications for policy and practice'** (part of the fourth work package) reports on each component and work package of the study, summarizing more exhaustively their content and objective, as well as the project's outputs.

Sources and additional information:

- McEvoy, D, Mullett, J, Millin, S, Scott, H & Trundle, *Understanding future risks to ports in Australia. Work Package 1 of Enhancing the resilience of seaports to a changing climate report series*, National Climate Change Adaptation Research Facility, Gold Coast, 2013, 77pp., available at: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/McEvoy_2013_Understanding_future_risks_to_ports_in_Australia_WP1.pdf
- Chhetri, P, Corcoran, J, Gekara, V, Corbitt, B, Wickramasinghe, N, Jayatilleke, G, Basic, F, Scott, H, Manzoni, A & Maddox, *Functional resilience of port environs in a changing climate – Assets and operations. Work Package 2 of Enhancing the resilience of seaports to a changing climate report series*, National Climate Change Adaptation Research Facility, Gold Coast. 2013, 118pp., available at: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Chhetri_2013_Functional_resilience_of_port_environs_WP2.pdf
- Kong, D, Setunge, S, Molyneaux, T, Zhang, G & Law, *Structural resilience of core port infrastructure in a changing climate. Work Package 3 of Enhancing the resilience of seaports to a changing climate report series*, National Climate Change Adaptation Research Facility, Gold Coast, 2013, 172pp., available at: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Kong_2013_Structural_resilience_core_port_infrastructure_WP3.pdf
- McEvoy, D &Mullett, J, *Enhancing the resilience of seaports to a changing climate: Research synthesis and implications for policy and practice*. *Work Package 4 of Enhancing the resilience of seaports to a changing climate report series,* National Climate Change Adaptation Research Facility, Gold Coast, 49pp., available at: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/McEvoy_2013_Enhancing_the_resilience_of_seaports_Synthesis_WP4.pdf
- Scott, H, McEvoy, D, Chhetri, P, Basic, F, Mullett, J, *Climate change adaptation guidelines for ports, Enhancing the resilience of seaports to a changing climate report series,* National Climate Change Adaptation Research Facility, Gold Coast, 2013, available at: http://global-cities.info/wp-content/uploads/2013/03/Climate-resilient-ports-series-Adaptation-Guidelines.pdf
- National Climate Change Adaptation Research Facility, Research> National Adaptation Research Plans >*Enhancing the resilience of seaports to a changing climate*, available at: https://www.nccarf.edu.au/content/enhancing-resilience-seaports-changing-climate

Associated British Ports Climate Change Adaptation Reports

Country/Region: United Kingdom of Great Britain and Northern Ireland, Europe

Date: 2011 and 2016

✓ Climate risks assessment process

✓Key climate change risks: Sea level rise, increased storm events and temperature changes

The *Climate Change Adaptation Reports* of the Associated British Ports (ABP) illustrate the practical implementation of the UK Climate Change Act 2008, addressed in Chapter 3.2 of this compilation. Pursuant to this Act, ABP, which operates 21 ports in the UK, has been directed by the Department for Environment Food and Rural Affairs (Defra) to report on climate change adaptation in relation to its role as harbour authority in four locations: Humber, Immingham, Hull and Southampton. ABP produced its first Climate Change Adaptation Report in 2011 and updated it in 2016.

The 2011 report is ABP's response to the request by Defra to report on climate change adaptation. The report provides a summary of the role of each harbour authority and informs on the functions that are likely to be affected by climate change, considering engineering, dredging, hydrography, vessel traffic service/local port service operations, pilotage and nature conservation. It further identifies potential risks and assesses each authority functions against them.

The following risks have been considered: i) Sea level rise and flooding; ii) Storm events and extreme weather, temperature, humidity, and precipitation; iii) Sedimentation; iv) Coastal erosion; v) Water temperature; vi) Water quality; and vii) Habitats and species.

For the latest report (2016), ABP reviewed the climate change risks "*based upon the latest information*" and incorporated ABP's "*more recent plans and programs to manage the increasing risks*" across the four identified locations. The report provides examples of climate-related events with a summary of impacts on ABP along with expected impacts due to climate change. It states that the risks potentially impacting the function of a harbour authority remained unchanged since the 2011 original report.

<u>Risk assessment process</u>

ABP conducted a risk assessment process, whereby each harbour authority function was assessed against the identified climate change risks. The impact and likelihood were assessed to ascertain whether the impact to ABP is considered to be high, medium or low. Impact was assessed and scored against the highest of the financial impact, reputation impact or service interruption.

Figure 5.5, extracted from the 2016 report, presents an example of the outcome of the risk assessment process covering the following elements: i) identified climate variable and its primary impact; ii) thresholds above which business function will be affected; iii) potential impact on organisation and stakeholders; iv) impact; v) likelihood; vi) risk rating; vii) proposed action to mitigate impact; viii) residual risks for the Harbour Authority and those outside of the Harbour Authority control.

Figure 5.5 Example of ABP's risk assessment process. Reproduced from Associated British Ports, Climate Change Adaptation Report 2016 Update, July 2016

Business function	Climate variable	Primary impact of climate variable	Threshold(s) above which business function will be affected	Potential impacts on organisation and stakeholders	Impact	Likelihood	Risk rating	Proposed action to mitigate impact	Residual risks for the Harbour Authority	Residual risks outside Harbour Authority control (interdependency)
Engineering	Sea Level Rise / Flooding	Flooding / damage of harbour authority assets.	Nominal quay height or standard of protection of sea defences.	Damage to infrastructure including electricity supply (and backup generators), loss of operation. Potential knock-on effects to other critical infrastructure.	3	4	High	Impact has occurred at Immingham and Hull; There has been significant investment to improve resilience of critical infrastructure (electricity, sub-stations, IT etc.). Updated business Continuity Plans, Flood Resilience Planning and safety Management System.	Uncertainty in extreme water levels may leave residual risk of flooding out with port control. Construction programs for individual asset improvements ongoing.	Electricity, communication and rail infrastructure outside port. On the Humber ports the failure of third-party flood defence schemes could increase the risks.

Sources and additional information:

- Associated British Ports, *Climate Change Adaptation Report: Humber, Hull, Immingham and Southampton Harbour Authorities*, 2011, available at: http://webarchive.nationalarchives.gov.uk/20130124005001/http://archive.defra.gov.uk/environment/climate/documents/adapt-reports/07ports/associated-british-ports.pdf
- Associated British Ports, *Climate Change Adaptation Report 2016 Update*, July 2016, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/573573/climate-adrep-associated-british-ports.pdf

ISO 14090 Standard on Adaptation to climate change

Country/Region: Global

Date: 2019

✓ International standard for adaptation to climate change

✓Generic, applicable to any organisation

The ISO (International Organization for Standardization) 14090 Standard *on Adaptation to climate change — Principles, requirements and guidelines* is a generic standard for adaptation to climate change. Adopted in June 2019, the main purpose of the standard is to "*provide organizations with a consistent, structured and pragmatic approach to prevent or minimize the harm that climate change could cause and also to take advantage of opportunities".*

Whilst not coastal transport-specific, the standard is intended to allow any organisation, irrespective of size and type, to give appropriate consideration to climate change adaptation when designing, implementing, improving and updating policies, strategies, plans and activities. The approach incorporated in the document is of non-linear nature to allow its use at any stage of the climate change adaptation process, in addition to supporting continual learning and improvement processes.

The standard first provides definitions along with listing principles of climate change adaptation before outlining six (6) stages of the climate change adaptation process an organisation might want to consider. These stages of the climate change adaptation process are the following: 1. Pre-planning; 2. Assessing impacts including opportunities; 3. Adaptation planning; 4. Implementation; 5. Monitoring and evaluation; 6. Reporting and communication. Further detailed elements of each stage are provided to guide organisations throughout the climate change adaptation process. Notes in relation to specific matters along with suggested further reading contained in the document are intended to enrich the process. An informative annex addresses systems thinking to assist organisations in setting boundaries for climate change adaptation.

In relation to assessing climate change impacts directly and indirectly effecting organisations, examples listed in the document include, *inter alia*, loss of coastal infrastructure, storm surge, flooding, disruption to supply chains and distribution networks. Risk assessment, vulnerability assessment and threshold analysis are listed as impact assessment methods. Further guidance, including practical examples, is provided on the threshold analysis by a second informative annex attached to the document. A coastal city with flood resilience infrastructure in place to a threshold of 0,7 m sea level rise is cited in this annex as an example for identifying suitable indicators.

Sources and additional information:

- *International Standard ISO 14090, Adaptation to climate change — Principles, requirements and guidelines,* available at: https://www.iso.org/home.html
- John Dora, *A Framework for 'Adaptation to climate change', How new standards for climate change adaptation can address most (if not all) transport adaptation issues [presentation],* UNCTAD Ad Hoc Expert Meeting on Climate Change Adaptation for International Transport: Preparing for the Future, 16 to 17 April 2019, available at: https://unctad.org/meetings/en/Presentation/dtltlbpls-AhEM2019_p20_JOHN%20DORA_en.pdf

UNCTAD, Climate risk and vulnerability assessment framework for Caribbean coastal transport infrastructure

Country/Region: Caribbean

Date: 2017

✓ Methodology on climate risk and vulnerability assessment for coastal transport infrastructure

✓Beach erosion GUI

As part of a technical assistance project on "*Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of SIDS*", implemented by UNCTAD over the period 2015–2017, in collaboration with a range of partners (https://SIDSport-ClimateAdapt.unctad.org), a methodology was developed to assist transport infrastructure managers and other relevant entities in SIDS in assessing climate-related impacts and adaptation options in relation to coastal transport infrastructure: '*Climate Risk and Vulnerability Assessment Framework for Caribbean Costal Transport Infrastructure*'.

The methodology provides a structured framework for the assessment of climate-related impacts with a view to identifying priorities for adaptation and effective adaptation planning for critical coastal transport infrastructure. It takes a practical approach that uses available data to inform decision-making at a facility, local, and national level. Technical elements include an 'operational thresholds' method, using operational thresholds to determine the climatic conditions under which facility operations might be impeded, as well as marine inundation modelling. The primary audience are port and airport managers in Caribbean SIDS, though it will also be relevant to local and national government agencies. At the same time, the methodology is transferable, subject to location-specific modification, for use in other SIDS within the Caribbean and beyond.

The framework includes four major stages (see Fig. 5.6):

1. **Set Context and Scope** – At the outset, briefly set the parameters for the assessment.
2. **Assess Criticality** – Understand the contributions of different elements of the transport system to the society and economy.
3. **Assess Vulnerability** – Understand how critical elements of the transport system respond to climate stresses, and how risks of costly damages or disruptions may change in the future.
4. **Develop Adaptation Strategies and Mainstream in Existing Processes** – Identify where further analysis is needed (and if so, circle back to stage 3), and where action can be taken without further analysis. Understand available options and strategies to reduce risks from climate variability and change. Monitor and evaluate to adaptively manage over time.

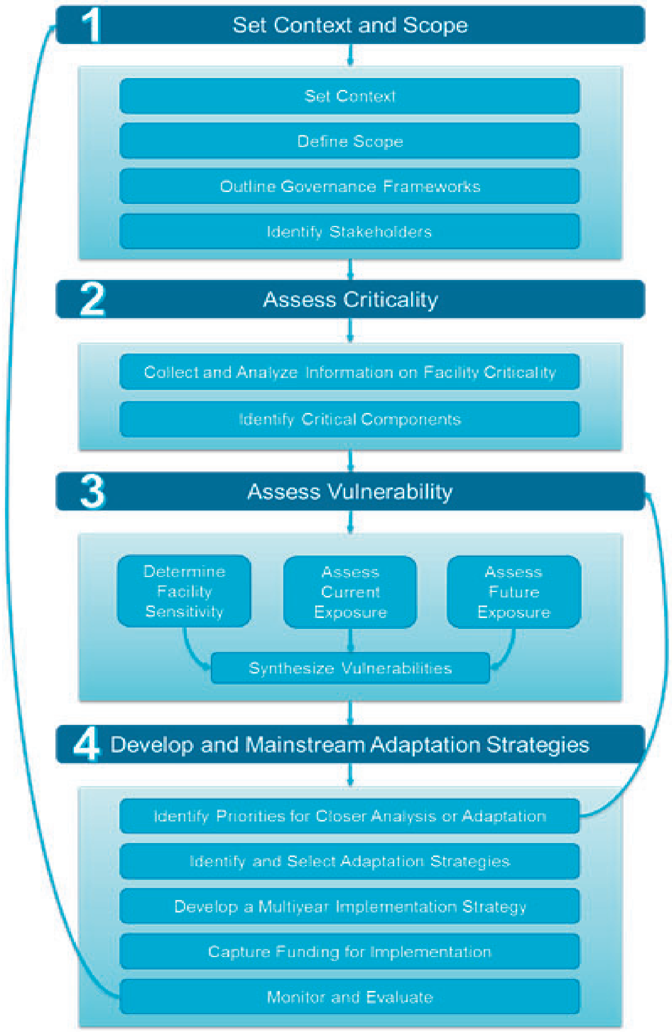
For each stage, the framework provides guidance and examples for how to conduct the assessment. The framework allows for flexibility based on available data, stakeholder engagement, and other relevant factors. The framework outlines a continuum of approaches that can be used depending on data available, ranging from a quantitative "Sensitivity Threshold Method" to more qualitative approaches within the same overall framework. Text boxes and other examples throughout provide alternate methods that may be preferable in some circumstances.

Three key principles apply throughout the process, and can inform the method used for each step:

1. **Keep the end goal in mind**: The purpose of assessing climate change vulnerability is to improve decision-making with respect to climate variability and change.

2. **Work within data limitations:** In any climate change vulnerability assessment, data availability will be less than ideal. Data limitations need not curtail adaptation efforts. This framework provides guidance on dealing with specific data deficiencies at each stage.
3. **Engage stakeholders:** Stakeholder engagement is central to an effective climate change vulnerability assessment process.

Figure 5.6 Schematic overview of 'Climate Risk and Vulnerability Assessment Framework for Caribbean Costal Transport Infrastructure'



As part of the UNCTAD project, a *beach retreat prediction methodology* was used to assess the ranges of long- and short-term beach retreats/erosion for different beach slopes in a Caribbean island (Saint Lucia), as well as sediment textures (grain size) and wave conditions, under different scenarios of mean sea level rise changes and/or storm induced sea level rises. The benefits of this approach include:

- This approach provides reasonable assessments of potential ranges of beach retreat under marine forcing (i.e. sea levels and waves), on the basis of (minimal) environmental information that can be obtained relatively easily.
- It provides ranges (maximum and minimum) of the horizontal excursion of cross-shore beach retreat/inundation, which could then be compared to the beach width that could be easily determined by remote-sensed imagery.

A toolbox is constructed to simplify the approach developed under the project and to allow replicability of this methodology by SIDS. The toolbox is provided as a *Guided User Interface* (GUI) suite. It is user- friendly, fast and requires no great expertise for its operation.

Sources and additional information:

- UNCTAD, 2017. *Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of Small Island Developing States (SIDS), Climate Risk and Vulnerability Assessment Framework for Caribbean Coastal Transport Infrastructure*. UNDA project 1415O, available at: https://sidsport-climateadapt.unctad.org/methodology-2/
- UNCTAD, *Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of Small Island Developing States (SIDS), Beach erosion Guided User Interface (GUI)*, UNDA project 1415O , available at: https://sidsport-climateadapt.unctad.org/beach-erosion-gui/
- UNCTAD, *Climate change impacts on coastal transport infrastructure in the Caribbean: enhancing the adaptive capacity of Small Island Developing States (SIDS), Training and guidance material*, UNDA project 1415O, available at: https://sidsport-climateadapt.unctad.org/training-and-guidance-material/
- Dedicated web platform on climate change impacts and adaptation for coastal transport infrastructure in the Caribbean, available at: https://sidsport-climateadapt.unctad.org/

UNECE, Climate Change Impacts and Adaptation for Transport Networks and Nodes

Country/Region: Europe

Date: 2019

✓ Climate change impacts on transport networks/nodes

✓Country experiences on climate change impact assessment and adaptation efforts

The joint United Nations Economic Commission for Europe (UNECE) – United Nations Conference on Trade and Development (UNCTAD) Workshop on “Climate Change Impacts on International Transport Networks” held under the auspices of the Working Party on Transport Trends and Economics in September 2010 discussed the important challenges that climate change impacts and adaptation requirements present for international transport networks. This workshop established a *Group of Experts on Climate Change impacts and adaptation for transport networks and nodes* to assist in the following:

- Identify and establish, if possible, inventories of transport networks in the Economic Commission for Europe (ECE) region[14] which are vulnerable to climate change impacts;
- Use/develop models, methodologies, tools and good practices to address potential extreme hazards (e.g. high temperatures and floods) to selected inland transport infrastructure in the ECE region under different scenarios of climate change;

[14] UNECE region includes the countries of Europe, but also countries in North America (Canada and United States), Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan) and Western Asia (Israel). For further information on geographical scope, visit the UNECE website: https://www.unece.org/oes/nutshell/region.html.

- Identification and analysis of case studies on the potential economic, social, and environmental consequences of the climate change impacts and provide a cost/benefit analysis of the adaptation options.

As part of its mandate, the Group of Experts prepared an interactive report on *Climate Change Impacts and Adaptation for International Transport Networks* in 2013, providing a review of the scientific background of climate change and its effects on both a global scale and in the ECE region; some of the potential impacts of the different manifestations of climate change on transport networks; a brief analysis of the results of the questionnaire circulated to UNECE member countries and international organizations in 2012; a summary of available adaptation responses as well as the conclusions and recommendations of the Group of Experts.

Subsequently, the Group of Experts prepared another report in 2019 on *Climate Change Impacts and Adaptation for Transport Networks and Nodes* focusing on the following: i) the main ECE transport networks and nodes (main roads, railways, waterways, including ports, and nodes) exposed to potential impacts of climate change (temperature, precipitation, snow, ice, sea level rise and extreme events), along with future projections (Part I); and ii) country experiences in the form of case studies demonstrating a range of efforts undertaken globally to analyse climate change impacts on transport assets, along with measures with a view to adapting to climate change (Part II). A series of lessons learnt have been further formulated by the Group of Experts, that may serve as a basis for recommendations towards improved resilience of the transportation system.

Sources and additional information:

- UNECE Group of Experts on Climate Change Impacts and Adaptation for International Transport Networks, *Climate Change Impacts and Adaptation for International Transport Networks*, available at: https://www.unece.org/trans/main/wp5/publication.html
- Economic Commission for Europe, *Report of the Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes*, available at: http://www.unece.org/fileadmin/DAM/trans/doc/2019/wp5/id_WP5-19_06e.pdf
- UNECE Group of Experts on Climate Change Impacts and Adaptation for International Transport Networks, *Introduction*, available at: https://www.unece.org/trans/main/wp5/wp5_ge3_intro.html
- International Conference "*Raising awareness on adaptation of transport infrastructure to climate change impacts*" (18-19 November 2019, Athens, Greece), available at: https://www.unece.org/trans/main/wp5/wp5_conf_2019_nov.html

Adapting to Climate Change I and II – Milford Haven Port Authority Reports to the UK Secretary of State

Country/Region: United Kingdom of Great Britain and Northern Ireland, Europe

Date: 2011 and 2015

✓ Identification of highest priority climate-related risks by seaport

✓Identification of climate change adaptation actions and update on implementation

The reports of the Milford Haven Port Authority (MHPA) on *Adapting to Climate Change* are other examples of the implementation of the climate change adaptation reporting process enshrined in the UK Climate Change Act, discussed in Chapter 3.2 of this compilation. Pursuant to the UK Climate

Change Act, MHPA was directed in 2010 by the Secretary of State, to report on the anticipated impacts of climate change and on proposals for adaptation. The Port Authority accordingly submitted its report *Adapting to Climate Change* in 2011 and reviewed it during the second reporting cycle in 2015.

The 2011 report on *Adapting to Climate Change,* assesses which MHPA functions could be potentially impacted by climate change, covering impacts on commercial as well as statutory functions. It highlights existing initiatives of particular relevance to understanding and responding to the potential risks associated with climate change (e.g. meteorological stations, tailored Imap reports). It further presents contributions from third party terminal operators, regarding adaptation measures that have been considered with respect to their own terminal activities.

In order to establish how climate change could affect MHPA's functions, activities and interests, MHPA ran a facilitated workshop for key port personnel. Based on climate projections, workshop participants identified the potential risks associated with a number of relevant climate change parameters and indicated their likelihood and consequence for the Authority's functions and activities.

The highest priority climate-related risks are those associated with increased flooding; increase in the frequency of high winds; and business continuity issues associated with extreme events. The report states that most risks identified are rather long-term risks, but it recognizes that preparatory actions will be needed to enable the Authority to make informed decisions about timely and cost-effective adaptation responses. The following adaptation actions are presented in that context (accompanied by information on timescales, estimated costs and department responsibility):

- **Hubberston Pill and Goose Pill water level sensors:** installation of a water level monitor at Hubberston Pill, where flooding occurred following rise of water level;
- **Hakin Jetty – Beacon and Notification of Flood Risk:** installation of a new beacon and notification of an increased flood risk at Hakin Jetty;
- **Marine Works Licence:** requirement for those applying for a marine works licence and capital dredging licenses to demonstrate that their proposals are climate-proof – this responds namely to the need for awareness-raising of potential climate change adaptation requirements amongst the authority's third-party stakeholders;
- **Meteorological Data Analysis and Monitoring:** a requirement has been identified for the collation of meteorological data and monitoring of trends, particularly those emerging as a consequence of climate change, i .e. the risk of:
    - increased flooding
    - increase in the frequency of high winds, and
    - business continuity issues associated with extreme events.

Adapting to Climate Change II (2015), provides a summary of what has been achieved by the Port until June 2015 based on the priority adaptation actions identified in the first reporting cycle. The report also informs on the Port's carbon footprint. MHPA monitors and calculates the consumption of utilities and presents in the 2015 report the 2014 carbon emission savings and emissions generated by the Port's own operations. A comparison against 2012 and 2013 is also provided.

Sources and additional information:

- Milford Haven Port Authority, *Adapting to Climate Change II*, Milford Haven Port Authority Second Report to the Secretary of State, June 2015, available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/466609/climate-adrep-mhpa.pdf

- Milford Haven Port Authority. *Adapting to Climate Change*, Milford Haven Port Authority Report to the Secretary of State, March 2011, available at: http://webarchive.nationalarchives.gov.uk/20130124005001/http://www.defra.gov.uk/environment/climate/sectors/reporting-authorities/reporting-authorities-reports/

Adaptation measures at the Port of Rotterdam

Country/Region: The Netherlands, Europe

✓ Flood risk management

✓Multi-stakeholder approach to climate adaptation

✓Economic damage

The Rotterdam Climate Initiative

Under the umbrella of the Rotterdam Climate Initiative, the Port of Rotterdam Authority, Deltalinqs, DCMR Environmental Protection Agency Rijnmond and the City of Rotterdam, largest port city in Europe, work as partners with the aim of enhancing the sustainability of the city, the port and the industrial complex. This partnership is based on the fact, among others, that whilst the port is situated in the outer-dike area and is directly linked to the river and the sea, it is nevertheless inextricably linked to the city of Rotterdam. By breaking new ground how it operates, the port of Rotterdam has the ambition to be the most sustainable port in the world.

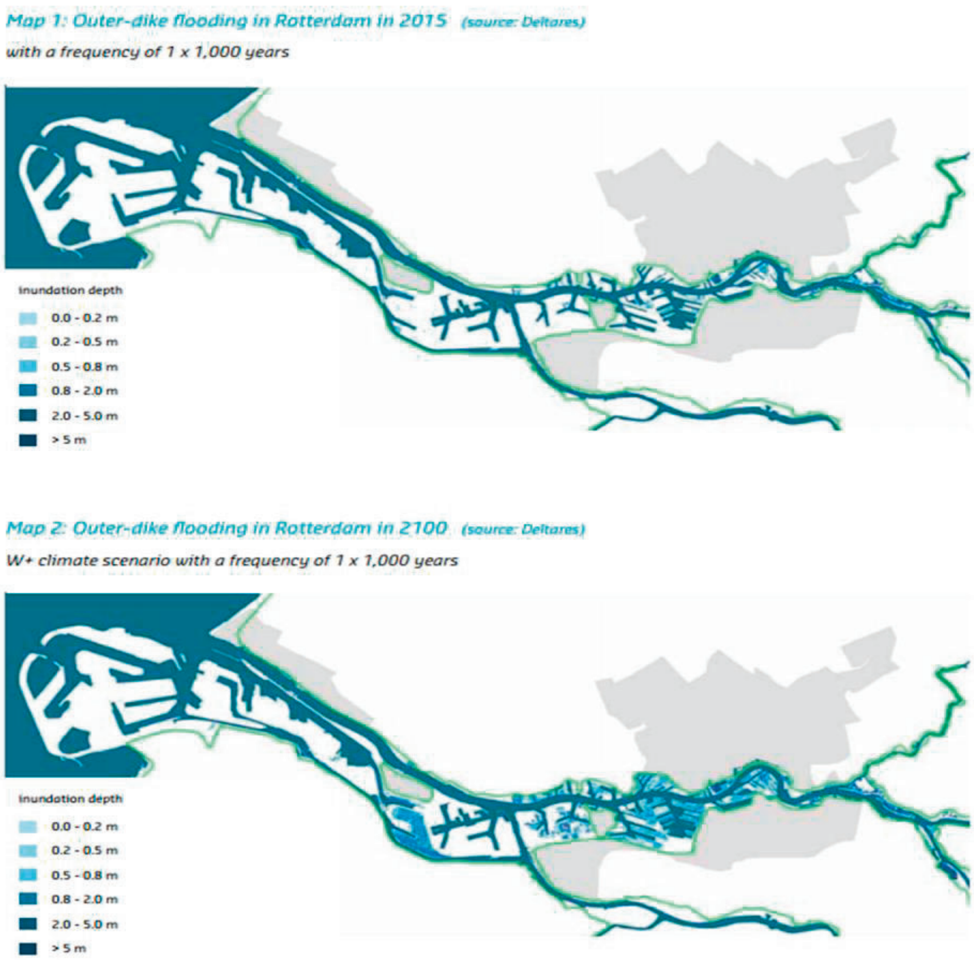
Rotterdam Climate Change Adaptation Strategy

As part of the Rotterdam Climate Initiative, in 2008, the City Council of Rotterdam ratified the Rotterdam Climate Proof programme. Implementation of climate change adaptation measures belong to the three main activities of this Programme. On that basis, the Rotterdam Climate Change Adaptation Strategy was adopted in 2013 setting the course to enable the city to adapt to climate change. The Rotterdam Climate Change Adaptation Strategy has been developed with the aim of making the city of Rotterdam climate proof by 2025. This Strategy foresees the following climate adaptive measures for the port of Rotterdam:

- Safe terp for the protection of goods at safe collections points,
- Wet-proof construction due to floodable ground floor and internal moving of goods to higher floors,
- Small compartment dike,
- Elevated infrastructure,
- Ecological structure,
- Dry-proof construction and flood wall to protect essential functions whose continual operation must be guaranteed.

Measures in the Rotterdam Climate Change Adaptation Strategy are the result of specific research. Within the framework of the Rotterdam Climate Proof climate change adaptation programme, extensive research was carried out on the effects of climate change for Rotterdam and on the consequences of the impacts of climate change. In the Rotterdam Climate Change Adaptation Strategy, this knowledge is applied to describe the climate change effects and consequences affecting Rotterdam. The identified direct consequences of climate change include: higher sea and river levels with increased risk of outer-dike flooding; more intensive rainfall; longer periods of drought and longer hotter periods (heat waves). The map (Fig. 5.7) illustrates the predicted flooding of outer-dike Rotterdam in 2015 and 2100 (W+) with a probability of 1 x 1,000 years.

Figure 5.7 Predicted flooding of outer-dike Rotterdam in 2015 and 2100 (W+) with probability of 1X1,000 years, : City of Rotterdam, Rotterdam Climate Change Adaptation Strategy, 2013



<u>Botlek Flood Risk Management pilot project</u>

The Botlek Flood Risk Management pilot project (2015-2016) has studied the potential consequences of climate change for two specific port areas situated outside the dikes (Botlek and Vondelingenplaat), addressing in particular possible future flood impacts. The Botlek area is of major economic importance and is home to a large number of petrochemical and chemical companies. The pilot project is a joint initiative of the Port of Rotterdam Authority, the Municipality of Rotterdam, the Ministry of Infrastructure and the Environment and Rijkswaterstaat.

The pilot project identified the situation affecting the two designated port areas, looking for example, at their economic importance, the presence of vulnerable infrastructure, etc. According to the results of the project, the main impact of possible flooding is expected to be economic damage, with limited risk of environmental damage and few or no human casualties. The results of the pilot project served as input for the '*Strategic Adaptation Agenda for Areas Outside the Dikes*'. The final report sets out adjustments and measures (adaptation strategy) that can be taken to avoid or minimise the negative effects of flooding and consequently protect the area in question. The following measures are identified in that respect: i) Preventive area programmes; ii) 'Climate robust' development of new sites; and iii) Contingency plans at the company and area level.

Sources and additional information:

- Port of Rotterdam, *'Flood Risk Management'*, available at: https://www.portofrotterdam.com/en/a-safe-and-accessible-port-of-rotterdam-both-today-and-in-the-future
- City of Rotterdam, *Rotterdam Climate Change Adaptation Strategy*, 2013, available at:http://www.urbanisten.nl/wp/wp-content/uploads/UB_RAS_EN_lr.pdf
- Tiedo Vellinga and Michiel de Jong, "Approach to Climate Change Adaptation in the Port of Rotterdam" *in* Asariotis, R. and Benamara, H. (eds.), *Maritime Transport and the Climate Change Challenge*, Routledge, 2012, 360p.

Port of Manzanillo: Climate Risk Management

Country/Region: Mexico, North America

Date: 2015

✓Climate risk/opportunities assessment

✓ Adaptation plan, recommendations

✓Linkages with Federal, State and municipal adaptation policy

In the light of the implications of climate change and variability for ports, the port administration of Manzanillo (Administracion Porturia Integral [API] de Manzanillo) partnered with the Inter-American Development Bank to prepare a study on climate change risks for the Port of Manzanillo. The port is considered Mexico's leading port in the Pacific and a critical node between the Pacific and the main national industrial belt.

The study identifies climate-related trends, including current and future climate conditions, as well as hydrological and oceanographic conditions for Manzanillo in particular. In light of these, an assessment for the Port was conducted, whereby climate risks, opportunities and adaptation actions were evaluated in relation to a variety of aspects of the Port's value chain. Thus, the study lead to an assessment of climate-related risks and opportunities for the Port and the development of an adaptation plan, key outcome of the study, on the basis of the risk analysis.

The assessment, which is reported as being the first climate risk management study performed on a full port in the Latin America and the Caribbean region, aims to address the following questions:

- "What risks and opportunities does climate change present for the port?
- How could the port manage climate risks and uncertainties in the most financially optimal way, taking account of environmental and social objectives?
- How could climate-related opportunities be developed and exploited?
- What key climate-related factors should API Manzanillo take into account to maintain its competitiveness and develop its medium and long-term business strategy?
- How should adaptation actions be prioritized and sequenced in an Adaptation Plan?
- Where could API Manzanillo work in collaboration with other stakeholders to best manage climate risks and take advantage of opportunities?"

The study covers the following aspects and possible climate risks (with high priority risks identified with an asterisk):

Table 5.3 Climate-related risks included in the study considering all aspects of the value chain of the Port of Manzanillo

Goods storage:	**Increased average and peak temperatures causing increased refrigeration and freezing costs**
Goods handling:	Increased intensity of rainfall events causing increased stoppages to handling equipment; decreased number of rain days reduces delays from rain to vessels loading/unloading; sea level rise combined with storm surge causes flooding of the port resulting in goods handling stoppages; increased maximum intensity and duration of maximum intensity of tropical cyclones causing increased handling downtime
Damage to port equipment, buildings and infrastructure:	Increased frequency of intense rainfall events causing damage to infrastructure and equipment through surface water flooding*; extreme storm event wind speeds damaging handling equipment; sea level rise combined with storm surge flooding of the port resulting in damage to port equipment and infrastructure
Implications of climate change impacts on maintenance costs:	Increase in intensity of rainfall causing increased sedimentation of the port basin, reducing draft clearance for vessels and terminal access; increase in intensity of rainfall requiring increased maintenance of the port drainage system; increased frequency of intense rainfall events causing damage to infrastructure and equipment
Port services:	Increase in intensity of rainfall causing increased sedimentation of the port basin, reducing draft clearance for vessels and terminal access*; increase in intensity of rainfall requiring increased maintenance of the port drainage system; wind and wave activity affecting berthing operations
Trade routes:	Increased intensity of rainfall causing surface water flooding of internal access road and entrance, causing disruptions to port operations*; increased storminess causing flooding in major rail and road routes connecting the port to its area of influence*; higher temperatures lead to reduced train speeds; increased disruption to regional and international maritime transport from tropical storms
Environmental aspects:	Climate change factors affecting API Manzanillo's environmental performance and insurance costs for mangrove habitat; increased problems of dust creation and dispersion in drier conditions; increased loss of water quality and benthic habitat due to increased runoff, maintenance dredging and disposal of dredge material
Social aspects:	Health and safety risks to workers at the port related to climatic factors (incl. favourable conditions for mosquitoes, heat stress and dehydration; increased dust generation and more cases of conjunctivitis); interactions between the port and the municipality of Manzanillo, and how these could be affected by climate change
Demand and consumption patterns:	Impacts on the global economy, the economy of the port's main trading countries, and the economy of Mexico, affecting trade flows at the port; changes in distribution of global production of climate-sensitive products
Competition with other ports:	Comparative assessment to evaluate severity of climate change hazards for the Port of Manzanillo compared to other main Mexican competitor ports
Implications of international and national agreements or commitments to reduce greenhouse gas emissions:	Increase import price of fossil fuel can affect volume flows of petroleum and its derivatives; effects of mitigation policy on GHG intensive cargoes may affect cargo flows of these commodities
Implications of future evolution of the insurance market:	Possible increases in premium costs due to future increases in the frequency of weather-related events and associated insurance claims

For each area, the study identifies and describes risks and opportunities, addressing thresholds and sensitivities, current and future climate and oceanographic variability and change. The report also categorizes each risk area according to priority level (high to medium and low) and rates it by considering the level of current vulnerability, certainty of future risk, whether the projected impacts of climate change are large, and if the decisions have long-lead times or long-term effects.

In addition, it provides possible adaptation options, and in some cases, offers a financial analysis and a breakdown of key risks to individual terminals, where appropriate. The financial analysis carried out for each area supports a financial and economic assessment of climate change risks for the Port, addressing for example the costs associated to a certain risk or impact, in particular if no action is taken. The study offers an analysis of the cost effectiveness of adaptation- related measures.

With the aim of contextualizing adaptation actions in light of adaptation planning and port planning at the Federal, State and Municipal levels, the report also provides a summary of key policy instruments guiding actions at those three levels and exposes the linkages in relation to the Adaptation Plan. The Plan presents recommended adaptation measures for the Port along with recommended leading entities for implementation and a set of indicators to monitor implementation. A Stakeholder Engagement Plan and next steps are also presented to support the implementation of the Adaptation Plan.

Sources and additional information:

- Richenda Cornell et al., *Port of Manzanillo: Climate Risk Management* (Final Report), September 2015, available at: https://publications.iadb.org/bitstream/handle/11319/7649/Port-of-Manzanillo-Climate-Risk-Management-Final-Report.pdf?sequence=2&isAllowed=y
- Richenda Cornell et al., *Port of Manzanillo: Climate Risk Management* (Executive summary), August 2015, available at: https://publications.iadb.org/bitstream/handle/11319/7639/Port-of-Manzanillo-Climate-Risk-Management-Executive-Summary.pdf?sequence=2

Climate Risk and Business: Ports - Terminal Marítimo Muelles el Bosque (Cartagena, Colombia)

Country/Region: Colombia, South America

Date: 2015

✓Identification and categorization of port risk areas due to climate change

✓Financial analysis

✓Adaptation options

The International Finance Corporation (IFC) undertook work on climate change adaptation to help its clients understand and respond to the risks of climate change. As part of its adaptation program, IFC investigated how some of its investments could be affected by climate change, looking at ports, hydropower, and agribusiness and manufacturing sectors in various regions.

One of IFC's clients, the Terminal Maritimo Muelles el Bosque (MEB), in Cartagena (the second largest port in Colombia) provided a case study through which risks and opportunities from climate change were assessed for ports. The report *Climate Risk and Business: Ports - Terminal Marítimo Muelles el Bosque (Cartagena, Colombia)* presents the outcomes of the assessment along with information on climate-resilient actions that might be considered.

The report discusses possible impacts of climate change on port performances, referring to examples of climate impacts on different ports around the world. The risk areas discussed are the following:

Vehicle movements inside the port
Demand, trade levels and patterns
Infrastructure, building and equipment damage
Goods storage
Environmental performance
Navigation and berthing
Goods handling
Inland transport beyond the port
Social performance
Insurance

Based on a preliminary analysis of MEB, all the above-mentioned areas have been defined as possible risk areas, which are likely to be affected by climate change, except for the area '*infrastructure, building and equipment damage*'. The report presents the assessment for each risk area separately, suggesting adaptation options along with providing a financial analysis. The financial analysis offers an overview of the possible financial implications of climate change risk and adaptation actions, including costs and benefits of adaptation.

In light of the assessment, the report categorizes the risks according to the type of implications they encompass (i.e. operational, financial, reputational, legal, environmental, health and safety, local community, external stakeholders) and the risk level, from 'low' to 'very high'. Information on the likelihood and consequence, rated from 1 to 5, is also provided. Figure 5.8 shows an example of the summarized risk assessment in relation to vehicle movements inside the port, assuming no adaptation:

Figure 5.8 Extract from the summary table of climate change risk assessment for MED over the 21st century, assuming no adaptation

Risk	Risk category	Risk level
Vehicle movements inside the port (Section5)		
Increased seawater flooding of port areas (observed sea level rise scenario)	Operational	**VERY HIGH**
Increased seawater flooding of port areas (accelerated sea level rise scenario)	Operational	**HIGH**
Increased maintenance of port unpaved areas	Operational	**LOW**

In terms of climate change adaptation measures, key options were formulated in relation to raising the height of the causeway road, paving unpaved areas, improving drainage, developing knowledge of climate resilient commodities or trading them, managing energy costs for refrigeration, protecting goods from seawater flooding and contracting additional insurance. The report also discusses possible barriers to climate change risk assessment and adaptation for the risk areas considered in the study.

Finally, the report provides information on the role of government ministries, departments and institutes in Colombia in taking action to assess and manage climate change impacts.

Source and additional information:

- Vladimir Stenek et al., *Climate Risk and Business: Ports - Terminal Marítimo Muelles el Bosque (Cartagena, Colombia)*, Washing, D.C.: World Bank Group, 2011, available at: http://documents.worldbank.org/curated/en/659131468027590522/Climate-risk-and-business-ports-terminal-maritimo-Muelles-el-Bosque-Cartagena-Colombia

Port Authority of New York and New Jersey - Design Guidelines for Climate Resilience

Country/Region: United States of America, North America

Date: 2015, 2018

✓ Step-by-step procedure to establish flood protection criteria

✓Examples of climate resilience design guidelines of a port authority

In 2015, the Port Authority of New York and New Jersey adopted design guidelines to ensure that climate resiliency is considered in the infrastructure and its building projects. The guidelines have been developed for project architects and engineers of the Engineering Department of the Port Authority and have been updated following Hurricane Sandy to improve infrastructure resilience to climate conditions and severe storms.

The short document provides examples of design adjustments related to higher temperatures, increased precipitation, sea level rise and severe storms; and presents climate changes projections in these areas that should be accounted for in the design of infrastructure over the assets design life. Example design adjustments include the following (Table 5.4):

Table 5.4 Examples of PANYNJ Engineering Design Guidelines, references to Climate Resilience, extracted from PANYNJ Climate Resilience Design Guidelines (v1.1), 2018

ARCHITECTURE	Consideration of: - Site selection, placement, and elevation for storm resilience - Wet and dry floodproofing for storm resilience - Higher roof albedo and better building insulation for extreme heat resilience - Higher wind rated roofs
CIVIL	Consideration of: - Vertical alignment of roadways and railways to accommodate sea level rise - Drainage capacity to manage increases in precipitation and/or sea level rise - Adjustment of hydraulic grade line to accommodate sea level rise - Watertight manhole covers and alternate venting for flooding/sea level rise
LANDSCAPE ARCHITECTURE	Consideration of: - Salt and floodwater tolerant plantings for storm resilience - Absorbent landscapes for storm resilience - Plant selection and locations for temperature increases - Preservation/expansion of tree canopies for temperature increases - Increased irrigation for extreme heat days - Water tolerant plants for increase in precipitation
MECHANICAL	Consideration of: - Equipment elevation to accommodate sea level rise - System redundancy for increasing frequency of extreme weather - Stronger equipment supports for wind loads - Submersible pumping systems for flooding/sea level rise - Adaptation for water supply pressure drop during power outages - Drain sizing to manage increased precipitation

In addition, the document contains a step by step procedure to establish flood protection criteria for a project, as well as a list of code changes due to enacted resiliency legislation as of 2015. The following ten steps are presented for the flood protection criteria procedure:

- **Step 1: Identify Flood Risks to Project Scope -** Determine if the project site is within the Federal Emergency Management Agency (FEMA) 1 per cent annual chance flood plain using FEMA mapping data, hurricane Sea, Lake, and Overland Surges from Hurricanes (SLOSH) mapping and the Agency's flood mapping. Projects which have a design life extending past 2025 should evaluate if sea level rise will extend the flood plain.
- **Step 2: Determine the Influence of Any Area or System-Wide Strategy** – Discuss area or system-wide strategies to determine if the project is sufficiently protected. The project team should discuss any high-risk consequences of perimeter protection failure before making a final decision not to proceed with the internal flood protection.
- **Step 3: Identify if the project is part of an Emergency Plan or Enterprise Risk Plan** – Discuss applicability of emergency plan or an enterprise risk mitigation plan to determine if the plans need to be incorporated into the project. Integrate any functional aspect of the plans related to the project into the Basis of Design.
- **Step 4: Review Current Codes** – Analyse the current codes to determine the minimum flood projection or elevation level required by the code.
- **Step 5: Determine Funding Source Requirements/Guidelines** – Identify source of federal, state or local funding and determine project-specific funding requirements or guidelines.
- **Step 6: Identify Critical Infrastructure** – The flood protection elevation for PATH tunnels, vehicular tunnels, power distribution facilities, emergency generators, fire protection systems and aircraft fuelling systems shall follow ASCE-24 freeboard requirements (BFE + 2 feet) for a category IV structure.
- **Step 7: Determine Life Expectancy** – A sample list of asset design can be consulted.
- **Step 8: Determine Flood Protection Level** – Utilize the Engineering Department's flood protection levels, which adjust for anticipated sea level rise based on the design life and criticality of the asset.
- **Step 9: Perform Benefit Cost Analysis** – Perform a benefit cost analysis to weight the capital investment, the benefits associated with the mitigation strategy and the costs of not performing the investment over time.
- **Step 10: Establish Flood Resilience Criteria** – Based on the conclusions from this process, review all information and agree upon an acceptable level of flood protection at a reasonable cost.

<u>**Sources and additional information:**</u>

- Port Authority of New York & New Jersey, *PANYNJ Climate Resilience Design Guidelines (v1.2), 2018,* available at: http://www.panynj.gov/business-opportunities/pdf/discipline-guidelines/climate-resilience.pdf
- Adaptation Clearinghouse, Resources - 'Port Authority of New York and New Jersey Engineering Department Manual – Climate Resilience Design Guidelines', available at: http://www.adaptationclearinghouse.org/resources/port-authority-of-new-york-and-new-jersey-panynj-engineering-department-manual-climate-resilience-design-guidelines.html

Port of Long Beach Climate Adaptation and Coastal Resiliency Plan

Country/Region: United States of America, North America

Date: 2016

✓ Asset vulnerability profiles

✓ Climate adaptation strategies

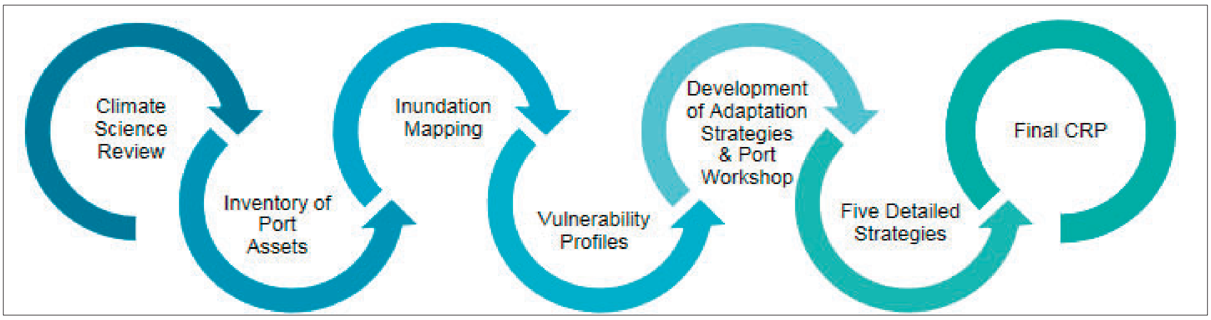
✓ Inventory of port assets

In 2016, the Port of Long Beach developed a *Climate Adaptation and Coastal Resiliency Plan* to "*manage the direct and indirect risks associated with climate change and coastal hazards*". Additional goals of the project leading to the elaboration of the Plan included the identification of most vulnerable port assets and the identification of potential adaptation strategies.

The Plan provides a framework for incorporating adaptive measures related to projected climate change into the Port's policymaking and planning processes, construction practices, infrastructure design, and environmental documents. The Port of Long Beach is an important economic engine for Southern California and a critical gateway to global trade. The Port's vulnerabilities were highlighted in August 2014 when storm surge and wave hazards resulting from Hurricane Marie ravaged the Southern California coast. The Climate Adaptation and Coastal Resiliency Plan reports that the Port suffered damage at the Navy Mole (Nimitz Road) and Pier F, and shipping operations were halted for multiple days. Access to the surrounding roads and facilities was impacted for several months.

The document summarizes the work efforts to date on climate adaptation. This includes a climate science review, which together with sea level and storm surge inundation mapping, was used to inform the development of vulnerability profiles. In addition, an inventory of port assets was prepared to identify assets that are important for the Port's business continuity, and then assess their vulnerability to climate change impacts in terms of exposure, sensitivity, and adaptive capacity. The work also includes a geographical information system (GIS) mapping of projected sea level rise, storm surge, and precipitation increase. Figure. 5.9 summarizes the steps undertaken to develop the Climate Adaptation and Coastal Resiliency Plan.

Figure 5.9 Steps to developing the Port of Long Beach Adaptation and Coastal Resiliency Plan. Port of Long Beach, Climate Adaptation and Coastal Resiliency Plan, Fall 2016



Vulnerability profiles were developed for piers, transportation, critical buildings, utilities, and breakwater, and demonstrated that several assets could be impacted by physical damage and disruptions in operations due to current and/or future extreme weather events and climate change. Based on the vulnerability profiles, adaptation strategies have been elaborated. Out of over 20 preliminary strategies, five have been developed into detailed studies or concept designs, and it is foreseen that seven others will be developed further by Port staff in the future.

The five adaptation strategies, summarized in the report, are the following:

1. **Addressing climate change impacts through Port policies, plans, and guidelines:** This strategy aims to recommend language that can be added to key port policies, plans, and guidelines to ensure climate change impacts are considered at the most appropriate time during planning and development projects. This strategy contains recommended text insertions, point of intervention, partners, implementation considerations, and next steps for implementation.
2. **Adding sea level rise analysis to the Harbor Development Permit Process:** This strategy recommends updating the Harbor Development Permit process to include climate change considerations. A new section on sea level rise and storm surge has been developed for the permit application forms. The section contains few questions as well as a vulnerability zone map which was created to clarify whether an applicant's project is located in an area that is vulnerable to inundation. This is completed by a guidance document developed to assist Port staff in understanding the key terms used to evaluate future flood hazard impacts.
3. **Pier A and B study – Combined impacts of riverine and coastal flooding:** The third strategy is based on a study on the impact of precipitation-based flooding combined with coastal flooding on two piers. Based on these results, flood protection improvements are suggested.
4. **Pier S shoreline protection:** Due to Pier S' vulnerability to overtopping of floodwaters and inundation of port assets, a conceptual design was proposed.
5. **Pier S substation protection – evaluation of multiple strategies:** The fifth strategy proposes several adaptation options for dock substation vulnerable to flooding under sea level rise scenarios. It concerns Pier S as this area was identified as vulnerable to flooding in the other phases of the project. In the context of this strategy, long-term and near-term adaptation strategies were evaluated to increase the resilience of the substation. The document provides a summary of each option, along with cost estimation, time-frame, and other implementation-related information.

Source and additional information:

- Port of Long Beach, *Climate Adaptation and Coastal Resiliency Plan*, Fall 2016, available at: http://www.polb.com/environment/climatechange.asp

Massport's resilience strategy and the Floodproofing Design Guide

Country/Region: United States of America, North America

Date: 2014 and 2015

✓ Resiliency strategy by a port authority for its transport assets

✓Floodproofing design guide

Massport's resiliency strategy

The Massachusetts Port Authority (Massport) initiated a *Resiliency Program* in 2014 to protect its transportation facilities from flooding hazards caused by extreme storms and rising sea levels as a result of climate change. Massport owns and operates three airports, including Boston-Logan International Airport, as well as terminals in the Port of Boston, including the Conley Container Terminal.

The Resiliency Program seeks to:

- Improve resiliency for overall infrastructure and operations;
- Restore operations during and after disruptive events in a safe and economically viable time frame;
- Create robust feed-back loops that allow new solutions as conditions change;
- Inform operations and policy, and implement design/build decision, through the application of sound scientific research and principles that consider threats, vulnerabilities and cost-benefit calculations;
- Become a knowledge-sharing exemplar of a forward-thinking, resilient port authority; and
- Work with key influencers and decision makers to strengthen understanding of the human, national and economic security implications of extreme weather, changing climate, and man-made threats to Massport's facilities in the region.

The program has specific strategies designed to plan and prepare for future threats. It contains five categories of possible activities with corresponding anticipated outcomes: strategic convening; research & planning; design resiliently; education & training; and operational preparedness. Sample activities include for example, the development of a climate disaster and infrastructure resiliency plan, which is expected to inform decision-making, and design guidelines for future construction.

Table 5.5 reproduces the resiliency program strategies as presented by Massport.

Table 5.5 Massport's Resiliency Program Strategies. Retrieved from Massport, Resiliency Program Strategy

RESILIENCY PROGRAM STRATEGIES

	Sample Activities	Anticipated Outcomes
Strategic Convening	Engage in Massport Strategic Planning focusing on resiliency Create a Task Force of partnering agencies with common goals Sit on external committees at federal state, and local level	Key decision-makers' understandings of threats and resiliency mechanisms are strengthened Effectively shared knowledge and collaborative planning A more resilient MPA and region
Research & Planning	Climate "Disaster & Infrastructure Resiliency Plan" Analyze resilience capacity for other threats (i.e. earthquakes) Design guidelines for future construction	Informed decision-making A balanced composite cost and risk plan Guidelines and standards integrated into best management practices
Design resiliently	Executive infrastructure-specific designs & specifications Implement standards for existing assets Issue RFP's for design and development	Existing facilities are "hardened" for intense storm events, sea-level rise, and other unplanned events Resilient construction is incorporated into all MPA assets
Education & Training	Provide education and tools for staff, consultants, contractors, and key stakeholders Present lessons learned at conferences	Staff, stakeholders, and future leaders informed about preparedness and resiliency Replicable models of research and design excellence

	Create accessible resources such as library, website, etc.	
Operational Prepared-ness	Develop ground transportation plan to staff to reach work during disruptive events Update the Continuity of Operations Plan Update IT data recovery plan	Cross-cutting operational training for resilience Less disruption, quicker recovery after an emergency or disaster Adequate funding in 30 Year Budget for resiliency

Massport Floodproofing Design Guide

As part of its Resiliency Program, Massport developed the *Floodproofing Design Guide* (original developed in 2014, revised in 2015) to help increase the resiliency of its infrastructure and operations to anticipated flooding hazards caused by storms and rising sea levels. Massport is incorporating this Floodproofing Design Guide into its capital planning and real estate development processes. In doing so, the guide is intended to achieve several flood resiliency objectives, including minimizing flood damage to critical facilities, providing operational continuity, enhancing business resiliency, etc.

The Design Guide is to be used by Massport staff, tenants, third party developers, design professionals and contractors during planning, design and construction of new, under substantial repair or retrofitted projects at Logan Airport, Conley Terminal, Fish Pier, Black Falcon Cruise Terminal, or other Massport properties in South Boston. It puts forth design flood elevations (DFEs)[15], which, together with floodproofing performance standards, are seen as necessary tools to programmatically address current and future risks from coastal flooding at Logan Airport and the Maritime facilities in South Boston.

The Guide provides guidance on permitted dry and wet floodproofing strategies. It specifies the cases, which cannot be subject to dry floodproofing, and the requirements related to dry floodproofed areas of a building or a facility. It also provides examples of dry and wet floodproofing measures. The guide presents two tables listing floodproofing performance standards: 1) for substantial repairs/improvements to existing facilities and floodproofing projects; and 2) for new facilities.

Finally, a floodproofing design implementation process is presented. The aim of this process is to identify floodproofing related issues early in the design process to ensure that the proposed floodproofing strategies are adequate and that operational, maintenance and storage requirements are clearly understood by all parties responsible for implementation. The process is reproduced in Table 5.6.

Table 5.6 Floodproofing Design Implementation Process. Retrieved from Massachusetts Port Authority, Floodproofing Design Guide (revised April 2015)

Design Stage	Design Flood Parameters and Calculations	Floodproofing Design Narrative and Drawings	Floodproofing Calculations	Flood Operations Plan	Floodproofing Inspection and Maintenance Plan
Schematic Design/ Pre-Design	Identify FIRM Map	Identify proposed floodproofing strategies and	Conduct facility condition	Identify parties responsible	Identify parties responsible for facility

[15]DFEs correspond to the maximum level of water that an engineered structure has been designed to resist.

	Information and Massport DFE	performance objectives to be achieved by design	assessment and/or site assessment	for facility flood emergency response	inspection and maintenance
30% Design	Preliminary design load assumptions and calculations	Identifies specific measures to achieve performance objectives; Review for code compliance, update narrative	Engineering report with structural calculations demonstrating floodproofed facility can withstand design loads	Outreach to parties responsible for implementing active floodproofing measures; Prepare draft plan	Outreach to parties responsible for inspection and maintenance of floodproofing measures; Prepare draft plan
90%	Update	Update narrative and drawings	Update structural calculations	Update draft plan	Update draft plan
Final Design	Finalize	Finalize narrative and drawings. Complete FEMA NFIP floodproofing certificate for non-residential structures signed/submitted. For new construction with lowest floor elevated above BFE or DFE, complete FEMA NFIP elevation certification, signed and submitted	Finalize	Final plan and approval memo	Final plan and approval memo

<u>Sources and additional information:</u>

- Massachusetts Port Authority, *Floodproofing Design Guide*, Revised April 2015, available at: http://www.massport.com/media/1149/massport-floodproofing-design-guide-revised-april-2015.pdf
- Massport, Business > Capital Improvements > Sustainability > Climate Change Adaptation and Resiliency >, available at: http://www.massport.com/massport/business/capital-improvements/sustainability/climate-change-adaptation-and-resiliency/
- Massport, *Resiliency Program Strategy*, available at: http://www.massport.com/media/2007/program-strategies-infographic.pdf
- Massport, *Resiliency Program Goals*, available at: http://www.massport.com/massport/business/capital-improvements/sustainability/climate-change-adaptation-and-resiliency/program-goals/
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Climate Change Projections for Port Louis: Adding value through downscaling

Country/Region: Mauritius, Africa

Date: 2012

✓ Downscaled climate projections

✓Assessment of climate change impacts on various sectors, including airport and seaport

Climate Change Projections for Port Louis: Adding value through downscaling is a report documenting a study on Port Louis where a downscaling methodology was applied to assess the possible impacts of climate change. It is part of the project *'Sub-Saharan African Cities: A Five-City Network to Pioneer Climate Adaptation through Participatory Research and Local Action'* lead by ICLEI (Local Governments for Sustainability). This project sought to develop an adaptation framework for managing the increased risk to African local government and their communities due to climate change impact using Cape Town (South Africa), Dar es Salaam (Tanzania), Maputo (Mozambique), Windhoek (Namibia), and Port Louis (Mauritius) as selected urban centres.

Port Louis hosts the only port on the island for export and import trade for Mauritius. With respect to the Port Louis study, the downscaling methodology (providing local scale data), developed at the University of Cape Town, was applied to nine Global Climate Models (GCMs) using downscaled modeling projections from the Vacoas and Plaisance weather stations located on Mauritius island. These two stations were the nearest available stations for Port Louis. Despite the fact that the projections were not directly produced for Port Louis, the projections were considered representative. The report presents the results of applying this methodology and the observed rainfall and temperature data from the nearest stations. It addresses historical trends and observations for Mauritius, GCM projections of future change for 2050 (considering rainfall, temperature, and winds), and statistically downscaled projections of those changes. It also informs on changes in cyclones and climate extremes with respect to rainfall, temperature and winds.

In light of the study, the report presents the impacts and vulnerabilities to which Port Louis is exposed, considering various sectors. The sectors covered include water, transport, health, energy and agriculture. It further highlights how impacts affect human livelihoods. With respect to transport, impacts are considered for road, rail, air and port. Table 5.7 provides an overview of the impacts for the latter sector as identified in the report (*increased risks in the future are presented in blue*):

Table 5.7 Port Luis - Impacts upon transport and on livelihoods. Retrieved from Mark Tadross and Peter Johnston, Climate Change Projects for Port Louis: Adding value through downscaling, Sub-Saharan African Cities: A five-City Network to Pioneer Climate Adaptation through Participatory Research & Local Action, March 2012

Type	Impacts upon Transport	Impact on livelihoods
Air	• Damage of infrastructure • Accidents and air crashes • Reduction in GDP • Airport closes for safety during cyclones • Increased insurance required by operators	• Reduces accessibility to airports • Delay in exports/imports • Decreased safety
Port	• Damage of infrastructure • Erosion to coastal infrastructure and equipment • Damage of boats • Erosion to harbor wall • Damage to anchored boats	• Days at sea lost • Work hours lost – reducing income, if the port is rendered unworkable then there is no income stream until the damage has been cleared • Delay in exports/imports • Increased insurance premiums

Source and additional information:

- Mark Tadross and Peter Johnston, *Climate Change Projects for Port Louis: Adding value through downscaling*, Sub-Saharan African Cities: A five-City Network to Pioneer Climate Adaptation through Participatory Research & Local Action, March 2012, available at: https://assets.publishing.service.gov.uk/media/57a08a7640f0b649740005e4/IDL-50410.pdf

Climate Risk Assessment for Avatiu Port and Connected Infrastructure

Country/Region: Cook Islands, Pacific

Date: 2013

✓ Qualitative climate risk assessment methodology

✓Risk assessment of connected infrastructure & services

✓ Perceptions of vulnerability

In the context of a project on coastal adaptation initiated by the Cook Islands Government entitled "*Coastal Adaptation Needs for Extreme Events and Climate Change, Avarua, Rarotonga, Cook Islands*", the Water Research Laboratory of The University of New South Wales conducted a study on "*Climate Risk Assessment for Avatiu Port and Connected Infrastructure*". The study developed a qualitative climate risk assessment methodology that identifies current and future climate change vulnerability and risk to the Avatiu Port and the connected infrastructure in Rarotonga. The study used Avatiu Port and Rarotonga as a case study for implementing a methodology that could be utilized in qualitative climate risk assessments by other ports in the Pacific.

The study report informs on the approach taken to define and adopt the qualitative risk assessment methodology and the methods used to capture factual and anecdotal information from users (managers and staff) of the Port and connected infrastructure. With respect to the Avatiu Port, the methodology sought to identify the existing and primary risks of climate change on port facilities and operations. In light of existing country reports, projected regional climate changes were listed in relation to port infrastructure and operations, with some climate conditions being identified as potential sources of risk. In order to ascertain the potential impacts of climate change on the Port, the General Manager, Harbour Master, Port Operations Manager and Port Finance and Administrative staff were interviewed on the water-side infrastructure, interface infrastructure, land-based infrastructure and connected infrastructure. The report outlines the range of responses and the interpretation of survey questions across the staff interviewed.

With the aim of identifying critical linkages between the Port and connected infrastructure, this study also assessed secondary risks to supply and services for the Rarotonga and wider Cook Islands communities, including fuel, energy, water, communications, transport, consumables and tourism. A list of key connected infrastructure and services that may affect or may be affected by port operations during extreme weather and with climate change has been developed. To have a better understanding of the impact of weather and climate on the connected infrastructure, interviews have been conducted with the following stakeholders:

- Emergency Management Cook Islands
- Cook Islands Trading Company (foods and goods)
- Ministry of Infrastructure and Planning (roads, bridges, drainage, water, water)
- TRIAD Pacific Petroleum

- National Environment Service
- Cook Islands Airport Authority
- Tourism Cook Islands
- Te Aponga Uira (power-electricity)
- Telecom Cook Islands (communications)

The report concludes that depending on the nature of the connected infrastructure, perceptions of vulnerability vary across connected infrastructure providers and stakeholders (from low to very high). The report offers an interpretation of the results and an assessment of the adaptive capacity of the different connected infrastructure, taking into account the experiences and perceptions shared as well as the level of seniority of the interviewees.

Key findings from the overall study are the following:

- Cyclones which are projected to increase in intensity with climate change create the highest risk to port and connected infrastructure;
- The Port's practice of removing all assets (water and land based) from the Port region in face of an approaching cyclone is an effective adaptation response which limits the risk and for 1:20 year Average Recurrence Interval (ARI) TC Sally event operations can be expected to resume within few days;
- The recent upgrades to the Port (with allowance for sea level rise) have assisted in limiting future damage and risk;
- The Port relies upon the road and bridge infrastructure network but can operate without water, power and communications; and
- In contrast the fuel, power, airport, food and goods and thus tourism and the economy can rely heavily upon the port.

Source and additional information:

- R J Cox, K Panayotou and R M Cornwell, *Climate Risk Assessment for Avatiu Port and Connected Infrastructure*, Water Research Laboratory, WRL Technical Report 2013/15, 2013, available at:https://www.pacificclimatechange.net/document/climate-risk-assessment-avatiu-port-and-connected-infrastructure

Brisbane Airport – New Parallel Runway Project

Country/Region: Australia

Date: 2013 (report); 2005 (engineering design and EIA)

✓ Consideration of climate change impacts in the design of a coastal runway

✓Adaptation to sea level rise, temperature increase, flood events and storm surge

As part of a series of 16 case studies on adaptation good practice in Australia, the National Climate Change Adaptation Research Facility prepared a study on Brisbane Airport's new parallel runway project. As one of the fastest growing airports in Australia, Brisbane Airport has been planning for a second runway, which will be located on a low-lying coastal area. The site is subject to inundation during flood events and is at risk of future climate change impacts. The project therefore aims to factor climate change considerations into infrastructure design. Work on the site began in 2012 with the major stages of construction now in progress (opening foreseen for 2020).

Figure 5.10 New Parallel Runway location of the Brisbane airport. National Climate Change Adaptation Research Facility, "Brisbane Airport- New Parallel Runway Project", Climate Change Adaptation Good Practice – Case Study, 2013

Sea level rise, storm surge, local/regional flood events and increase in average temperatures are the key climate change risks identified for this project. The design phase sought to mitigate these risks, taking into account historical weather patterns and future projections. Six options were considered for the runway placement and layout, each of which presented issues for assessment, including cost, operating and safety standards, noise restrictions, environmental impacts, and climate change. With respect to climate change, sea level rise, storm surge and flood events had to be taken into account in the final design, whereby the level and likelihood of the risk was considered along with the cost of the risk mitigation (e.g. raising the height of the runway).

<u>**Design response to climate change impacts**</u>

The report further informs on the design response to the potential climate change impacts identified. In particular, the following can be highlighted:

- Sea level rise and increased frequency of cyclonic events was addressed by incorporating a 400 mm allowance + 500 mm additional wave set up freeboard in the hydrological modelling undertaken for the project;
- Consideration of temperature increases in future decades was accounted for in the ultimate length planning for both the existing main runway and for the new runway, each of which had significant additional lengths available to be added in the future.;
- With regards to runway height, given the combination of original design modelling, compatibility requirements with the existing infrastructure, and updated, independent sea level rise evaluation, the design level adopted for the new runway at RL 5.0 m (Airport Datum) was validated as providing sufficient freeboard above the design storm tide level;
- The taxiways linking the new runway with the apron areas are set above the 1 per cent Average Exceedance Probability (AEP) storm surge event;
- Construction of tidal channels;
- Installation of a new sea wall along the northern boundary of the Airport.

According to the report, the design project has determined measures that "*far exceed minimum requirements to ensure future climate impacts are mitigated*". The report further highlights that the cost during the preliminary design to incorporate consideration of climate change impacts was negligible as storm and flood modelling is a normal requirement for any project. Thus, it was a simple process to include climate change considerations into these modelling exercises.

Finally, the report identifies critical success factors of the project, whereby success "*has-been driven by strong leadership and excellent connectivity between all stakeholders, extensive engagement and by sustainable vision"*. Table 5.8 summarizes lessons learnt in the context of the project, as captured by the report.

Table 5.8 Critical success factors and lessons learnt in the design of the New Parallel Runway project (Brisbane airport). Extracted from National Climate Change Adaptation Research Facility, "Brisbane Airport- New Parallel Runway Project", Climate Change Adaptation Good Practice – Case Study, 2013

Leadership lesson learnt:	Project leaders having a long term view meant climate change was considered from the original design brief, throughout research stage and throughout the life of the project to completion.
Engagement lesson learnt:	Use a range of channels and activities to reach all key stakeholders and effected communities.
Sustainability lesson learnt:	Planning for predicted impacts and exceeding minimum regulatory requirements alleviates pressure of additional construction for the next 50 - 60 years.
Cost lesson learnt:	The cost of good design and the additional outlay of funds is outweighed by the confidence that all future climate change impacts have been considered and there will be no need to upgrade the runway for some time.

Sources and additional information:

- National Climate Change Adaptation Research Facility, "*Brisbane Airport- New Parallel Runway Project*", Climate Change Adaptation Good Practice – Case Study, 2013, available at: https://www.nccarf.edu.au/business/publications/brisbane-airport-new-parallel-runway-project
- Brisbane's New Runway, Brisbane Airport Corporation, available at: https://bne.com.au/corporate/projects/brisbanes-new-runway

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ISBN 978-92-1-112970-0

Printed at United Nations, Geneva
2001312 **(E)** – May 2020 – 1,394
UNCTAD/DTL/TLB/2019/1