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Impacts of Climate Change on Ports: Current Levels of Preparedness.

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This paper displays the results obtained through exploratory research carried out through an online form that sought to assess the level of preparation of ports and port terminals in the face of climate change. This work was developed with the intention of complementing and continuing the research carried out by UNCTAD 2018 and published under the name UNCTAD Research Paper nº 18. That work identified biases due to the low number of participating ports in the South American and Caribbean region. This research was conducted with the objective of filling this gap. This paper also highlights the main differences between the two studies.

KEY WORDS: Climate change, Impacts, Adaptation, Ports, Seaports, Preparedness.

INTRODUCTION

In recent years, concerns about the impact of climate change has increased and gained ground in areas such as academia, media, public policy, industry, and the society as a whole. The universe of the port and maritime industry, following this movement, has begun to question whether the port facilities, which make up a strategic link in international trade, are sufficiently aware and prepared to face the challenges and uncertainties that this phenomenon presents to the sector.

In 2018 the Division on Technology and Logistics of the United Nations Conference on Trade and Development (UNCTAD) published an online survey carried out with the intention of answering this question (UNCTAD Research Paper nº 18). The research was conducted with the aim of helping to improve the understanding of weather and climate-related impact on ports and to identify data availability and informational needs, as well as determine current levels of resilience and preparedness among different ports. Although the aforementioned study highlights the importance of the theme for Small Islands Developing States (SIDS) and for other vulnerable countries, and despite the fact that the questionnaire was widely circulated to the port industry, it was demonstrated that the survey could have some 'bias' in the results. The majority of respondent ports (73%) were located in developed countries, and there were no responses from Caribbean seaports, a region particularly exposed to climate variability and change. Additionally, as the questionnaire was circulated via industry associations to port management, individuals who have provided answers might not necessarily be part of a port department familiar with the specific issues addressed by the survey.

To address the limitations of the survey carried out by UNCTAD, this paper replicated the research by sending a similar questionnaire to individuals who belong to the strategic body of port authorities located mainly in ports in the Caribbean and South America. Though, ports in other regions were not excluded. The objective of this survey was to obtain information on the level of preparedness and resilience of the ports, as well as gain a better understanding about their status of adaptation planning in relation to climate change. The methodology used to carry out the research was direct exploratory research using an online form questionnaire.

The distribution of the questionnaire had the strategic support of three important institutions, namely: a) Ministry of Economy of Brazil; b) Inter-American Committee on Ports of the Organization of American States; and c) Association of Mediterranean Ports (MEDports). With the support of these organizations it was possible to obtain a relevant number of corresponding ports. In general terms, it can be anticipated that the objective of the research was partially achieved, since there was significant participation of the ports in South America, but the research failed to obtain the participation of ports in the Caribbean region, due to lack of direct communication with the port operators. The ports that responded to the survey are located in South America, Central America and Mediterranean region. The countries in South America were Brazil, Chile, and Colombia, While Mexico was from Central America and Italy, Morocco, Slovenia, Spain, and Tunisia were the countries from the Mediterranean region.

The survey results demonstrate that the level of awareness and information of the ports regarding the relevant factors (significant port operational and infrastructure design parameters, such as wave height, period and direction and average and extreme precipitation and temperatures, etc.) on climate changes and events related to climatic variation is relatively low, with few ports showing to be advanced and well-structured in relation to the theme. The results also indicate the level of preparedness in the face of climatic emergencies in the ports is also relatively low, with few ports demonstrating that they have measures and actions dedicated to make the port or terminal more resilient to face impending climatic events.

LITERATURE REVIEW

Nowadays, several nations of the modern world like to boast of their pioneering spirit regarding navigation and trade across the seas. The economic theory often refers to ports as important factors of economic development, particularly from the historical point of view, where they promoted trade and the well-being of nations. Most major cities in the world are port cities (Rodrigue, 2020). But since the beginning of the history of navigation, the brave and fearless explorers of the seas have shared a common point: the need to find a port with serene and peaceful waters for the moment when they need to dock their ships.

In the past, cross-border commercial activity dependent on navigation, was established and developed almost naturally, where geography and climate were more favorable (natural bays, indentations on the coast, esplanades in the curve of a river or a stable slope in a natural lake) and navigation adapted to the conditions of the environment along its routes and stopping points (Walker, 1988). The most dangerous 'terrains' (waters) were explored by those who did it more out of a desire for adventure than as a way of prospering in the merchandise trade, although throughout history these two desires may often have followed the same routes (Patenaude, 2015). But the combination of advances in different fields of science and the emergence of new technologies has led to a leap in the quality of life for humanity and, consequently, to an exponential growth in the demand for goods and services to serve a population in rapid expansion and change in habits (Harari, 2015.). These achievements have also made transport, especially maritime transport and its essential link, ports, refrain from to evolve in an adaptive way and become drivers of expressive interventions and modifications of the natural spaces they occupy to materialize and produce its ends. Thus, ports have ceased to be mere places for carrying out stowage and unloading cargo, to become springs for the growth and strengthening of entire nations (Rodrigue, 2020), in addition to having the strength to shape the personality of the cities where they are inserted (Ducruet, et al, 2019).

Due to the catalytic power of internal and external forces, good and bad, that the ports have, they experience a trade-off phenomenon, where, on the one hand, they must advance and evolve to meet the advancement, growth and consolidation of cities, metropolises, industrial centers, tourist destinations and other activities. On the other hand, its own insurgency, expansion and modernization, create the opportune conditions for the flourishing of dynamic environments where various activities start to happen due to the favorable environment that the port complex provides.

Port clusters can have substantial indirect economic effects. They can attract other industries that are to some extent dependent or attracted by the port, including logistics and a variety of industries and services sectors. There can be backward and forward linkages between the port and other economic sectors: there are suppliers to port sector and the port sector also supply goods and services to other sectors in an economy. In addition, many port impact studies also calculated the induced economic effects, meaning the effects of workers in direct and indirect port sectors spending their salaries (Merk and Li. 2013). Direct benefits involve the revenues that accrue from the port activity and arise from the various charges levied on ships and cargo for the use of the port. The volume of the port is thus directly proportional to revenue. They mainly include fees charged for pilotage, berthing and towing, charges for cargo handling and demurrage charges (Rodrigue, 2020).

Indirect or induced effect of port clusters is often calculated using input/output that assess the extent of the inter-relations between sectors in an economy (Merk and Li. 2013). Indirect benefits involve firms that import or export goods from the port. Also include cost savings that arise from reduced operating costs, some of which may be realized outside the immediate port area. Lower shipping costs due to reduced turnaround time from improvements such as more berth space, better channel access, better terminal productivity, and reduced processing time for cargo at the port, are other examples of indirect benefits that can be provided by ports (Rodrigue, 2020). On the other hand, induced benefits include the benefits that filter through to the suppliers of input factors, such as income to labor directly employed in port-related activities, and income to industries supplying the port with goods and services and which creates indirect employment. These incomes generate in turn re-spending which further induces employment and income through the economic multiplier effect. Port investment may also have the effect of stimulating economic activity in industries that use the port (Voigt, 1981).

Due to the potential direct and indirect economic effects promoted by a port, that the threats of climate change are gaining increasing importance. A monitoring of environmental performance carried out annually between the ports of The European Sea Ports Organization (ESPO) showed in the 2019 report that, climate change was in the top 10 of the environmental priorities for the first time two years before, is the third top priority after air quality and energy consumption in 2019 (ESPO, 2019).

The ESPO report (2019) informs that, since 2018, there has been an increase in the number of ports that report operational challenges due to climate change from 41 to 47% and that the same trend is observed with the 62% of ports that are taking measures to strengthen the resilience of their existing infrastructure to adapt to climate change. The survey also indicated that 75% of the ports are taking climate change into account for the development of their future infrastructure projects and there is clear evidence that making climate-proof infrastructure is becoming a high priority (see Fig. 1). The only shortcoming of the ESPO (2019) was it was only focused on European ports.

	2016	2017	2018	2019
1	Air Quality	Air Quality	Air Quality	Air Quality
2	Energy comsumption	Energy comsumption	Energy comsumption	Energy comsumption
3	Noise	Noise	Noise	Climate change
4	Relationship with the local community	Water quality	Relationship with the local community	Noise
5	Garbage / Port Waste	Dredging operations	Ship waste	Relationship with the local community
6	Ship waste	Garbage / Port Waste	Port development (land related)	Ship waste
7	Port development (land related)	Port development (land related)	Climate change	Garbage / Port Waste
8	Water quality	Relationship with the local community	Water quality	Port development (land related)
9	Dust	Ship waste	Dredging operations	Dredging operations
10	Dredging operations	Climate change	Garbage / Port Waste	Water quality

Fig. 1: Top 10 environmental priorities for European Sea Ports 2016 – 2019 (adapted from ESPO Environmental Report 2019).

The Threats and its Related Impacts

From rising sea levels to loss of habitat, the effects of the climate crisis are likely to cause damage for several nations, especially for coastal cities (Oppenheimer, 2019). What are then, the main threats related to seaports and inland ports?

Seaports are practically exposed to all threats that afflict coastal areas to a certain extent depending on their size and the extent of their land and direct surroundings. According to Winckler, et al. (2015), the impacts associated with climate change in the coastal zone can be generally classified into:

- flooding of coastal areas
- loss of deltaic territories
- disappearance of wetlands
- coastal erosion on beaches and cliffs
- effects on the dynamics of the dunes, beaches and cliffs
- effects on the hydrodynamics and morphodynamics of estuaries
- effects on the operational and structural behavior of maritime works
- increased damage during floods and storms
- saline intrusion into aquifers and rise in the level of the groundwater.

On the other hand, the key meteorological parameters directly influencing the navigation on inland waterways, are the: precipitation and air temperature. These parameters determine the water supply and the water temperature in the navigable river sections. The changes, especially in the water supply, will alter the occurrence of extreme hydrological conditions and thus will indirectly change the navigability of waterways (PIANC, 2008). Since the river hydrology is interrelated with river morphology, the latter is an indirect driver of change to navigation too.

Inland ports and its waterways can, in its turn, be affected by both floods and droughts. Fluvial floods can have major impacts such as the suspension of navigation, damages to port facilities and flood protection works, silting, and changes in the river morphology. Inland ports can also be affected by low water levels that can inhibit access by heavier vessels during droughts (Asariotis, *et al*, 2020). For inland navigation, the consequences of climate change could be a question of reliability or even of fundamental existence. A small change in the level of water in rivers and ports, for example due to a change in the seasonal pattern of rainfall, may affect the number of days per year that waterways can be used without restriction. For industries using navigation as the primary mode of transportation for their goods, climate change is a fundamental question for the future location of their production facilities (PIANC, 2008).

Gomes and Fanjul (2016) stated that beyond obvious parameters, such as sea level or waves, other variables whose impact is less apparent were covered, such as water temperature (relevant in that it may contribute to the development of algal blooms and therefore to the hypoxia) or air temperature (relevant to the behavior of the materials that make up the infrastructure). The study by Gomes and Fanjul (2016) focused on ports in Spain and they concluded that most of the ports that participated in that survey had perceived the waves (by windy sea or by deep sea) as the meteorological phenomena that most of the time affect its operations, bringing the risk of paralyzing port activities. Whilst extreme rainfall also causes problems in about half of ports, although with less risk of paralysis of activity. The risk of loss of human lives due to climatic phenomena is generally reduced, with extreme winds, overflows and wave surges at the entrance channels and outside of the port, being the phenomena that concern a greater number of Port Authorities in Spain.

Interestingly, as Spain is a country bordering two oceans, with quite different morphological characteristics, that study also sought to identify if the various climatic conditions affected the ports in different ways, depending on the maritime border in which it is located. The authors concluded that the results were similar for the ports on both coasts. Based on the information obtained from that study, Table 1 was formulated, with an intention to offer an overview of the main climatic factors subject to intense variations, caused by climate changes, and which may have direct and indirect impacts on infrastructure and port operations.

Table 1: Climate factors and likely aspects of vulnerability on ports.

Climate Factor	Aspects of vulnerability[1]
Sea level rise	Lack of draft due to incompatibility of the berthing infrastructures in some ports, floods and increased long wave phenomena.
Ocean surges - Outside the port	Limitations to the entry and exit of ships; prevents the embarkation / disembarkation of the pilot; makes it impossible to anchor in some outside docks. Excessive waves outside the port can also make it impossible to anchor ships at the anchorage area.
Ocean surges - Inside and outside the port	Overflow of dikes, which can interrupt the passage of vehicles and people in exposed areas, reducing activity or even leading to the operational closure of some berths. Difficult navigation to access piers and dock (Especially for smaller vessels), complicate the mooring of certain vessels in the internal berths and hinder the loading/unloading operations of ships. More tugs may be required to push ships against defenses to avoid breaking anchorages. In case of a groundswell, the waves' agitation can prevent the depth scan and impair the mooring of large ships. Interruptions for some short sea shipping services and impair the regular passenger services.
Ocean surges with overflow events	Causes sporadic problems in port operations. It is usually sufficient to interrupt the passage of vehicles and people in the most exposed areas. In fewer cases, overflowing can reduce port activity on certain docks, affecting port facilities, causing the operational closure of some berths or preventing mobility along the dike roads.
Long-wave penetration	Inhibits the movement of ships docked in inland docks, breaking of moorings or flooding of docking infrastructure.
Extreme winds	Limits the access of certain types of ships to the port and its docking/undocking maneuvers. Puts the safe performance of anchored ships at risk. Mooring line reinforcement may be needed and tugs may be required for larger ships. Difficulty in loading/offloading of powdery bulks as extreme winds increases the suspension of solid particles in suspension and deteriorates air quality. This can lead to the interruption of operations in case of exceeding legal limits, under the risk of spreading allergens in addition to other annoyances to the affected population. In the case of containers, they can force the port crane service to be stopped or limit the height of its stacking. It also can cause damage to port administrative and operative buildings.
Extreme precipitation – Seaports and River ports	Reduces visibility for ship maneuvers and flooding of facilities. Heavy rainfalls interrupt the loading and offloading of bulks, and increases sediment drag to rivers which can be redirected into port basins. Dredging would be required due to sediment accumulation and reduction in the depth of berths and canals. In seaports connected to the mouth of a river, the evacuation of river waters can generate problems of excess flow. This can be aggravated when combined with high tides with consequent navigation problems. Heavy precipitation can also lead to the overflow of the city's sewage system with consequences for the docking facilities in the port.
Thick fog	Lack of vision and danger of reach in the operations of the ships, which can determine the closure of the port. Foggy conditions may make it too dangerous for berthing, especially in ports with congested access channels and with little width, creating worse conditions for maneuvering.
Intense marine currents	Difficulty to access to the mouth of the port and mooring operations at external docks. Intense marine currents can also impact water quality by increasing the dispersion of dredged sediments during extraction, transport and deposition operations.
Extreme heat	Poor water quality due to refrigerating vessels discharge and algae production. Risks for the loading and unloading of volatile substances such as petroleum and gas and also for some issues related to steel products. Vessel delays due to the slowdown in loading/unloading processes. Loss of productivity of high-cost equipment and labor-force. Increase issues related to maintenance in terminal pavements and can shift the timing of construction activities to occur at cooler parts of the day.
Storms	Electrical storms can affect the port's communication systems and the unloading operations of certain goods, such as liquefied natural gas.

Changes and Trends in the Climate Parameters

This paper does not intend to go deeper into discussing or reviewing the reasons and causes that have been causing climate change because the relationship between greenhouse gas emissions and climate change is already well explained in several other works. It is enough to remember that human

[1] Vulnerability is the viability of the exposed subject or system being affected by the phenomenon that characterizes the threat (Winckler, *et al, 2015*).

influence on the climate system is clear, and recent anthropogenic emissions of greenhouse gases are the highest in history and that warming of the climate system is unequivocal, and since the 1950s, many of the observed changes are unprecedented over decades to millennia (IPCC, 2014).

The Intergovernmental Panel on Climate Change (IPCC) establishes anthropogenic emissions of greenhouse gases (which have increased since the pre-industrial era, driven largely by economic and population growth, and which are now greater than ever) as the cause climate change. This has led to unprecedented atmospheric concentrations of carbon dioxide, methane and nitrous oxide. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and have been the dominant cause of the observed warming since the mid-20th century (IPCC, 2014). The IPCC (2014) also summarized the projected changes[2] in the climate system by stating that the surface temperature is projected to rise over the 21st century under all assessed emission scenarios and it is very likely that heat waves will occur more often and last longer. In addition, extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level will continue to rise.

A brief overview of the observed trends and projections of those changing climatic parameters most relevant for port are discussed. It is important to note that climate projections are not the same as climate predictions. Climate change scientists can't predict the future but with knowledge of past climates and detected climate trends, it is feasible to project climate change into the future using various scenarios. The IPCC did several projections in the IPCC Fifth Assessment Report (AR5) and some projections from this report are discussed below:

Sea level rise (SLR): a major effect of the global warming is the mean SLR. Global average sea level rose at an average rate of around 1.7 mm per year between 1950–2009 and the current rate of sea level rise is 3.2 mm per year, an increase from earlier estimates (Farmer and Cook, 2012). 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 (Asariotis, 2018). SLR has recently accelerated further to more than 4.0 cm per decade, a trend that has been mainly attributed to continental ice melting (Asariotis, *at al*, 2020). In 2007, the IPCC projected that during the twenty- first century, sea level will rise another 18–59 cm. Although IPCC explicitly refrained from projecting an upper limit of total sea level rise in the twenty- first century, 1 m of sea level rise is well within the range of more recent projections. From recent measurements of sea level worldwide, it is generally agreed that the IPCC projections were conservative (Farmer and Cook, 2012).

It is expected that the gradual (slow onset) mean sea level will combine with the future extreme tides, storm surges and waves to generate extreme sea level events that can have devastating impacts on port locations. Extreme sea level events of certain magnitude that currently have a low recurrence frequency in a location will become more frequent in the future. As the recurrence frequency/return period of extreme sea levels, and associated waves, form fundamental parameters of the design of coastal defenses 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 extreme sea level of certain magnitude (Asariotis, *at al*, 2020). 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 years respectively, by 2050, accordingly recent projections. The largest changes expected for the African, South American and the Mediterranean coasts. (Asariotis, *at al*, 2020).

Air Temperature: The global mean surface temperature change for the period 2016– 2035 relative to 1986–2005 is similar for the four RCPs[3], and will likely be in the range 0.3°C to 0.7°C with medium confidence. This range assumes no major volcanic eruptions or changes in some natural sources (e.g., methane (CH4) and nitrous oxide (N2O)), or unexpected changes in total solar irradiance. Future climate will depend on committed warming caused by past anthropogenic emissions, as well as future anthropogenic emissions and natural climate variability. By the mid-21st century, the magnitude of the projected climate change is substantially affected by the choice of emissions scenarios. It is generally expected that the Arctic region will continue to warm more rapidly than the global mean with very high confidence. The mean warming over land will be larger than over the ocean with very high confidence, and larger than global average warming. It is virtually certain that there will be more frequent hot and fewer cold temperature extremes over most land areas on daily and seasonal timescales, as global mean surface temperature increases. It is very likely that heat waves will occur with a higher frequency and longer duration. Occasional cold winter extremes will continue to occur (IPCC, 2014). 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, road asphalt rutting, bridge damages, rail track buckling and speed restrictions, higher energy consumption for cooling and health/safety issues for personnel and passengers (Asariotis, 2020).

Precipitation: Global land rainfall data show an increasing trend, especially in middle and high latitudes. Precipitation

[2] In order to obtain climate change projections, the climate models use information described in scenarios of GHG and air pollutant emissions and land use patterns. Key factors driving changes in anthropogenic GHG emissions are economic and population growth, lifestyle and behavioral changes, associated changes in energy use and land use, technology and climate policy, which are fundamentally uncertain. The standard set of scenarios is called Representative Concentration Pathways (RCPs).

[3] The Representative Concentration Pathways (RCPs) describe four different 21st century pathways of greenhouse gas (GHG) emissions and atmospheric concentrations, air pollutant emissions and land use (IPCC,).

shows a high natural variability as it can be strongly influenced by Climate Phenomena like El Niño-Southern Oscillation (ENSO) and Monsoon Systems (Christensen, *at al*, 2013). It is expected to change in a complex manner, with increases in precipitation projected for some regions and droughts for others. 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. Increases in the frequency/intensity of downpours has been observed in many regions. Downpours are projected to be more intense over most of the mid-latitude and wet tropical regions. Extreme seasonal rains can also intensify with climate change and lead to flooding of rivers by sustained above-average rainfall (Asariotis, *at al*, 2020). In sea ports this may mean the occurrence of compound flooding, which is the combination of river floods and extreme coastal water levels (Ganguli, 2019). In inland ports, heavy rains cause saturation of the soil and decrease the resistance of the river's natural slopes, thus leaving the mooring structures in river ports under instability. In both cases, the resilience of a port in the face of events of extreme precipitation and floods is strongly related to the degree of natural preservation of the banks of the rivers, with the quality of the drainage systems of the city and the port and with the resistance of its own infrastructure.

Adaptation and Resilience

Adaptation means actions by ports to decrease their vulnerability or increase their resilience to weather and climate-related impacts (Asariotis, *at al*, 2020). Vulnerability is defined as the possibility that the exposed subject or system is affected by the phenomenon that characterizes a threat. As in most cases it is not possible to intervene in the threat, to reduce the risk, there is no alternative but to modify the vulnerability conditions of the exposed elements or, if possible, try to reduce the level of exposure (Winckler, *et al, 2015*).

It is also worth noting to know that adaptation and mitigation are not the same thing. They are complementary measures: adaptation is related to the adoption of measures to manage the risks associated with climate change and the creation of resilience (Winckler, 2015). However, measures do not act on the roots of the problem. In other words, they do not offer any type of solution for the reduction of emissions that has aggravated and accelerated global warming and its consequences. Mitigation measures include strategies for reducing the sources of the climate change (Kolev, *at al*, 2012). Substantial emissions reductions over the next few decades can reduce climate risks in the 21st century and beyond and increase prospects for ports to effectively adapt (IPCC, 2014). The clear distinction between adaptation and mitigation actions is also important when organizations known as Climate Investment Funds (CIF), offer funds to tackle climate change. CIF are administered by governments or institutions, such as National Development Banks, with a focus mainly on mitigation projects (Samaniego and Schneider, 2015).

As pointed out, there are many climatic and oceanographic variables relevant to the study of impacts that climate changes may have on ports. Some are more prominent in some ports than others. For some of these variables, such as water temperature or sea level, there are global projections for the entire 21st century as seen before. However, to carry out local interventions, it is necessary to personalize such projections. especially in areas with relevant climatic, hydrological, or oceanographic particularities (Gomes and Fanjul, 2016). However, the task of regionalizing climate projections is a complex and sometimes quite costly task. Furthermore, experts recommend that decisions should never be made based on studies supported by a single projection model. which makes it even more valuable to know which impacts are being perceived by the ports as the most important. Having this knowledge, both at a global level, but also in a regionalized way will enable public and private agents to define the best strategies for research and promotion of climate studies at local and regional level and thus, to be able to provide technical subsidies for decision-making in adaptation and mitigation measures to confront the impacts caused by climate changes in the port system.

Methodology Employed

The methodology is based on direct research through the application of an online form and subsequent statistical treatment of data and analysis of responses. After the first stage, the results obtained were compared with the UNCTAD Research Paper nº 18, hereafter called ‘Reference Study’.

Questionnaire

The survey is structured in four blocks of questions. The first of which aims to qualify respondents. The second is dedicated to investigating the history of impacting climatic events experienced by the port. The third deals with the availability and / or lack of data and information necessary to deal with climate change events in the port environment. Finally, the last group of questions seeks to investigate how prepared the port is to face events related to climate change.

The questionnaire was released in tree languages: English, Portuguese, and Spanish. This effort was made with the intention to reduce idiomatic barriers in order to get a greater number of respondents to the survey. It is not possible to say exactly how many questionnaires were sent, as there was no control over the forms sent through the Inter-American Committee on Ports or the Association of Mediterranean Ports. However, it is estimated that forms have been sent to at least 400 ports and port facilities. The number of emails sent was much higher than this amount, as for some ports the form was sent to more than one recipient. On the other hand, the number of companies that received the form is lower than the number of recipient ports since there are companies that own more than one port facility. After a period of approximately two weeks, a reminder was also sent and only a portion of the recipients were able to receive phone calls with the intention of guaranteeing their adherence to the research. In total, the survey obtained 50 forms answered, totally or partially. All of them were considered in the results analysis.

It should be noted that the form applied is very similar to the form applied in the Reference Study, but some questions were excluded and others were adapted after a careful evaluation. An example is the question regarding the volume of cargo handled by the port or terminal. This was removed because it increased the level of difficulty in filling out the questionnaire without providing information that would be very relevant to the overall analysis of the situation. In this work, it was understood that justifying the representativeness of the sample based on the comparison between the volume of cargo handled by the respondent ports and the volume of global cargo handled by the ports, was not relevant, since the main objective of this research was to cover the information gap for the regions previously mentioned.

Another modification to the Reference Study was the financial data. As the form was issued in three different languages, it was also considered appropriate to allow respondents to provide questions about financial data in their local currency. Regarding the type of available interior connections, the ports were asked about their connectivity with airports, as airports are critical infrastructure in emergency or catastrophic situations. Few other questions had minor adjustments, which the main objective of it was to try to make the question clearer and to make it easier to get answers.

Target Audience and Population

The target audience of the research are individuals who are working in port authorities, port terminals or in government agencies responsible for policies and programs in the port sector. The introduction text of the questionnaires and in the correspondence with the recipients, stated that the questionnaire should be filled out, preferably, by professionals working on issues related to the subject. However, there was no way confirm that this objective was fully achieved. It is possible that part of the questionnaires has been answered by individuals who might not necessarily be part of a port department familiar with the specific issues addressed by the survey. Although there was no specific question designed to identify the qualification or level of understanding of the professionals who responded to the survey, it is understood that the forms were filled out by professionals, most of them familiarized with the subject of the research.

This research does not distinguish between public or private ports. Both are part of the target audience of the research. Leased terminals whose facilities are within ports that operate under the landlord port regime are also considered as part of the target audience.

Method and Way of Distribution

The method of distribution of the research form was completely online. The questionnaire was created in the Google Forms application and then sent to the recipients' e-mail. A portion was sent directly to some of the recipients, after prior consultation on their individual availability to respond to the survey. Another part was forwarded using the support of the Brazilian Ministry of Economy, the support of Inter-American Commission on Ports of the Organization of American States (ICP/OAS), and the contribution from the Mediterranean Ports Association (MEDports). The support of these institutions was to obtain a high number of respondents, especially with valid responses.

Qualitative Assessment of Responses

A preliminary evaluation of the completed questionnaires was carried out to define their acceptance within the set of valid data for statistical processing. When the questionnaire was prepared, only one question was marked as mandatory. All others were optional. On the one hand, this provided flexibility for the respondents, but also made it possible to send questionnaires where no answer had been filled out, except the mandatory answer. This occurred with only two forms which were removed from the set of forms considered in the analysis.

Statistical Analyses of Responses

In this stage, the data from the valid forms were grouped together for the analysis and statistical processing. All data were processed in an integrated manner, such that the identity of the participating ports was preserved. This analysis was done with the support for the application Google Sheets and Microsoft Excel, both suitable to the purpose. For easy visualization of the data, they were plotted in appropriate graphics to the type of associated information. The quantitative data for monetary values were converted from local currency to American dollar based on the currency conversion rate on May 28, 2020[4].

Analysis of Results

After processing the data and plotting the graphs for each question, they were analyzed individually and also compared with the Reference Study. After this stage, the most relevant conclusions were summarized.

The Results

The results will be presented according to the 4 blocks of questions asked. The most important aspects will be discussed and others will be mentioned in a closing statement of the block.

Block I - Profile and General Information

Participants: The characterization block of the respondent ports begins with the question of which country the port is located in. The results were then grouped by regions as shown in Fig. 2.

The survey obtained the total participation of nine different countries, most of them located in South America, a region that had 72% of respondent countries. In second place, the region with the most respondents was the Mediterranean, with 22% of

[4] 1 Euro = 1.10 US$; 1 Mexican Peso = 0.045 US$; 1 Real = 0.10 US$; 1 Moroccan Dirham = 0.10 US$. Data obtained at May, 28 06:07 UTC from: https://economia.uol.com.br/cotacoes/cambio/dolar-comercial-estados-unidos/

the respondents and the Central America region was the region with the lowest participation, with only 6% of the total respondents. In this respect, it can be said that one of the research objectives was achieved. However, the research failed to obtain results from ports located on the small islands of the Caribbean region.

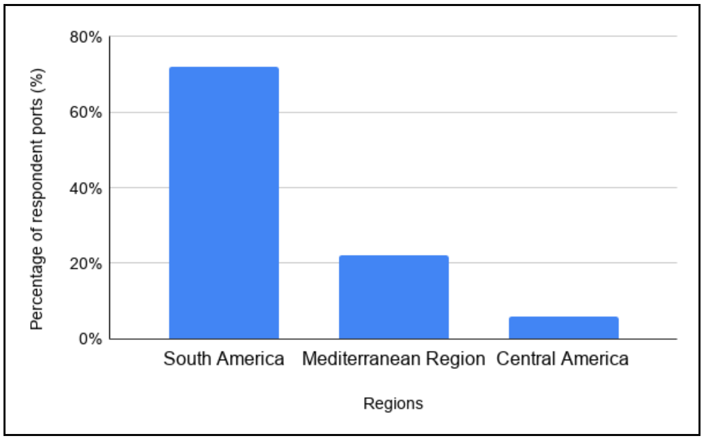

Fig. 2: Distribution of participating ports by regions.

This was due to the form's distribution method (direct mail distribution) and the time available for collecting responses (approximately 2 months only). The number of respondent ports in South America and the Mediterranean increased substantially after a campaign of telephone calls to confirm the receipt of the forms issued by the supporting organizations. However, such a campaign was not possible for ports in the Caribbean region, because there was no direct communication access with the respondents who received the questionnaire. Hence, follow up was difficult.

Another point that may have hampered the ports' adherence to the research was that the launch of the research coincided with the peak of the expansion of the Corona virus pandemic in the world, a time when companies in the sector were directing their priorities for the management of misfortunes caused by the pandemic. However, the number of forms received was considered quite satisfactory, since this research received ten more responses when compared with the Reference Study has gotten.

Stakeholder category: Following the context of the characterization of the respondent ports, it was also asked to which category of stakeholder the responding company belonged to. The results were grouped in the graph of Fig. 3.

It was identified that 48% of the respondent ports are port authorities and the second largest group with 34% belongs to the category of private ports. It should be noted that fully privatized ports are located in South America. Port terminals represents 12%, port management companies 4% and others 2%. When this result is compared with the Reference Study, a more significant presence of private ports is noteworthy. This can be explained by the change in the regulatory framework of the Brazilian port sector, which from 2012 onwards allowed the exploration of private terminals and with this the presence of this type of port facility in the South American region has significantly increased.

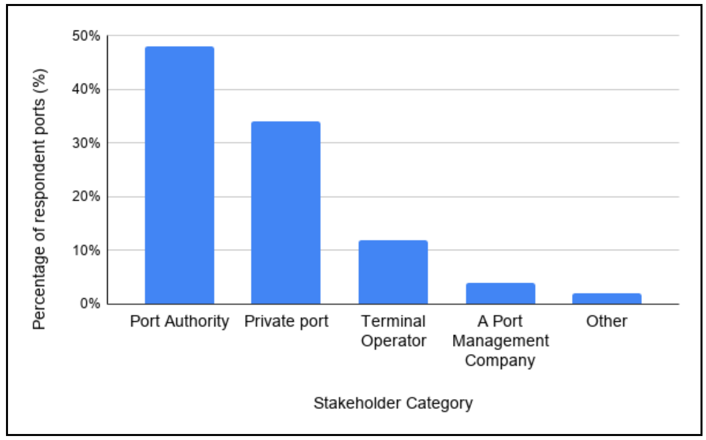

Fig. 3: Participation according to the stakeholder category.

Breakwaters: The ports were also asked about the presence or absence of breakwaters at their facilities and the responses obtained demonstrates that 16 of the 39 ports that answered this question indicated the presence of breakwaters. Of the 16 ports, 9 of them are located in the Mediterranean, 6 in South America, and only one in Central America (see Fig. 4).

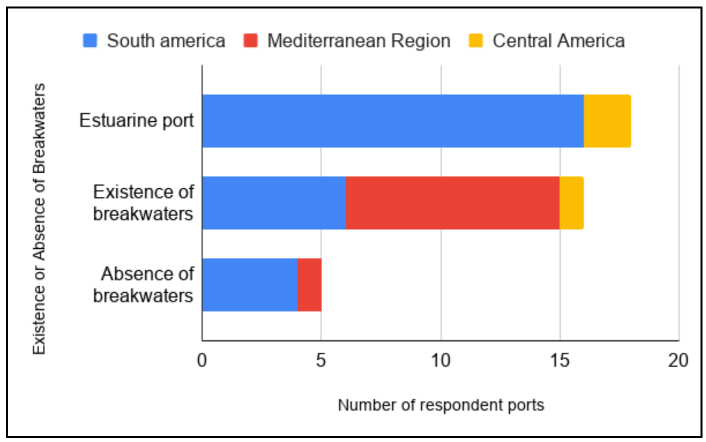

Fig. 4: Existence or absence of breakwaters (number of respondent ports).

This question was complemented by asking the ports to indicate the length of their breakwaters and their respective elevations above the Highest Water Level of spring tides (HWS). The results provided are tabulated in Table 2.

Among the respondent ports that indicated the presence of the breakwater, the one with the greatest length and elevation is located in the Mediterranean region and has 11.7 km and 12 meters of elevation above the WHS. The smallest one indicated an extension of only 1.0 km and only 1.0 meter of elevation above HWS and is also located in the Mediterranean region. The overall average length of breakwater between respondent ports was 3.78 km. In turn, 5 ports signaled the absence of breakwaters. However, it is noteworthy that 18 ports stated that they do not have breakwaters as they are estuarine ports.

Table 2: Length and elevation of the respondent ports that indicated the existence of breakwaters.

Region	Length (in kilometers)	Elevation (in meters)
South America	6.50	1.70
	5.80	2.00
	4.60	-
	2.44	5.80
	1.10	8.00*
	1.01	3.00
Central America	3.95	8.00
Mediterranean	11.70	12.00
	8.00	11.00
	4.00	10.00
	2.65	0.80
	2.60	0.07
	2.00	13.00
	1.65	13.00
	1.50	3.20
	1.00	1.16

* M.L.W.S.: mean low water springs

Hinterland connections: Respondent ports also provided answers on the modes of transport to which they are connected. The results of this question are shown in the Table 3.

Table 3: Number of respondent ports indicating their set of hinterland connections.

Type of hinterland connection	Nº of responses
Road, Rail, Inland Waterway and Airport	2
Road, Rail and Airport	7
Road, Inland Waterway and Airport	5
Road, Rail and Inland Waterway	3
Road and Rail	13
Road and Inland Waterway	7
Road and Airport	1
Road	8
Inland Waterway	3
Rail	1

Unlike the Reference Study, this survey included 'airports' as an internal connection option. This was done because as a presumably stable element in recovery scenarios, air cargo plays a significant role in supporting the recovery of the supply chain and the regional economy (Zubkov, 2020), especially in the face of disruptive events that may become more frequent due to climate changes. In principle, this shift from waterway to air transport can be a disadvantage for ports. But it is an advantage when the ports would require some basic materials such as sanitary items in case of a disruption in their operation. The ports will have a better chance of reestablishing its functions if it can count on the services of a nearby airport in case there is a total or partial disruption of operations.

To more effectively visualize whether the ports in this study have a good level of hinterland connectivity, the results from Table 3 were plotted in order to demonstrate the degree of connectivity of the respondent ports. This arrangement can be seen in Fig. 5.

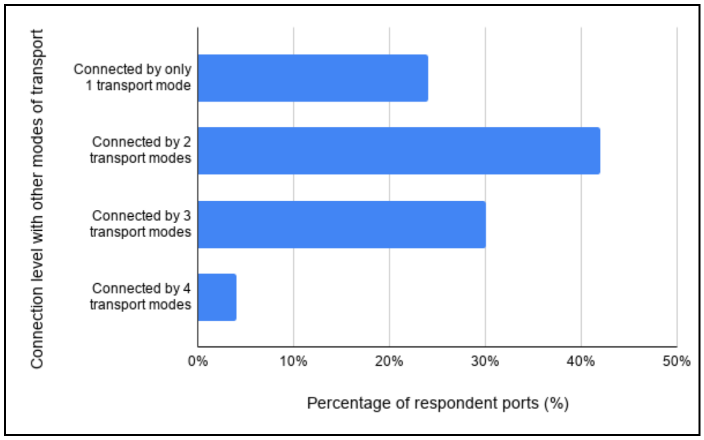

Fig. 5: Percentage of the connection level with inland modal transport.

Climate change may affect all connecting transport modes, but port connectivity through alternative transport access routes and modes provides redundancy and enhances resilience. On the understanding that ports with more modal connections have relatively greater resilience than those with less modal connections we can observe that about 1/3 of the respondent ports are connected to three or four different modes of inland transport. But the vast majority, about 2/3, are connected to just two or even just one mode of inland connections.

In this study, air transport was introduced among the possibilities of hinterland connection. Nevertheless, the results obtained were very much in line with those of the Reference Study. In the Reference Study, a fifth of the respondent ports indicated that they depend only on a road connection while in this study almost a quarter are dependent on only one type of interior connection, making them dependent on the resilience of these connections in the face of disruptive weather events.

Profile of cargo handled: The ports were also asked about the type of cargo they handle. The responses of the 50 ports that answered this question are illustrated in the Fig. 6.

Through the aggregated analysis of the data it was possible to observe that 88% of the respondents indicated dry cargo as the preponderant cargo revealed. Secondly, containers were indicated by 60% of the respondents as a type of cargo mostly handled. This result draws attention when compared to the results of the Reference Study, where 88% of the predominant cargo was containerized cargo. This is because the preponderant group of respondent ports in this research belong to developing countries where the volume of trade in containerized products is much lower when compared to the volume of this same type of trade in developed countries.

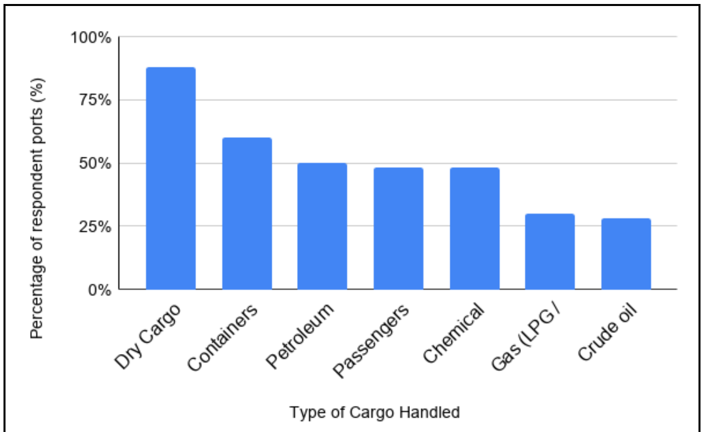

Fig. 6: Percentage of respondent ports by type of cargo handled.

However, in a disaggregated analysis of the data revealed that among the 50 ports that answered this question, 9 small ports in South America handle dry cargo exclusively, 1 port in South America handles exclusively chemical products, 1 small port also in South America handles exclusively containers and 1 port in Central America handles exclusively passengers. This information draws attention to the dependence of these ports on only one type of cargo.

It is known that climate change will affect ports directly and indirectly. Direct impacts are those that can affect infrastructure, operations and services, while indirect impacts include changes in demand for port services resulting from the effects of climate change on trade, investment decisions, demography, agricultural production, forestry, exploration, consumption of energy, and fishing activity (Asariotis, 2018). If agricultural production is impacted, the dependence, exclusive or predominant, of a port in only one type of good, gains even more importance. Especially if this product is bulk food, which is one of the main export products of the developing economies.

There is still not much certainty about how climate changes will affect agricultural production in the main world granaries, but there is evidence that indicates that the production of certain crops will be strongly impacted and such impacts can mean complete abandonment of certain areas by ineptitude soil, or lack of water for irrigation, or even the need to change the type of crop. This implies that ports that handle a wide range of products have high specialized structural arrangements and greater flexibility compared to ports that handle specific types of cargo. Hence, the 24% of the ports that responded to the survey, depending on only one type of cargo, are of concern.

Investment plans: To complement the characterization of the ports' profile the future investment plans was required. In this regard, it was first asked what the total volume of investment planned was and then, the ports were asked to indicate in which area these investments would be made. 76% of the respondent ports revealed that they have future investment plans, against 24% which indicated that they have no investment plans for the 5 coming years.

For ports that responded positively to the previous question, they were also asked at what scale these investments would take place (results plotted in Fig. 7). The data shows that among the 28 ports that indicated the total planned future investment value, the vast majority have plans to invest between 10 and 100 million US dollars.

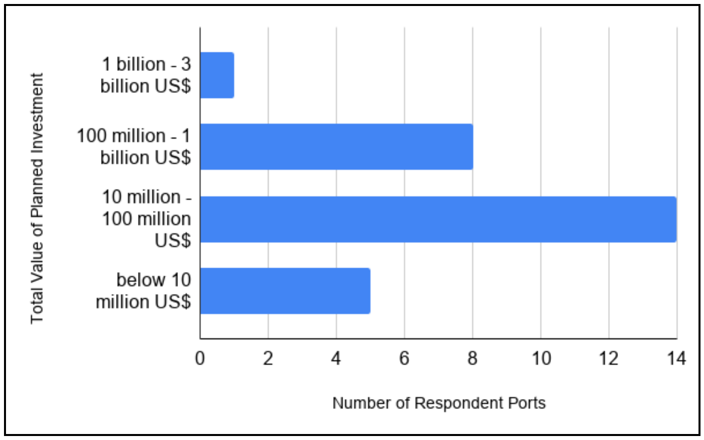

Fig. 7: Number of respondent ports indicating the value of investment planed in the 5 coming years, by ratio (US dollars).

It is also important to know the areas these investments would take place to ascertain if there are planned investments for areas particularly more exposed to climate risks. Responding to this question, 55% of the ports indicated plans for future investments in dredging predominantly. All the investment expectations among the group of respondent ports exceed eight billion US dollars. In second, third and fourth place, with very similar percentages, 11% had intentions of investing in installation, 10% had interest in sea defenses and 9% were interested in hinterland connections as shown in Fig. 8. Investments in equipment and information technology appeared in the sixth and seventh plan, with 4% and 2% respectively.

The question that closes the profile characterization block is whether the planned future investments consider climatic factors. The result showed only 53% of the ports have future investment plans take into account climatic factors in their planning, a value 30% lower than that obtained by the Reference Study.

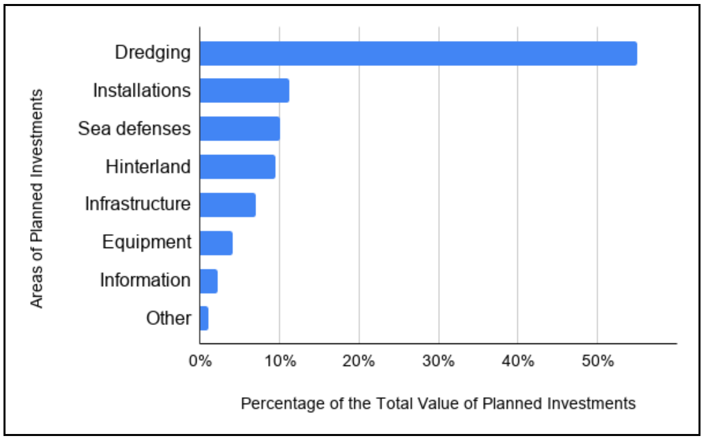

Fig. 8: Percentage of ports indicating planned investments by area.

Block II - History of Weather and Climate-Related Impacts

This group of questions is dedicated to investigating the history of impacting climatic events experienced by the port.

Previous extreme climate events: Regarding this matter, about 72% of ports reported they have already been impacted by extreme weather events, against only 28% who reported not. This result is the same with the Reference Study. When observed by region, 100% of the ports in Central America, 82% of the Mediterranean ports and 67% of the ports in South America, said they had already been affected by extreme weather events.

Type and level of impacts: The ports which responded affirmatively to the previous question were also asked about the extent of the damage caused by these extreme weather events. The results can be seen in Fig 9.

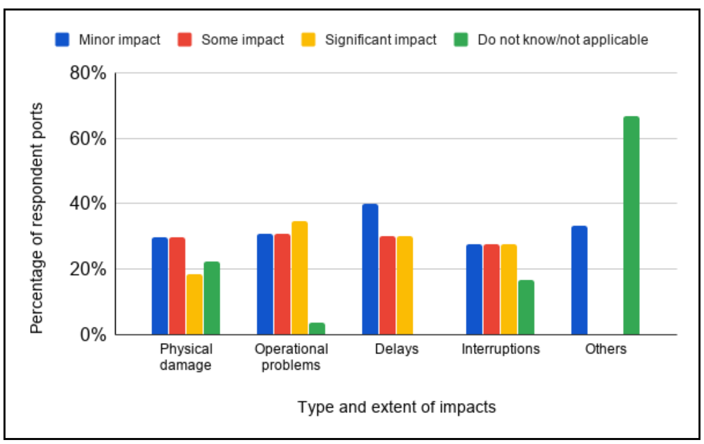

Fig. 9: Percentage of respondent ports by type and extent of extreme climate-related events.

Those which reported the occurrence of physical damage, approximately two-thirds, said that this damage was small (30%) or medium (30%). However, those who revealed to have experienced operational impacts, mostly indicated that the impacts were significant (35%). Those who reported having experienced delays pointed out that these impacts were mostly small (40%). The intensity of the impacts was the same for the ports that reported having suffered interruptions in their operations. A similar portion (28%) indicated that the impacts were of low, medium, or high magnitude. 67% of those which reported having suffered from other types of impacts, indicated most of them not knowing how to assess the magnitude of these impacts.

These data show certain variations when compared to the Reference Study which indicated that the impacts related to physical damage were classified as mostly small and those that caused operational problems or interruptions were of medium extent.

When analyzed by region, the types of damage that were prevalent were similar between the three regions represented in this study. However, in the Mediterranean ports, physical damage and operational problems are relatively more prevalent than in other regions (Fig. 10).

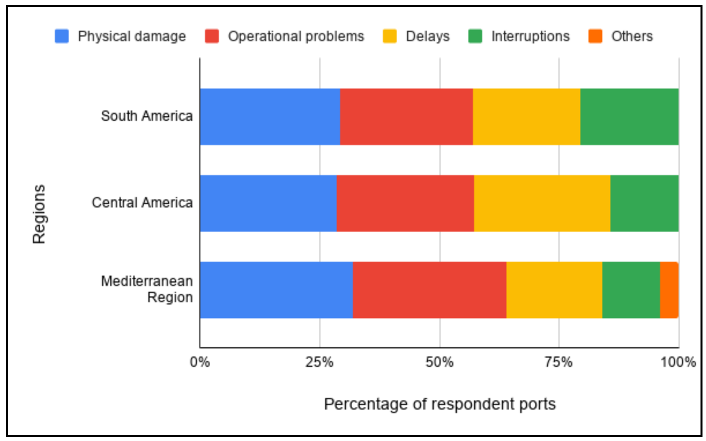

Fig. 10: Preponderant type of impacts by region.

Regarding the history of impacts caused by climate events, recurring or extreme, it is possible to conclude that although the majority of the ports mentioned that they have already been affected in some way by climate-related events, it was also possible to identify that these impacts are still within of a manageable level, where most of the impacts involved operational problems and delays. These types of impacts have consequences that are, apparently, mostly of a financial nature (resulting in compensation or loss of revenue) that, depending on the size of the port, the type of cargo handled and the volume of revenues, can be distributed and absorbed throughout the year's accounting result.

Type of Climate factors and port element impacted: The ports also indicated what events occurred and in what ways did these extreme weather events affect the port. The data obtained is summarized in Fig. 11.

These data show that the types of extreme weather events most reported were extreme winds (28%), extreme rainfall (26%) and storms surges (19%), and they were similar to the Reference Study.

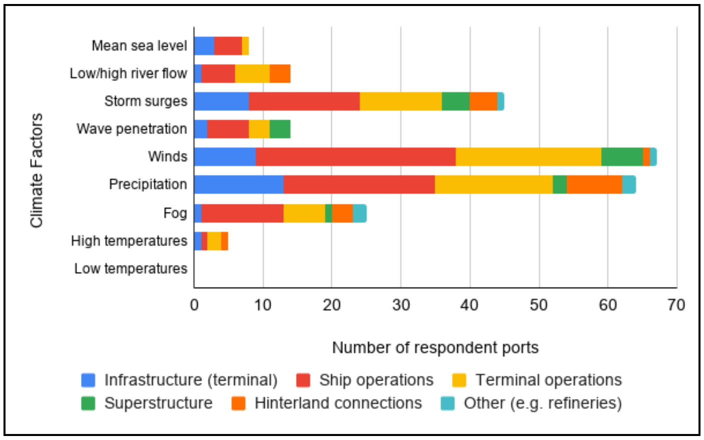

Fig. 11: Impact of climate factors by port component.

The respondent ports reported that these events had a major impact on ship operations (39%), terminal operations (28%) and the port infrastructure (16%). In the Reference Study, terminal operations were the most indicated aspect among the respondent ports of that study. Nevertheless, when analyzed by regions the data show that in South American ports there was a greater indication of the ports in that region being impacted by extreme precipitation, more than by extreme winds. As for the ports in Central and Mediterranean America, the indications of more impacts due to extreme events were predominantly windy. The result showing that extreme rainfall being a major concern in the South America's ports, may be because ports in that region are located on waterways, where the precipitation factor has a more relevant character concerning to winds.

Fog was the fourth biggest impact indicated by all respondent ports, but mainly for 11 ports in South America and 5 in the Mediterranean. Interestingly, no port in Central America indicated fog affecting any area of the port. The two areas most indicated to be affected by fog were ship operations and terminal operations. Only two ports in South America indicated that fog also impacts access to the port. These ports are located on the Atlantic coast and access to them consists of crossing mountainous regions by road and rail.

Trends in magnitude of the damages: When asked how the magnitude of damage and / or interruptions caused by climate or events related to the climate evolved, the responses obtained were: 53% of the 49 respondent ports indicated that they remained unchanged; 16% increased; 6% decreased; only 6% reported that the magnitude of the damage decreased as a result of specific measures adopted by the port or terminal, and 18% did not know to inform (Fig 12). These results are like those found in the Reference Study.

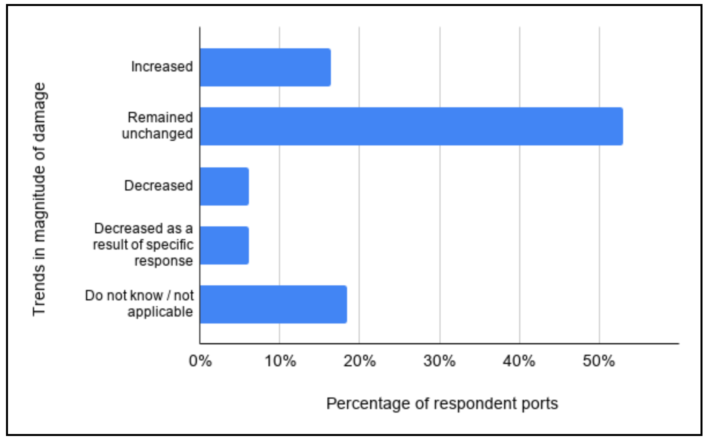

Fig 12: Trends in magnitude of damage and/or disruption over time.

Claims for action from clients: The ports were to inform if port customers have already asked them to take effective response measures in the face of damage or interruptions caused by weather events. 79% of the 47 ports that responded to this question indicated that they have not yet received such requests from its customers, against only 21% who indicated that were requested by its clients to take response measures. These responses are also similar to the Reference Study. What is worth noting is that among the ports that reported that their customers have already requested response measures, they are ports located in South and Central America. None of them in the Mediterranean. The reason why most ports have informed that their customers have not asked for concrete mitigation actions, may be associated with the low perception that these customers may have about the losses caused by such events. In seasonal cargo and for trump voyages (which do not call the same port regularly), the observation of an increasing pattern of losses or risks associated with climate change may be impaired. Shipping companies that have regular lines and customers that ship cargo on a regular basis are expected to be the first ones to observe the necessity of protective or mitigation measures on ports or terminals.

Changes experienced in insurance: 49 ports provided response on changes in premiums, terms or coverage of insurance policies due to climate events experienced by the port. Only 10% of the ports indicated that their insurance had been altered in some way, against a majority of 90% that replied that they have not yet undergone any changes in their insurance policies. These results are also in line with the results of the Reference Study for the same question. The high percentage of negative responses to the question about changes in insurance experienced by ports would deserve to be investigated more deeply, in a dedicated study, as it is possible to imagine that the types and coverage of port insurance may vary widely from one port to another, even inside the same country, and mainly between different countries which has different laws and practices.
Although there is a greater number of respondent ports revealing that they consider climatic factors in planning future investments, the percentage value of those that said that they do not take climatic factors into consideration is quite high.

Respondents who report not considering climate factors in their investment plans are mainly located in the South America (18) and Mediterranean (3) region, although 15 of them reported they have already been impacted by extreme weather events.

Block III - Availability of Data and Information Needs

Block three is dedicated to measuring the availability or absence of climatological data in ports.

Availability of climatological information: In order to find out if the ports are well supported in terms of information availability, they were asked to answer whether the port has past and present information on weather data that are usually critical for assessing a facility's vulnerability or exposure level to climate risk. This data set are: sea/river level; height, period and direction of waves; wind speed and direction and number of strong wind days; medium and extreme precipitation; and, medium and extreme temperatures. The answers for this question varied considerably in relation to the number of respondent ports for each aspect individually. The data are summarized in Fig. 13 and shows that most of the respondent ports have past and present information on critical meteorological parameters.

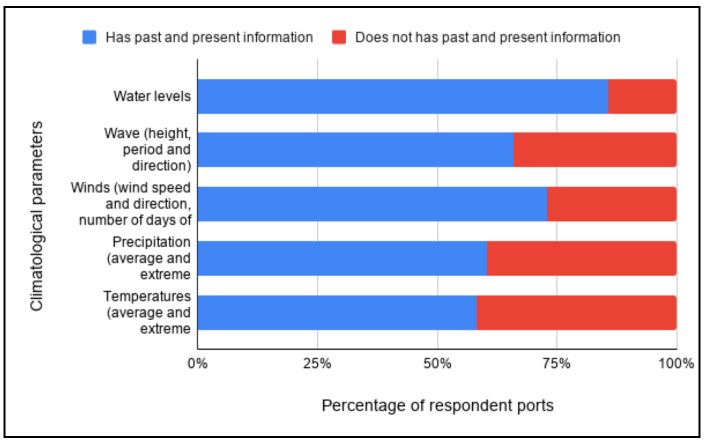

Fig. 13: Availability of past and present information on critical climatological parameters.

More than 50% in all cases responded that they have data for these parameters. It was extreme/average temperatures and extreme/average precipitations the parameters for which a greater number of ports reported that they do not have data available, followed by height, period and directions of waves. It is interesting to note that 6 ports in South America have reported that they do not have any past or present climatological data. All ports in Central America and the Mediterranean reported having data for almost all the parameters mentioned.

Trends on climatological relevant parameters: The ports which have responded affirmatively to the previous question were asked to say if they observe that relevant data show climate changes over time that could be considered a trend. Of the 48 ports that answered this question, 46% reported that the data showed that these critical parameters present a pattern of changes that could represent a trend.

Need of response measures: For ports that responded affirmatively to the previous question it was also asked whether they think that such trends point to the need for adoption of response measures. Only 47% of the 34 ports that provided an answer to this question indicated that they understand they will need to implement response measures to address these trends.

Types of response measures expected: Among the ports that detailed what these response measures would be, most of them indicated the realization of the most frequent maintenance dredging and the adaptation of breakwaters as the most relevant. Only one port in the Mediterranean region highlighted the need for changes in the routine of operations (ship berthing/unberthing routines) and only one port on the Atlantic Coast considered that the sea level rise is a positive aspect for its operations since it would allow the docking of vessels of greater draft, although this port has not provided details on the needs of infrastructure adaptation to get this purpose.

Impact of long-wave penetration: Ports were asked about the extent to which the occurrence of long-wave penetration represents a problem for them Fig. 14.

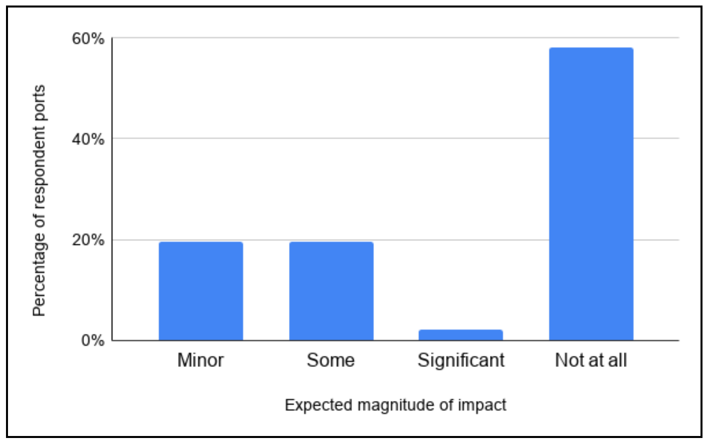

Fig. 14: Expected level of impact in the occurrence of long-wave penetration.

This question had the following answers from 46 respondent ports: 58% answered that the penetration of long waves does not means any problem; 20% indicated that it represents some problem; and the same amount indicated that it represents only a small problem; and only 2% said it represents a major problem.

Availability of data on marine currents: The ports were asked about the information available on currents and the results of this question are shown in Table 4, below:

Table 4: Percentage of the respondent ports by type of information on currents.

Type of information	Number of responses
Observation only	18
Modelling only	7
Modelling validated by long-term observation	2
Observation and modelling	5
Observation and Modelling validated by long-term observation	3
Observation, modelling and Modelling validated by long-term observation	2
Total of respondent ports	37

In addition, for ports which answered affirmatively to the previous question, they were also asked to indicate the basis for information on currents that they use. The results are shown in Fig. 15.

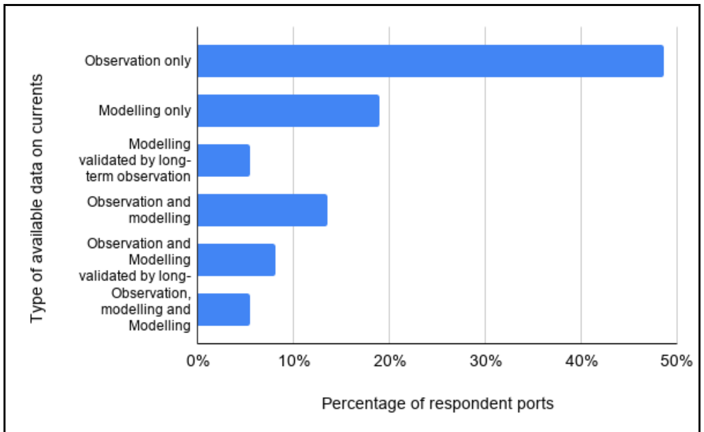

Fig. 15: Basis of information on currents.

The majority of respondent ports indicated that data on currents in their respective ports are obtained through observations only (49%) and in the second place modeling only (19%). Only 14% said they utilize information on currents from observations plus modeling. Information on currents based in observations plus modeling, validated by long-term observations obtained even lower percentages of response (8%). A small percentage of 5% reported their information on current is based in modeling validated by long term observations or observations plus modeling, plus modeling validated by long term observations.

Downscaling forecasts: It is important to know the existence of downscaling forecasts on climate factors because downscaling assesses regional climate change for areas characterized by high space variability and many climate types, such as the South America and the Mediterranean (Mancosu, 2015). The scale reduction technique is applied to obtain refinement in local and regional climate prediction models. Downscaling is particularly important for assessing regional climate change for areas characterized by high space variability and many climate types, such as the South America and the Mediterranean (Mancosu, 2015). This technique is interesting for ports, particularly because it is suitable to help with classification and climate predictions in mountainous regions and coastal areas, where the complexity of the variables involved in predictive models is not resolved by the structure of a large global climate model (UNCC, 2015).

Concerning the existence of downscaled forecasts[5] on mean sea level rise, extreme sea level rise, waves, winds, temperatures and precipitation, an average of 34% of the 37 ports responded affirmatively to this question, against about 66% who responded that they did not have downscaled forecasts (Fig. 16).

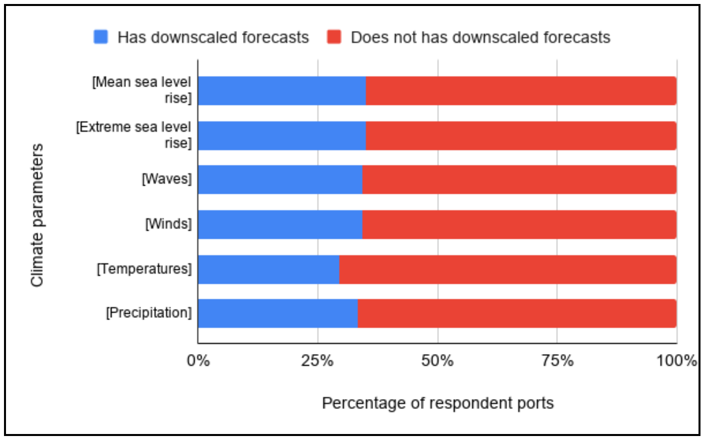

Fig. 16: Existence of downscaled forecasts for critical climatological parameters.

Interestingly, most of the ports that responded positively to the existence of downscaled forecasts are in the Mediterranean. The ports also indicated the extent of the period on which these forecasts were based on an individual basis for each climate parameter. The answers are presented in Fig. 17. Fig. 17 shows that most of the participating ports indicated that the data available to be employed in downscaled forecasts are 10 years and 50 years.

[5] The downscaling of global climate change projections has been developed to serve the needs of decision makers who require local climate information for impact assessments. Global Climate Models (GCMs) provide information at scales on the order of 100–500 kilometers for studies that focus on large geographic regions and direction of change, e.g., increase or decrease in temperature. Downscaling to 10–50 kilometers is necessary for the assessment of region- and station-scale climate information (USAID, 2014).

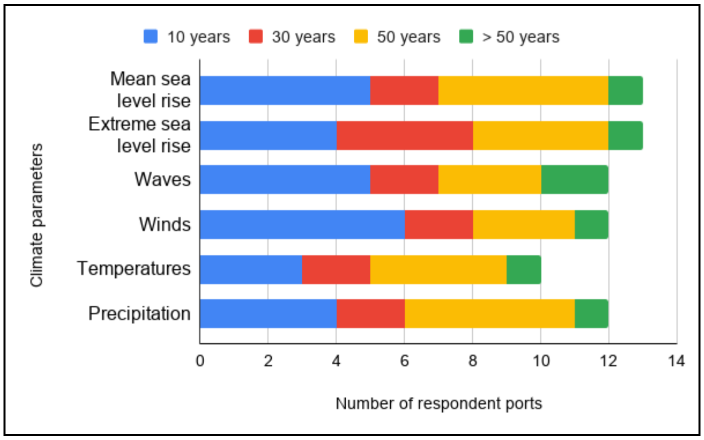

Fig. 17: Timescale of downscaled forecasts and assessments for climatological parameters.

BLOCK IV – Resilience, Level of Preparedness and Adaptation Planning

This block was built to find out if the ports participating in the research have plans and adaptation measures to face climate changes and try to identify the level of preparation and resilience that can be expected from these ports.

Costs to upgrade breakwaters: the ports were asked whether they think updating the breakwaters to cope with the mean sea level rise, can be done at a manageable cost. This question had just over half (53%) of the 32 respondent ports, indicating that they think it is possible to update the breakwaters at a reasonable cost. Lack of response from the other ports is likely related to the location of the port because breakwaters may not be needed in estuarine ports, for instance.

It is interesting to note that, in relative terms, the region that had the most ports indicating that the cost of updating breakwaters would be at a reasonable level, was the Mediterranean and Central America (78% and 67%, respectively), against 40% in South America.

To complement the previous question, it was requested to indicate the estimated values for the construction of new breakwaters or for the adaptation of existing ones, if necessary. Only 6 ports provided information for this question. The ports that indicated the two lowest values are located in Central America (US$ 315,000.00 and US$ 2,250,000.00) and those that indicated the 2 highest values (US$ 495,000,000.00 and US$ 660,000,000.00) are located in the Mediterranean. Only one port in South America provided information to this question indicating the value of about US$ 46,550,000 to update its breakwater. The low number of answers to this question may be because this information seems not to be readily available to the survey respondents.

Thresholds for climatological parameters: The ports were asked about what thresholds they expect that various climatological parameters may cause damage or impair the functioning of the infrastructure or superstructure (equipment).

For all parameters, the number of responses was low, indicating possible information gaps or restrictions related to internal communication on data relevant to the assessment and management of port vulnerability. The results are indicated in Fig. 18.

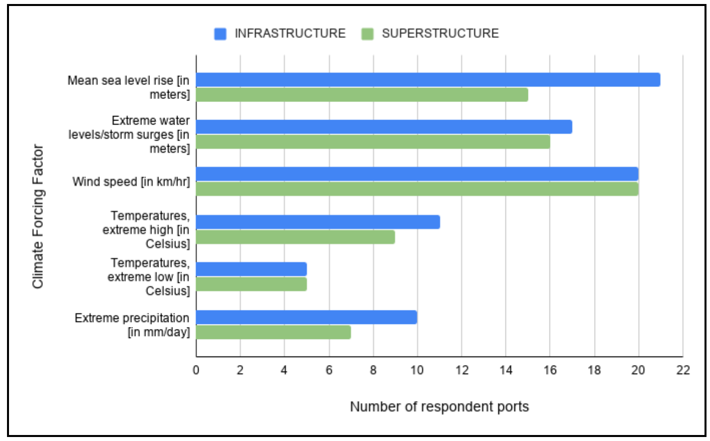

Fig. 18: Nº of respondent ports indicating expected thresholds for climate stressors for infrastructure and superstructure.

19% of the 26 respondents provided limits for extremely low temperatures, while, on average, 69% of respondents provided limits for the integrity of infrastructure and equipment related to the mean sea level rise. Infrastructure thresholds for mean sea level rise reported ranged from 0.25 meters to 9 meters, with thresholds of 1 and 2 meters being the most reported; equipment thresholds also varied between 0.5 meters to 9 meters. There were indications of thresholds of up to 20 meters, but these indications refer to ports on waterways, located in the course of major rivers in South America, therefore, this information was disregarded. The results are presented in Fig. 19.

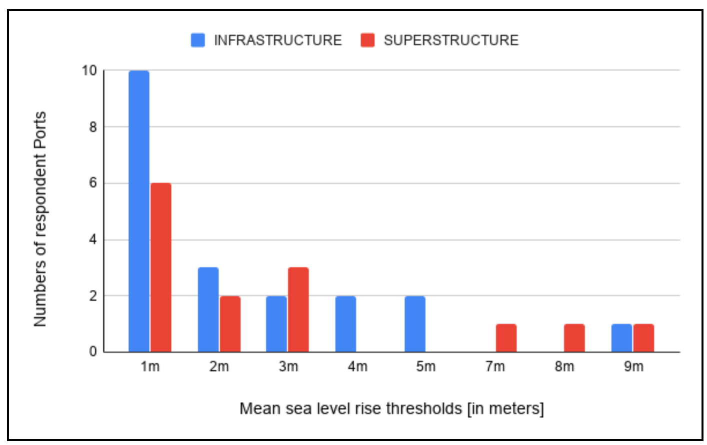

Fig. 19: Expected thresholds for mean sea level rise for infrastructure and superstructure.

Regarding the wind sea speed, the reported limits related to infrastructure ranged from 8 to 120 km/hour, and those related to superstructure ranged from 10 to 120 km/hour. The range of 30 to 60 km/h was indicated as the most common stress limit for both, infrastructure and equipment (see Fig 20).

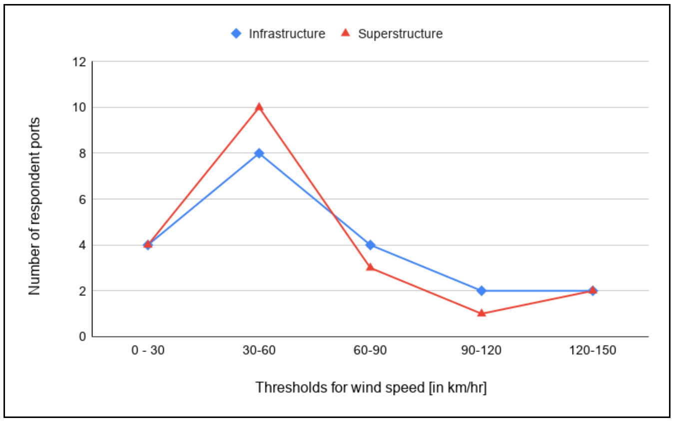

Fig. 20: Expected thresholds for wind speed expected for infrastructure and superstructure.

Regarding thresholds related to the extreme sea level, reported thresholds for infrastructure and equipment ranged from less than 1 meter to 10 meters, with the most commonly reported values being 1, 2, 4 and 10 meters for infrastructure and 1, 4 and 10 meters for equipment (see Fig. 21).

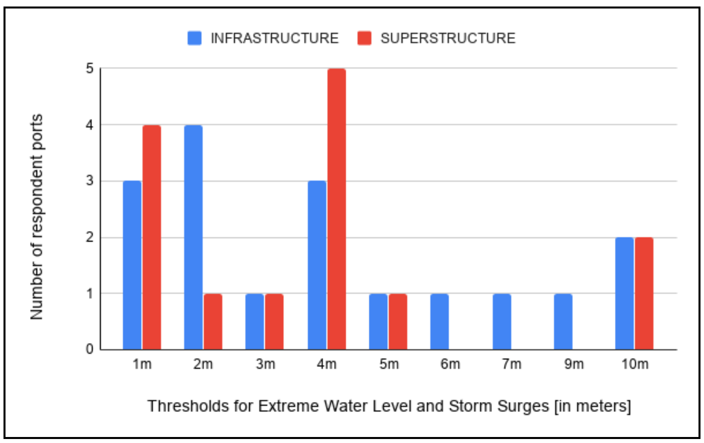

Fig. 21: Expected thresholds for extreme water levels / storm for infrastructure and superstructure.

It is observed that there was an indication of a threshold of 30 meters for extreme sea level, but this threshold does not apply to a seaport, but to the flooding phenomenon that occurs in rivers of great depth. The port that indicated this threshold is found in the Amazon region, in South America where the variation in the water level of certain rivers can vary enormously between ebb and flow periods, therefore, this information was disregarded.

The 9 of the interviewees who indicated high temperature stressors thresholds for infrastructure, indicated thresholds in the range of 40° - 50°C, both for infrastructure and for equipment. In turn, the 3 ports that reported low temperature stressors thresholds, indicated these thresholds ranging from 1° to 10°C, also for infrastructure and equipment.

For the extreme precipitation stressor phenomenon, the limits varied between 10 and 5000mm/day, with the most common limit value reported at 10mm/day, also for infrastructure and equipment.

Emergency response measures: Ports were asked to report whether they have emergency response measures, in progress or being planned, to confront threats related to climate change. About 41% of the 46 ports that offered an answer to this question said that there is no emergency measure in progress or being planned, as shown in Fig 22. Other 41% reported that emergency measures are in progress and 18% said emergency measures are being planned. 59% was the percentage of the respondent ports who have emergency measures in progress or planned. Though that rate is greater than those that do not have, it is still small. It is a matter of concern, that 41% of respondents reported not having or planning any emergency measures responses.

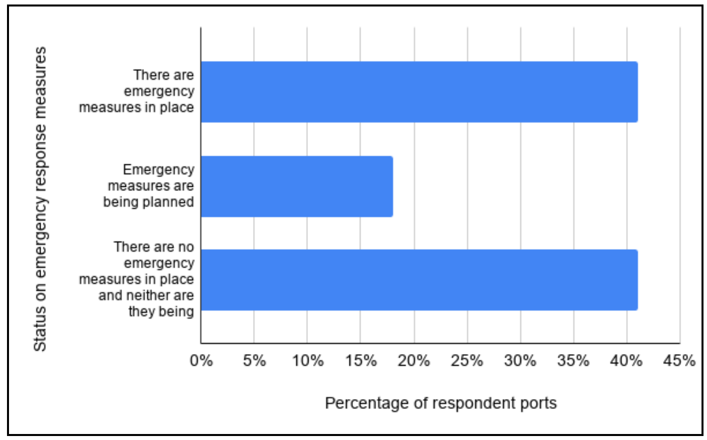

Fig. 22: Status on emergency response measures for climate-related threats.

Vulnerability Assessments: Similarly, 56% of the 47 respondents indicated that their port has assessed or is planning to assess/to measure the degree of vulnerability of the port in relation to climate change. 44% indicated that they are not assessing or planning to assess vulnerability to climate-related events (see Fig 23).

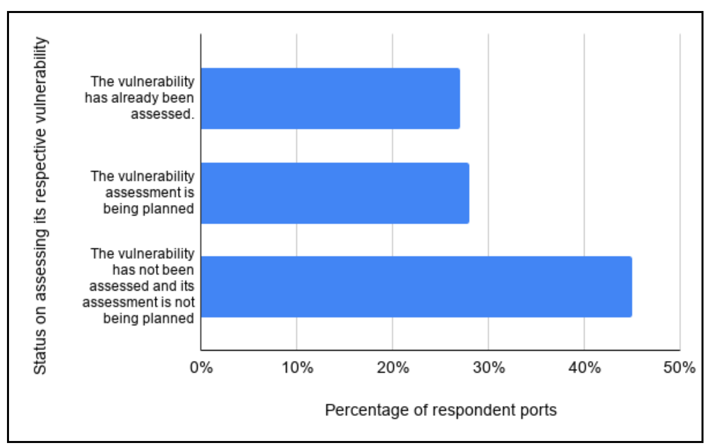

Fig. 23: Status on assessing its respective vulnerability to weather or climate-related events.

Complementarily, the ports that answered positively to the previous question, were asked about what climatic parameters are being measured or is being planned to measure, taking into account the port elements that may be affect by them (Fig. 24).

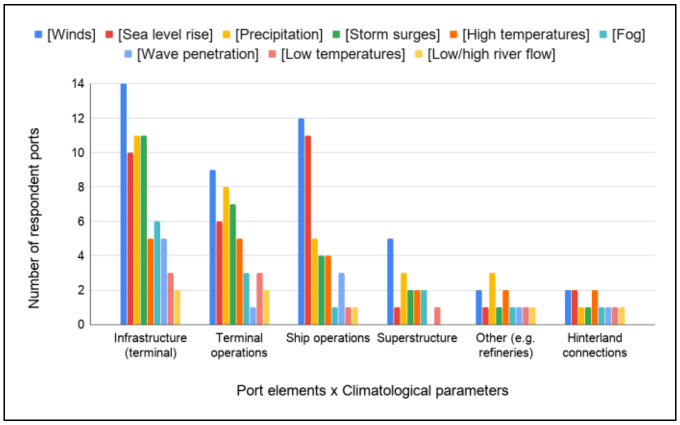

Fig. 24: Climate-related events taken into account for vulnerability assessment by type of port element.

All participating ports offered responses to at least one climate parameter. The results show that ports seem to be more engaged in assessing the vulnerability of the following port elements: infrastructure with 35%; terminal operations with 23%; and ship operations with 22%. In relation to these components, the ports indicated that the assessment of the vulnerability of the following parameters are the most relevant: winds with 23%; sea level rise with 16%; precipitation with 16%; and, storm surges with 13%. Meanwhile, high temperatures with 10%, fog with 7%, long-wave penetration with 6%, low temperatures with 5%, and high or low river levels with 4% were the least indicated parameters.

Expected impacts: It was also asked what types of impacts are expected to affect the ports due to weather or climate induced changes in a broad and general manner. The data were consolidated in the Fig. 25.

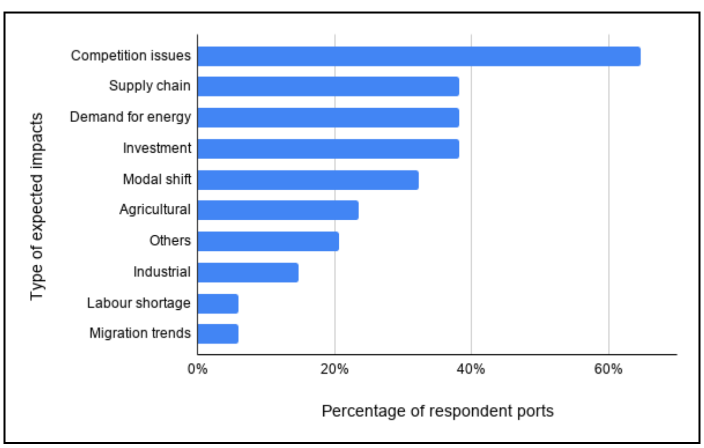

Fig. 25: Expected impacts due to climate-induced changes.

Of the 34 ports that provided an answer to this question, 65% believe that the greatest impact will be on competition between ports, meaning trade diversion to other ports. The second, third and fourth most cited impacts were supply chain disruptions, changes in demand for energy inside the port and changes in investments, with 38% of the respondent ports indicating such impacts with the same intensity. Fifthly, 32% of the respondent ports expressed concerns on changes in transport modes that could affect connections with the port's hinterland.

Twenty-one percent of respondents indicated other types of impacts. Of these, 4 ports mentioned direct impacts related to ship operations and 1 port, interestingly, responded that impacts related to sanitary and health issues are expected, but without providing further details.

Mainstreamed climate consideration on infrastructure provisions: To know if new infrastructure provisions are being planned, designed and built considering climate change, we ask the ports to say if they have mainstreamed climate information in such process. The survey got 57% of affirmative answers, from the 47 ports that provided answers to this question.

Adaptation measures: The ports were also asked whether the port/terminal carried out any work, including research, to identify and evaluate possible adaptation measures for potential climate change related issues. With a 92% response rate, this question got 72% of the respondents reporting “NO”, while only 28% said “YES”. For adaptation measures, the ports were asked about participation on corporative actions to tackle climate change. With an 88% response rate, this question obtained the half of the respondents indicating they are not participating and do not have plans to participate in any corporative adaptation strategies, and the others 50% said yes, they are.

It should be remembered that, in this study, a greater participation of private ports than port authorities were identified in the first block. This aspect may represent a possible barrier to the participation of these terminals in corporate climate defense strategies. Terminals that operate under the umbrella of a port authority, can benefit from the synergies generated in the port community to demand support and obtain government, non-government or external aid for example, since together, they are parts of a more relevant whole. This seems to be a hypothesis that deserves further investigation by future works.

To complement the previous questions, the ports were asked to indicate, where applicable, what areas were object of implemented or planned adaptation measures. Only 27 ports provided information for this question and the five most indicated areas were: emergency management plans and processes with 63%; port investments with 63%; port design, construction and engineering with 56%; port planning with 52% and frequency of maintenance and inspections with 50%. 41% of respondent ports also indicated adaptation measures in port management. 37% indicated changes in types of materials used for construction. 33% indicated measures aimed at adapting equipment and operations and only 11% indicated adaptations on insurance conditions (Fig. 26).

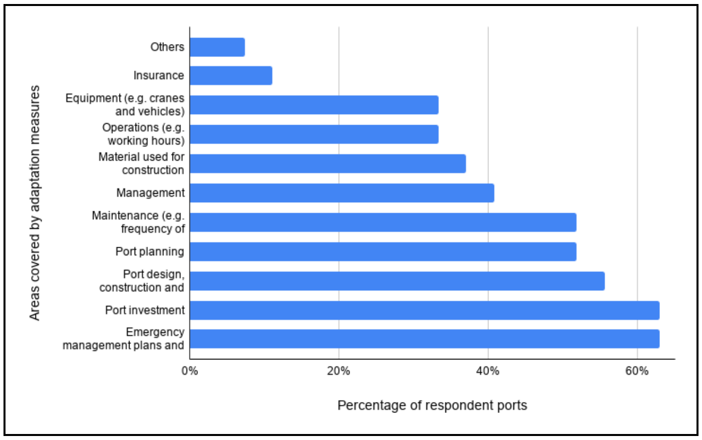

Fig. 26: Indication on what areas were object of implemented or planned adaptation measures.

The previous question is complemented by the question about estimated or projected total expenditure for adaptation measures in the port / terminal. Only 5 ports reported the amount of investment to be employed in specific measures to adapt to climate change, being 3 in South America, 1 in Central America and 1 in the Mediterranean. The average value was around US$ 37.9 million. The lowest was US$ 2.5 million and the highest was US$ 110.0 million.

Finally, the ports were asked to indicate whether they received any type of financial assistance or other assistance from external governmental or non-governmental organizations, for programs or projects to deal with climate change. Only one port answered affirmatively to that question and this port is located in South America. Of the 45 ports that offered an answer to this question, 28 ports said that they did not receive any help or expect to receive it, and 16 said that they have not yet received it, but they expect to receive some assistance in the future (Fig. 27).

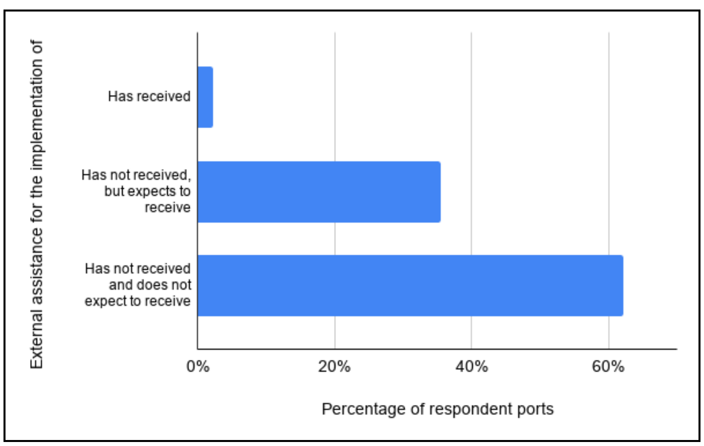

Fig. 27: Indication about assistance from external sources to tackle climate change.

In the end, the participating ports were asked to provide spontaneous information on actions or measures implemented by them that are considered good practices or good examples of facing threats from climate variations. The responses obtained are reunited in Table 4.

Table 4: Samples of actions indicated by 18 respondent ports as good practices on facing impending climate treats.

Port Location	Action
South America	Electric Crane acquisition.
	Preventive maintenance, and improvement in electrical installations.
	Installation of a small meteorological and tide station.
	Periodic monitoring of weather conditions for ship maneuvers
	Automation of the terminal in order to depend less on human labor, as a way to eliminate hours of stoppage of the terminal when under bad climatic conditions
	Improvements in navigation aid systems in the port access channel, like autonomous and self-synchronizing LED lanterns.
	Improvements in the lighting of the berth for night operations.
	Installation (rental) of cylindrical pneumatic fenders, providing greater efficiency and agility in replacement in case of need.
	Implementation project. implementation of the Vessel Traffic Management Information System (VTMIS)
	Dredging the port entrance access channel to reduce the effects of storm surges.
	Implementation of a good water drainage system that prevents contamination from external agents.
	Dredging and other measures that allow safe night maneuvers.
Central America	Planning, construction, and maintenance.
	Breakwater construction
Mediterranean	Use of extreme events for the production of clean and renewable energy.
	Change in design patterns for new infrastructure.
	Breakwater construction
	Remodeling to increase the dock level

An interesting aspect to note from this opened question is the low number of ports that reported the adoption of mitigation measures as good practices. Only two ports reported measures of this nature. One that reported the acquisition of a large electric cranes, in order to not contributing to greenhouse gases emissions and other which reported being taking advantage of the occurrence of extreme events to produce clean and renewable energy.

SUMMARY OF FINDINGS

The main differences found between this research and the Reference Study will be summarized here, by block of questions.

Block I: Comparison between the results for Profile and General Information (Table 5).

Table 5: Comparative findings between this survey and the Reference Study on ports' profile and general information.

Aspect	This study	The Reference Study
The 4 types of traffic most reported	Dry cargo 88% Containers 60% Petroleum 50% Passengers 48%	Containers 88% Dry cargo 83% Passengers 61% Petroleum 51%
Percentage of ports indicating future investment plans	76%	93%
Percentage of ports indicating the total of planned investments	65%	89%
The range of planed investments most indicated was…	10 million - 100 million US$ (for 14 ports)	100 million - 1 billion US$ (for 16 ports)
The total value of the planned investment will take place in …	Dredging (55%)	Infrastructure (54%)
Percentage of ports indicating they take climate change into account for future investment plans	53%	83%

Dry cargo was the predominant type of traffic between the ports in this study while containers were in the reference study. In general, it can be said that the ports in the Reference Study are in a more critical situation because they have a higher percentage of ports operating containers and passengers than those in this study. Both are types of traffic where impacts, even of small magnitude, such as delays, can trigger a series of other indirect impacts on the entire logistics chain.

In the Reference Study almost all the ports expressed intentions for future investments, and the expectations related to the scale of investments were much higher than this study. In the Reference Study, most of the ports that indicated investment plans revealed that the scale of these investments would be between 100 million to 1 billion of American dollars, while in this research the scale of expected investments is predominantly between 10 to 100 million US dollars. This data is because the respondent ports in the Reference Study were from developed nations and in this one from developing nations. This result was already expected, and it is confirmed by the data obtained from the survey. A lower general investment capacity, consequently could means a lower specific investment capacity to face the effects of climate change.

Comparing the investment areas, several divergences were also found. While the Reference Study revealed a massive preference for investments in infrastructure, this research indicates a prevalence of investments in dredging. This can be explained by the expressive number of ports that are reported to be estuarine ports, where the need for constant dredging is usually the rule. Whereas in ports formed by breakwaters, the maintenance of these infrastructures may be more necessary.

In the Reference Study 83% of respondent ports indicated they consider climatic factors in investment planning against only 53% in this study. Even showing the same trend, the results have a notable difference of 30%. This difference may mean a certain gap in the level of awareness between the ports represented by this study and the ports represented by the Reference Study. This is relevant and demonstrates that this issue needs to be better addressed among the ports in the regions represented by this study.

Block II: Comparison between the results for History of Weather and Climate-Related Impacts (Table 6).

Both the Reference Study and this study showed that 72% of the ports had already been impacted. All ports in both studies reported that they already experienced impacts that caused to them physical damages, delays, interruptions, and/or operational problems in some extent. In both studies the climate factors which represent big concerns to the ports are: winds, extreme precipitations, and storm surges.

Almost the same percentage of respondent ports, 53% in this study and 50% in the Reference Study, reported that they believe the relevant climate parameters show climate changes over time which can be considered a trend. A great percentage of respondent ports, 79% in this study and 68% in the Reference Study, said that its respective users did not request that effective response measures be taken. And also a great percentage of the respondent ports, 90% in this study and 79% in the Reference Study, informed that they have not been experienced changes in insurance level of premiums, terms or coverage as a result of weather or climate-related events.

The comparison between the results of the questions in block II revealed a great adherence between the two surveys, indicating that although the profile of ports represented in this research was different from the profile obtained by the Reference Study, with respect to the impacts caused by weather or climate related events, including by extremes, the ports express a similar history of impacts.

Although some results in this study could suggest that ports represented by this study were not very affected by events related to climate change as ports in the Reference Study (such as a lower percentage of ports indicating that they have already undergone changes in insurance), this result must to be interpreted with caution. This is an indicator that should be closely monitored since the insurance sector is also becoming more concentrated and has also started to incorporate climatic lenses in its transactions. What means that changes in this sector are quickly incorporated by all its segments around the world.

Table 6: Main findings between the present study and the Reference Study related to history of climate-related impacts.

Aspect	This study	The Reference Study
Percentage of ports already impacted by extreme climate-related events	72%	72%
Impacts experienced by ports which indicated have been already impacted by climate-related events	physical damage, delays, interruptions and operational problems to some extent	physical damage, delays, interruptions and operational problems to some extent
Climate event of greatest concern	Winds, extreme precipitation and storm surges	Winds, extreme precipitation and storm surges
Percentage of ports indicating a perceived trend in the magnitude of damage caused by climate-related events.	53%	50%
Percentage of ports indicating if their users have requested for climate action	79% do not requested	68% do not requested
Ports indicating they have experienced changes in insurance as a result of climate-related events	90% do not experienced	79% do not experienced

It is also possible to state that the ports represented by this research have more information deficiencies than ports in the Reference Study. For example, with regard to information on currents, to which the responding ports in this study indicated they have information based only on observations, mostly. The data also show a lack of predictive information based on data from long periods of observation, what hampers the use of downscaled forecast (mainly for temperatures), especially the Statistical Downscaling, which involves the establishment of empirical relationships between historical atmospheric and local climate variables (USAID, 2014). Although, in this study, through an open question we obtained the information that some ports in South America has been implementing real time system for monitoring the meteorological and oceanographic parameters (wind speed and direction, currents, temperature and waves) and another port in the same region that said it would be interesting to count on such a system, in order to be able to have forecasts or assessments based on downscaling models.

Block III: Comparison between the results for Availability of Data and Information Needs (Table 7).

Table 7: Main findings between the present study and the Reference Study related to history of climate-related impacts.

Aspect	This study	The Reference Study
Existence of past/present information on critical climatological parameters	69% have past and present information	64% have past and present information
Percentage of ports indicating a perceived trend in relevant climate parameters	46%	31%
Percentage of ports indicating that the perceived trends in climate parameters will require adaptive responses	47%	65%
Long-wave penetration as a significant issue	For 59% it does not represent a problem. For 2% it is a significant issue	For 63% it does not represent a problem. For 3% it is a significant issue
Basis for information on currents	49% relay on observations only. 14% relay on observation plus modeling	35% relay on observations only. 26% relay on observation plus modeling
Percentage of ports indicating the existence of downscale forecast available for critical climate parameters	33% have downscale forecast, most of it for a 10 years' timescale.	32% have downscale forecast, most of it for a 10 years' timescale.

About the availability of information, the results presented trends similar to those of the Reference Study but with slightly worse percentages, demonstrating in the same way the existence of important gaps in terms of relevant information available to the ports.

From block III questions it was found that an average of 69% of the respondent ports reported they have past and present information about critical climatological parameters available. Compared to the Reference Study, the results were quite similar. Surprisingly, 46% of respondents in this study reported they see changes in relevant climatological data as a trend when compared with the 31% for the same question at the Reference Study. This result calls attention because it is 15% higher than the Reference Study, and it demonstrates that the majority of the survey participants do not yet see changes in the observed climatic parameters as a trend in both studies, but a growing proportion see such changes as a possible trend.

But, for the ports which answered affirmatively to the previous question in this study, a proportion of only 47% indicates they think that such trends will require adaptive response measures. In the Reference Study, this result was 65%. This difference indicates that, although a smaller number of ports in the Reference Study had the perception of the appearance of trends in the parameters, they believe that such trends may influence the need for response measures.

Similar proportion of respondent ports indicated that long-wave penetration does not represent a major problem for them (59% in this study and 63% in the Reference Study). And just a small proportion of 2% in this study and 3% in the Reference Study said long-waves penetration means a significant issue for them.
The results about the current information bases in this study show some variations when compared to the Reference Study, but both have the majority of respondents indicating that data on currents in their respective ports are obtained through observations only (49% in this study and 35% in the Reference Study). Even so, for the second most used combination, which is observations combined with modeling, the Reference Study showed a greater percentage of ports that use this set of information. 26% compared only 14% who indicated this in this study. Therefore, it is possible to say that the ports of the Reference Study have a relative advantage in terms of the quality of the analysis of the data on currents, considering that there is an increasing degree of accuracy as the observations are combined with modeling and these in turn are augmented with data from long-term observations.

Finally, both studies showed similar results on regard of the existence of downscaled forecasts. These results indicate that most of the considered climatic parameters have downscaled forecasts based on 10-year periods (33% in this study and 32% in the Reference Study). Only one difference stands out when comparing the two studies. For the parameter of mean sea level rise, the results indicated that majority of the ports in that research informed that this parameter had downscaled forecasts for periods of more than 50 years. This difference is because the several ports participating in the Reference Study were ports in Northern Europe, a region of the terrestrial globe where the mean sea level has always been a factor of concerns for the nations that have large territorial portions in coastal plains that are frequently threatened to be invaded by the sea if they were not protected by the maritime defenses that decorate its coastlines. In general terms, the results in block III are in line with those of the Reference Study, where some gaps in the availability and quality of information that could be filled / improved were also observed.

Block IV: Comparison of results for Resilience, Level of Preparedness and Adaptation Planning is shown in Table 8.

For the level of preparedness and resilience, all results in this study also presented similar trends to those of the Reference Study, but also with some items with slightly worse indexes.

53% of the responded ports indicated they think breakwaters could be updated at a manageable cost. This result is almost opposite to that of the Reference Study, where 54% of the respondent ports indicated that breakwaters could not be updated at a reasonable cost. Perhaps an explanation for this difference on costs perception between the two studies can be explained by the availability of construction materials and types of construction of breakwaters between the studied regions. A deeper research into this aspect can prove valuable for the sector.

About the expected thresholds for climatological parameters, the results of this study, when compared with those of the Reference Study, varied slightly, but in general followed the same patterns. In this study, the overall average of respondent ports that indicated the limits of climatic stressors that can affect their infrastructure and equipment was slightly higher than those of the Reference Study, but they were still low. Equally to the Reference Study, it is believed that this low level of responses may mean the existence of information gaps and/or restrictions associated with the internal communication of relevant information, with potentially significant implications for assessing the vulnerability of ports to climate change, and consequently the planning of the necessary adaptation measures.
The number of ports with emergency measures in progress or planned (59%) in this study is much smaller when compared to the Reference Study, where 70% of the respondent ports responded that they already had emergency actions in progress or being planned.

About emergence response measures the data in this study, in relative terms, are compatible with those of the Reference Study, which also indicated a preference for gauging vulnerability to the same climatological parameters, except for the penetration of long-waves that was more important in the Reference Study. Again, this difference can be explained by the different port typologies prevalent between the two studies.

In the Reference Study, ports also showed greater preference in assessing the vulnerability of the following components: infrastructure, terminal and ship operations, more than other port elements. It is remarkable that, in absolute numbers, in the Reference Study, 26 ports were far more interested in assessing the vulnerability of inland connections, whereas in this study only 13 ports indicated this concern. A certain lapse for assessing the vulnerability of inland connections, can be seen as a potential vulnerability of the port as a whole, in a more extreme scenario of materialization of climate threats.

Table 8: Main findings between the present study and the Reference Study related to history of climate-related impacts.

Aspect	This study	The Reference Study
Percentage of ports indicating that breakwaters can be updated at a manageable cost	53%	46%
Most expected thresholds impairing the ports' functionality: - Wind - Mean sea level rise - Storm surges - Precipitation	30-60 km/h 1 meters 4 meters 10-100mm/day	50-100 km/h 2 meters 5 meters 101-200mm/day
Percentage of ports which have emergency response measures for climate threats in place or planned	59%	70%
Percentage of ports which have assessed or is planning to assess its respective vulnerability	55%	60%
Main areas considered for vulnerability assessments	Ship operations / terminal operations / Infrastructure	Infrastructure / terminal operations / ship operations
Main climate parameters considered for vulnerability assessments	Winds / Mean sea level rise / Storm surges	Winds / Storm surges / Mean sea level rise
The four main indirect impacts expected	Port competition issues / disruption on supply chain / changes in demand for energy / changes in investments	Disruption on supply chain / changes in ports competition / modal shift / changes in industrial production
Percentage of ports which have mainstreamed climate-related considerations in planning, design and construction of infrastructure	57%	76%
Percentage of ports which have carried out works to evaluate adaptation measures	28%	59%
Percentage of ports which developed or is planning to develop a corporate adaptation strategy	50%	58%
Main covered areas for of adaptations measures	Emergency management plans and process and port investment	Port design and port planning
Average estimated total expenditure for adaptation measures	US$ 37.9 million	US$ 127.9 million
Percentage of ports which have received or expects to receive financial or other assistance for the implementation of adaptation measures	62% has not received or expects to receive any kind of assistance	71% has not received or expects to receive any kind of assistance

These results in this study for expected impacts, when compared with those of the Reference Study, show some variations. For example: in the Reference Study, 44% respondent ports indicated that they expect more impacts related to industrial production and 19% expected migration, against 15% and 6% in this study, respectively. It is worth remembering that the Reference Study had the bias of having a more expressive participation of ports located in Europe, a more industrialized region and that currently faces problems related to migratory processes on a larger scale than the region's most expressively represented in this study.

In comparison with the Reference Study, although the results follow the same direction, the percentage of ports that answered positively to the existence of Mainstreamed climate consideration on infrastructure provisions was much higher in the Reference Study (76%).

The results in this study, about the existence of studies/researches to support adaptation measures in the port differs greatly from the results founds in the Reference Study, where the majority (59%) of the respondent ports reported they carried out work or studies with the intention of evaluating adaptation measures in relation to the potential threats arising as a consequence of climate changes. About participation or plans to participate in corporative strategies to develop solutions to tackle climate change, the results in this study (50%) were similar to the Reference Study, where 58% of the respondent ports in that study reported being participating or to have plans develop corporative adaptation to climate change.

Regarding areas that were object of implemented or planned adaptation measures, the results in this study differ greatly from the results of the Reference Study. In that study, the percentage

of ports indicating implemented or planned adaptation measures was much higher for all areas. Yet, in the Reference Study the area that had the highest percentage of indications for adaptation measures was port design, construction and engineering (86%), followed by port planning with 82%. In this study, the main area indicated for the implementation of adaptation measures was emergence management plans and processes and port investment with the same percentage of responses (63%).
Also noteworthy is the much higher number of ports that indicated adaptation measures in the insurance area in the Reference Study (29%) compared to only 11% in this study. On the one hand, in the Reference Study, where the ports indicated port engineering and planning as the most common fields where adaptation measures were implemented or planned, raised a concern about the possibility of over-engineering, in this study, have being emergency management plans and processes the area with the highest indication of adaptation measures, brings a concern that ports represented by this study, are focused mostly on reactive and non-preventive measures. In other words, only when the climate threat has materialized, does the port expect to act on it. This result also points to a perception that these ports expect climate threats to materialize more in the form of extreme and one-off climatic events, with direct effects on their infrastructures and superstructures, than lasting climatic events and of permanent and indirect consequences, as can be expected. In the case, for example, of a climate change that may permanently affect industrial or agricultural production.

Perhaps, a greater preference for soft adaptation measures, may also be motivated by issues of unavailability of funds to be used in hard adaptation solutions. As seen, the estimated average value for investments in adaptation measures for the ports in this study (US$ 37.9 million) is significantly lower than those indicated in the Reference Study (US $ 127.3 million). On the other hand, this result is consistent with the results that showed deficiencies in information about relevant climatic parameters preventing the waste of resources that could result from over-engineering.

Finally, for the question about financial assistance or other kind of assistance from governmental or non-governmental organizations, including external assistance the results in this study are very close to that found in the Reference Study, where only 29% of the respondent ports reported that they received or expected to receive some type of assistance. However, it can be said that the results on the degree of resilience and level of preparedness of the ports to face the climatic changes for the ports in this study are also aligned with those of the Reference Study and indicate that still have a lot of improvements to be done in order to reinforce its resistance and ensure adequate levels of productivity and profitability.

CONCLUDING REMARKS

The main objective of this research was to try to identify the level of preparation and resilience of ports in the regions of South America and the Caribbean in the face of climate change. These regions were established as a target audience after observing the low level of participation of ports from these regions in the UNCTAD Port Industry Survey on Climate Change Impacts and Adaptation (the Reference Study).

For this purpose, a questionnaire similar to that of the Reference Study was prepared and distributed online to ports and port terminals located in these and other regions. In order to increase the understanding of the potential implications of climate change in ports, a brief review of the literature sought to show in a general way recent information about climate trends and some projections and to point out some direct and indirect impacts of climatic factors in sea and inland ports, as well as in their hinterlands.

The research partially covered the purpose of filling the biases suggested in the UNCTAD study and it can be said that the research was successful because it has received 50 forms answered by ports present in a total of 9 countries in South America, Central America, and also in the Mediterranean, although it failed to get participation, especially from ports in the small island in the Caribbean.

In this study, most of the respondent ports are located in developing economies (81%), in contrast to the Reference Study where 73% of respondent ports were in developed economies. This fact proved that the economic state of the countries where the ports are located impacted the results. It is hoped that this work will contribute to inform and advance the issue of effective climatic adaptation for ports, especially those belonging to the regions represented in this research.

The results of the present study demonstrate that there is a need for actions to increase the level of information and the knowledge base in ports in relation to several aspects, such as, the formation of local databases of relevant climatological parameters, downscaled projections of permanent and transitory risks for port operations and infrastructure in different climatic scenarios, and also in terms of expanding the current information basis, for example.

The research results clearly indicate that more research is needed on risk assessment and the development of effective and innovative adaptation measures in response to the challenges posed by climate change. As the results showed the expressive participation of inland ports, it is suggested that specific research be carried out in order to reveal possible peculiarities inherent to these ports.

To deepen the theme, for further works, it is also suggested a tailored survey with the pilotage and port assistance services to assess how these stakeholders have been perceiving and preparing for coping with climate changes regarding their activities. A research on port insurance would be valuable to better understand how insurance sector have been innovating to adapt to the challenges imposed by climate change.

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