Contribution by the UNCTAD secretariat to Part I of the report of the Secretary-General on Oceans and Law of the Sea 2020: "Sea level rise and its impacts"

(ii) Observed and projected environmental, social and economic impacts and resulting challenges relating to sea level rise

Climate variability and change: Impacts on seaports and other coastal transport infrastructure

Transportation accounts for a significant fraction (about 25 %) of global (GHG) emissions[1] and, at the same time, faces severe challenges as a result of climate variability and change[2] (CV & C)[3]. With over 80 per cent of global merchandise carried by sea, from port to port, seaports are most critical coastal transportation assets and at the heart of international trade and globalization. They are points of convergence between maritime and inland transportation, providing access to global markets for all countries. Ports as well as related coastal transport infrastructure that provide multimodal linkages to hinterland connections (i.e. coastal roads, railways, as well as inland waterways) consist of complex systems, which will be particularly affected by the impacts of climate variability and change[4]. 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[5], but other climatic changes, such as increased mean temperatures and extreme temperature variability, also pose serious threats to seaports and related coastal transport infrastructure and operations. In the case of large seaports, which are mostly integrated within large coastal urban agglomerates, relevant impacts may affect large populations and a broad range of socio-economic activities.

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, climate variability and change impacts on ports and their hinterland transportation links can have broad ramifications for a range of economic sectors. In addition to causing damage to infrastructure and equipment, climate change impacts may also result in significant operational disruptions and delays and lead to extensive economic and trade-related losses. Thus, port infrastructure damages and/or operational disruptions and delays may adversely affect trade, energy and food supply and tourism. 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 SIDS. Indirect impacts of climate change on ports include those arising from climate-driven

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[1] 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 km of their journey. See UNECE, 2015. Transport for Sustainable Development: The case of Inland Transport. United Nations Economic Commission for Europe, Transport Trends and Economics Series ECE/TRANS/251. https://www.unece.org/fileadmin/DAM/trans/publications/Transport_for_Sustainable_Development_UNECE_2015.pdf.

[2] 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).

[3] UNECE, 2019. Report of the Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes. Informal document WP.5 (2019) No. 6, available at: http://www.unece.org/fileadmin/DAM/trans/doc/2019/wp5/id_WP5-19_06e.pdf

[4] See also UNECE, 2019. Report of the Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes, Informal Document, WP.5 (2019) No.6. https://www.unece.org/trans/main/wp5/wp5_ge3_intro.html; UNECE, 2013. Climate Change Impacts and Adaptation for International Transport Networks, ECE/TRANS/238. https://www.unece.org/fileadmin/DAM/trans/main/wp5/publications/climate_change_2014.pdf

[5] E.g. Becker et al., 2013. A note on climate change adaptation for seaports: A challenge for global ports, a challenge for global society. Climatic Change, 120, 683-695.

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.

Seaports and other coastal transport infrastructure (i.e. coastal roads, railways, and airports) will be particularly affected by sea-level rise and associated extreme events (Table 1). 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[6].

Coastal inundation from extreme events can render port and related 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. Impacts could include disruptions to operations and damages to port infrastructure and vessels, as well as hinterland connections. Extreme sea levels (ESLs) are set to increase almost everywhere[7]. ESL events of certain magnitude that currently have a low recurrence frequency in a location will become more frequent in the future[8]. As the recurrence frequency/return period[9] of extreme sea levels (and associated waves) form fundamental parameters of the design of coastal defences for coastal (transport) infrastructure, both assessment of impacts and choice/design of effective adaptation options will need to be considered on the basis of future projections of the return periods of ESLs of certain magnitude. Extreme winds and waves can also be catastrophic, as they can cause coastal erosion, port/coastal defence overtopping and flooding, infrastructure failures and operational disruptions

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)[10] 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 dollars. Hoshino et al (2016)[11] 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). Another 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[12].

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[6] See e.g. Vousdoukas et al., 2018. Global probabilistic projections of extreme sea levels show intensification of coastal flood hazard. Nat. Commun. 9, 2360. https://doi.org/10.1038/s41467-018-04692-w; Monioudi et al., 2018. Climate change impacts on critical international transportation assets of Caribbean Small Island Developing States (SIDS): The case of Jamaica and Saint Lucia. Regional Environmental Change, 18 (8), 2211–2225, https://doi.org/10.1007/s10113018-1360-4, https://rdcu.be/Q1OY; Giardino et al., 2018. Coastal hazard risk assessment for small islands: assessing the impact of climate change and disaster reduction measures on Ebeye (Marshall Islands). Regional Environmental Change, 18, 2237–2248

[7] See IPCC, 2019. Special Report on the Ocean and Cryosphere in a Changing Climate, IPCC, 2019: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, et al., (eds.)] https://www.ipcc.ch/srocc/. See also Losada et al., 2013. Long-term changes in sea level components in Latin America and the Caribbean. Global and Planetary Change 104, 34–50

[8] Vousdoukas et al., 2018. Fn. 6, above

[9] 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 appears once in 100 years (the 1-100 years event).

[10] Lenton et al., 2009. Major Tipping Points in the Earth's Climate System and Consequences for the Insurance Sector. 89 pp.

[11] Hoshino et al., 2016. Estimation of increase in storm surge damage due to climate change and sea level rise in the Greater Tokyo area. Natural Hazards, https:/doi.org/10.1007/s11069-015-1983-4

[12] Jevrejeva et al., 2018. Flood damage costs under the sea level rise with warming of 1.5 °C and 2 °C. Environ. Res. Lett. 13 07401

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[13], with Dominica's damages/losses assessed to be in excess of 200 % of its Gross Domestic Product (GDP)[14]. 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[15]. 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[16].

Table.1 Major impacts on coastal transportation infrastructure and operations from sea-level rise and extreme sea levels. Extracted from: Climate Change Impacts and Adaptation for Coastal Transport Infrastructure: A Compilation of Policies and Practices, UNCTAD/DTL/TLB/2019/1.[17]

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

The special case of the SIDS

Particularly for Small Island Developing States, often highly vulnerable and with limited adaptive capacity, addressing the impacts of climate variability and change, including sea-level rise, on ports and coastal transport networks is both important and urgent. Ports and airports in coastal zones are critical lifelines for external trade, food, energy and tourism. Many SIDS face particular threats from climate change, such

[13] WMO 2018. Statement on the State of the Global Climate. World Meteorological Organization Report 1212. https://library.wmo.int/doc_num.php?explnum_id=4453

[14] Gov. Dominica, 2017. Post-Disaster Needs Assessment, Hurricane Maria September 18, 2017, A Report by the Government of the Commonwealth of Dominica, available at: https://reliefweb.int/sites/reliefweb.int/files/resources/dominica-pdna-maria.pdf

[15] IDB, 2019. Damages and other impacts on Bahamas by Hurricane Dorian estimated at $3.4 billion: report, Press release, 15 November 2019, available at: https://www.iadb.org/en/damages-and-other-impacts-bahamas-hurricane-dorian-estimated-34-billion-report

[16] EQECAT Inc., 2012. Post-landfall loss estimates—Hurricane Sandy—Nov. 1, 2012

[17] For details, see also Asariotis et al., 2017. Port Industry Survey on Climate Change Impacts and Adaptation. UNCTAD Research Paper No. 18, UNCTAD/SER.RP/2017/18. 37 pp plus Appendices, available at: https://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=1964 ; and UNECE, 2019. Report of the Group of Experts on Climate Change Impacts and Adaptation for Transport Networks and Nodes. Informal document WP.5 (2019) No. 6, available at: http://www.unece.org/fileadmin/DAM/trans/doc/2019/wp5/id_WP5-19_06e.pdf

as increasing mean and extreme sea levels, changing wave patterns and rising temperatures, which increase the exposure of their critical transport infrastructure to damage, delays and disruption[18]. At the same time, climate change can induce/exacerbate coastal erosion and coral bleaching with direct and indirect impacts on tourism and trade. SIDS are vulnerable to extreme weather events, such as tropical cyclones as shown by e.g. the devastating impacts of the recent Caribbean hurricane season 2017 and of Hurricane Dorian in September 2019.

Climate change is expected to increase the frequency and severity of such natural hazards, thus increasing the exposure of SIDS' key transport infrastructure to hydro-meteorological hazards, particularly those associated with sea level rise, storm surges and tropical cyclones[19]. A recent assessment by UNCTAD of the climate change induced impacts on 8 seaports and coastal airports of two Caribbean SIDS (Jamaica, St. Lucia), which focused on the risk of coastal flooding and of potential operational disruptions under different climate scenarios[20], highlights the importance of climate change adaptation for critical international transportation assets. The study projected severe impacts on coastal transport infrastructure and operations that could cause major disruptions to the connectivity of SIDS to international markets as well as to related economic sectors, such as tourism. Thus, most of the examined assets are projected to experience severe flooding in response to the 1 in 100 years extreme sea level event as early as in the 2030s, when average global temperatures are expected to reach 1.5 °C above pre-industrial levels, unless effective adaptation measures are taken.

(iii) Opportunities in responding to those challenges, including through cooperation and coordination at all levels on scientific, technical, technological, and financial aspects and capacity-building

Responding to challenges from climate variability and change, including sea-level rise

The fact that an estimated 80 per cent of the volume of world trade is carried by sea, with seaports in developing countries accounting for more than 60 per cent of goods loaded and unloaded at the global level[21], illustrates the strategic role of seaports and of other key transport infrastructure as part of the global trading system. Therefore, and given the potential for climate-related damage, disruption and delay across global supply chains – with significant associated costs and economic and trade-related losses – enhancing their climate resilience is a matter of strategic economic importance. Effective adaptation and resilience building for ports and other key transport infrastructure assets will also be key to achieving progress on many of the goals and targets that collectively make up the international community's 2030 Agenda for Sustainable Development. This includes SDG 13 - *Take urgent action to combat climate change and its impacts*; SDG 9 - *Build resilient infrastructure, promote inclusive and sustainable industrialization*

[18] IPCC, 2018. Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [V. Masson-Delmotte, P. Zhai, H. O. Pörtner et al. (eds.)]. https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf

[19] Ibid. and IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp., available at: https://www.ipcc.ch/report/ar5/syr/

[20] Monioudi, et al. Reg Environ Change (2018) 18:2211–2225. Climate change impacts on critical international transportation assets of Caribbean Small Island Developing States (SIDS): The case of Jamaica and Saint Lucia. doi 10.1007/s10113-018-1360-4, https://rdcu.be/Q1OY. See also see also IPCC, 2018; IPCC, 2019.

[21] UNCTAD, 2019. Review of Maritime Transport 2019, https://unctad.org/rmt.

and foster innovation; SDG 14 - *Conserve and sustainably use the oceans, seas and marine resources for sustainable development*; and SDG 1.5 - *By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters*.

UNCTAD has been working on the implications of climate change for transportation since 2008, with particular focus on impacts and adaptation needs of seaports and other coastal transport infrastructure[22], including in SIDS. Relevant research and analytical work, including peer-reviewed publications, as well as the outcome of a series of expert meetings and technical cooperation activities with a focus on SIDS[23] and in collaboration with a wide range of partners, have significantly helped to raise awareness and advance the international debate[24], and benefit from strong support of Member States.[25] Most recently, UNCTAD published a compilation of policies and practices of relevance to climate change impacts and adaptation for coastal transport infrastructure[26], to assist in the development of effective adaptation policies and response measures.

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 change considerations into coastal transport infrastructure planning/operations as well as pursuing policy coherence among transport, trade, 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 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.

In view of the long service life of transport infrastructure, effective adaptation requires re-thinking established approaches and practices early. Moreover, a good understanding of risks and vulnerabilities is needed for the development of well-designed adaptation measures that minimize the adverse effects of climatic factors. This, however, presents 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, 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

[22] See https://unctad.org/ttl/legal for further information and documentation.

[23] See in particular https://SIDSport-ClimateAdapt.unctad.org, presenting activities and outcomes of a UNDA funded project (2015-2017). For a HL Panel discussion at the UNFCCC COP 25 in Madrid, held in December 2019, as part of an ongoing UNCTAD-UNEP technical assistance project, see https://unctad.org/en/pages/MeetingDetails.aspx?meetingid=2354

[24] 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 Climate Action Pathway for Transport and Resilience (https://unfccc.int/climate-action/marrakech-partnership/reporting-and-tracking/climate_action_pathways), as well as port guidance developed by industry organization PIANC, The World Association for Waterborne Transport Infrastructure, (and work of the UNECE Group of Experts on Climate Change Adaptation for International Transport Network and Nodes, which was established following a joint UNCTAD-UNECE workshop (2010) on the subject.

[25] See the Maafikiano (TD/519/Add.2), paras. 55 (f),(k),(l).

[26] Climate Change Impacts and Adaptation for Coastal Transport Infrastructure: A Compilation of Policies and Practices, UNCTAD/DTL/TLB/2019/1, available at https://unctad.org/en/PublicationsLibrary/dtltlb2019d1_en.pdf.

world, whereas melting permafrost could become a major problem in others. However, there are still important knowledge gaps about vulnerabilities, as well as the specific nature and extent of exposure that individual coastal transport facilities may be facing, as evidenced by the results of an UNCTAD port industry survey on climate change impacts and adaptation[27].

For the purposes of risk-assessment and with a view to developing effective adaptation measures, generation and dissemination of more tailored data and information is important, as are targeted case studies and effective multi-disciplinary and multi-stakeholder collaboration. Infrastructure inventories, higher resolution data, including better Digital Elevation Models (DEMs), [28] as well as a better understanding of coastal processes under climate change are required for effective risk-assessment and adaptation planning; and detailed technical studies at facility level are needed to avoid maladaptation. Technical adaptation measures are widely needed, but these should involve innovative and efficient designs to avoid over-engineering; ecosystem enhancement can play a significant role in reducing risks. Increased investment in human resources and skills (in particular skilled coastal scientists/engineers) at local/regional levels will be critical for successful adaptation and resilience building in the future, as will be the mainstreaming of climate change considerations into ordinary transport planning, operations, and management.

Guidance, best practices, checklists, methodologies[29] 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 airports for food and energy needs, external trade and – crucially – tourism, which typically accounts for a major share of GDP. In this context it is important for to explore ways to raise and allocate the necessary financial resources, especially for developing countries, and to consider how best to highlight and integrate the above considerations as part of Nationally Determined Contributions (NDCs) under the Paris Climate Agreement and in National Adaptation Plans.

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 though 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. Appropriate policies and standards also have an important role to play, particularly in the context of infrastructure planning and coastal zone management. Examples of relevant approaches include the amended EU Directive on Environmental Impact Assessment (Directive 2014/52/EU), in force since May 2017, which requires climate change

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[27] Asariotis et al., 2017. Port Industry Survey on Climate Change Impacts and Adaptation. UNCTAD Research Paper No. 18, UNCTAD/SER.RP/2017/18. 37 pp plus Appendices, available at: https://unctad.org/en/pages/PublicationWebflyer.aspx?publicationid=1964.

[28] See, e.g. Bove, G., et al., 2020. A method for regional estimation of climate change exposure of coastal infrastructure: Case of USVI and the influence of digital elevation models on assessments, Science of The Total Environment, Volume 710, 2020, 136162, https://doi.org/10.1016/j.scitotenv.2019.136162

[29] Examples include guidelines for ports developed by industry organization PIANC and methodological frameworks, such as developed by UNCTAD. See 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/. See also UNCTAD 2019, Climate Change Impacts and Adaptation for Coastal Transport Infrastructure: A Compilation of Policies and Practices, UNCTAD/DTL/TLB/2019/1.

impacts to be taken into account as part of environmental impacts assessments for large infrastructure projects; the Climate Change Policy Framework for Jamaica (2015), which provides for cross-sectoral mainstreaming of climate change considerations, and the recently adopted ISO Standard 14090 (Adaptation to climate change — Principles, requirements and guidelines, 2019), which provides a framework to enable organizations to prioritize and develop effective, efficient and deliverable adaptation tailored to the specific climate change challenges they face, and using a consistent, structured and pragmatic approach[30].

[30] For further information on these and other relevant regulatory and policy approaches, as well as practices, see UNCTAD 2019, Climate Change Impacts and Adaptation for Coastal Transport Infrastructure: A Compilation of Policies and Practices, UNCTAD/DTL/TLB/2019/1.