U.S. Environmental Protection Agency

Planning for Climate Change Impacts at U.S. Ports

White Paper

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1. Introduction

Over the coming decades, climate change is likely to cause sea levels to rise, lake levels to drop, more frequent and severe storms, and increases in extreme high temperatures. These effects can have mild to severe impacts on port infrastructure and operations, depending on their geographical setting and design. Ports are critical to the trade and transportation networks of the United States. Specifically, ports handle 78% of all U.S. foreign trade by weight and 44% by value.[1] The United States' ports also represent billions of dollars in capital improvements and new investments. While the risk that climate change poses to ports is unclear, what is clear is that ports need to better understand climate change, how it may impact them, and what they can do to ensure reliable services for their customers.

The purpose of this paper is to help raise awareness of the effects of climate change, so that ports can work with government, industry and communities to make more informed adaptation decisions. To date, port authorities have more likely addressed climate change in the context of reducing the "carbon footprint" of freight transportation. Commendably, port authorities are increasingly working with their business partners to reduce the carbon and other harmful emissions from marine vessels, cargo handling equipment, trucks, and trains. However, most ports do not appear to be thinking about, let alone actively preparing to address, the effects of climate change.

There are several likely reasons for this lack of action. Primarily, ports do not have specific information about either the types of impacts that they can expect on their facilities or the probabilities of different impacts occurring.[2] Although climate change science is making considerable advances, impact projections are not available below a regional scale. Some ports also believe that climate change does not pose an immediate threat to their facilities. Still, a few ports are beginning to think about how to prepare for climate change. These include the Port of Miami, The Port Authority of New York and New Jersey, The Massachusetts Port Authority, the Port of Seattle, Washington, The Port of Corpus Christi, and Georgia Ports Authority. Some local, regional, and state governments are also taking action on behalf of ports.

Several resources are available to ports as they study their risk from climate change, including both climate projections and prototypical planning models. Two major studies released in the past year have examined the potential impact of climate change on transportation systems, including ports. But the field is largely overwhelmed by a need for more and better data and information. A common finding across many studies on the topic is that there is a clear need for further research.[3]

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[1] Testimony of Jean Godwin, AAPA, March 17,2007

[2] Nicholls, R. J. *et al.* (2008), "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", *OECD Environment Working Papers*, No. 1, OECD Publishing. Available at: http://www.oecd.org/dataoecd/16/58/39720578.pdf .

[3] Ibid.

2. Climate Change Science and Ports

How transportation contributes to GHG emissions is now well understood. Less is known about the risks that the U.S. transportation system faces from climate change and how those risks can be mitigated. Research on these topics is generally in the very early stages of development.

The principal resource for predictions of global climate change is the United Nations Intergovernmental Panel on Climate Change (IPCC). In its Fourth Assessment Report, published in 2007, the IPCC estimated that global average sea level will rise from 18 to 59 cm (7.1 to 23.2 inches) by the last decade of the 21st century.[4] The IPCC further concluded that because of global warming, thermal expansion of the oceans will likely continue to increase sea levels for many centuries after greenhouse gas (GHG) concentrations in the atmosphere have stabilized.[5]

These predictions are adequate for long-term projections of impact on ports at a global scale. A January 2008 study for the Organization for Economic Cooperation and Development (OECD) analyzed how climate change could affect the exposure of the world's 136 largest port cities to coastal flooding due to storm surge by the 2070s. The study took into account the anticipated effects of climate change (sea-level rise and increased storm intensity) as well as worldwide economic and population growth projections. When the cities are considered as a group, there is near certainty (99.9% chance) that at least one of them will be affected by in a 1-in-100 year flood event in any given five year period. When ranked by the number of people that would be exposed to a 1-in-100-year flood event, three U.S. port cities (New Orleans, Miami and New York-Newark) were in the top twenty-five. When ranked by the value of assets exposed, six U.S. cities ranked in the top twenty-five (including the three above) and ten ranked in the top fifty.[6] These predictions indicate that several U.S. port cities have a high risk of adverse impacts from climate change, but they do not consider that these cities and their ports may implement particular adaptation measures.

Likely patterns of future climate change and sea level rise vary regionally within the United States. The Atlantic and Gulf Coasts are at particular risk from sea level rise because of their low-lying topographies and patterns of land subsidence. In the Pacific Northwest and Alaska, sea level rise may be less of a threat because of tectonic uplift. The Atlantic and Gulf Coasts are also vulnerable to increased hurricane activity. All of the United States is expected to warm during the coming century. The most pronounced warming trend is expected over the northern portion of Alaska during the winter. Coastal areas are expected to experience less than

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[4] Intergovernmental Panel on Climate Change (IPCC), "Climate Change 2007: Synthesis Report. Summary for Policymakers," November 2007. Table SPM.1., p.8. Available at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf.

[5] IPCC 2007, p. 20

[6] Nicholls, R. J. *et al.* (2008), "Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates", *OECD Environment Working Papers*, No. 1, OECD Publishing. p. 56. Available at: http://www.oecd.org/dataoecd/16/58/39720578.pdf .

average warming. Most climate models predict that precipitation will increase during the winter in northern states and decrease during the summer in western and southern states.[7]

In fact, the United States is already experiencing climate change and sea level rise. Sea level rose between 0.8 to 1.2 inches per decade along most of the Atlantic and Gulf coasts during the 20th century. In the past few decades, average temperatures for the contiguous United States have risen at nearly 0.6 °F per decade.[8] Climate theory and models suggest that extrapolation of these trends would underestimate the rates of change that could occur in coming decades.[9]

The past several years have seen a number of studies address climate change impacts on transportation infrastructure at a regional scale. The "Gulf Coast Study", the first phase of which was recently released by the U.S. Climate Change Science Program, contains a preliminary assessment of risks and vulnerabilities in the Gulf Coast region.[10]

Looking particularly at the impact of storm surges, the Gulf Coast Study determines the percentage of marine transportation facilities in an area from Mobile, AL to Galveston, TX that would be affected by certain levels of storm surges. The study predicts that relative sea levels in the region will rise between 0.3 and 7 feet, depending on location, over the coming century. Average temperatures in the region are likely to increase between 0.9°F and 4.5°F over the next fifty years.[11] The study provides probabilities for some impacts at the regional level. For example, if relative sea levels rise 4 feet, 72 percent of ports in the region will be at least partially inundated.[12] But probabilities of specific impacts on individual facilities cannot be assigned with confidence.[13]

The U.S. Department of Transportation (U.S. DOT) initiated another effort to examine the risk to transportation infrastructure from climate change along the Atlantic coast. The study is identifying the transportation infrastructure that, without protection, will regularly be inundated by the ocean or is at risk of periodic inundation due to storm surges. Phase 1 of the report, covering Washington D.C., Maryland, North Carolina, and Virginia, was released in December 2007. In the state of Maryland, the study found that 28% of port acreage would be regularly inundated or at risk of periodic inundation if sea levels rose just 6 cm (2.4 inches). Phase 2 is expected to be completed in mid-2008. The work is intended to produce high-level estimates of the extent of the nation's transportation infrastructure that is at risk. The study's authors caution that it would be inappropriate to use the results to estimate local changes. For example, the

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[7] National Science and Technology Council, "Scientific Assessment of the Effects of Global Change on the United States." A Report of the Committee on Environment and Natural Resources. May 2008. Available at: http://www.climatescience.gov/Library/scientific-assessment/Scientific-AssessmentFINAL.pdf. pp. 4-6.

[8] National Science and Technology Council 2008, pp. 6, 4

[9] USCCSP 2008, p. ES-4

[10] U.S. Climate Change Science Program (USCCSP), Impacts of Climate Change and Variability on Transportation Systems and Infrastructure: Gulf Coast Study, Phase I. Synthesis and Assessment Product 4.7, March 2008. Available at: http://www.climatescience.gov/Library/sap/sap4-7/final-report/.

[11] USCCSP 2008, p. ES-4

[12] USCCSP 2008 p. ES-6

[13] USCCSP 2008, p 5-23.

study did not take into account existing coastline protection measures or local rates of land subsidence and tectonic uplift. [14]

Several other studies have also addressed climate impacts on transportation infrastructure and possible adaptation measures at a regional scale. These have included the Metropolitan East Coast Assessment, CLIMB (Climate's Long-Term Impacts on Metro Boston), the Seattle Audit of Climate Change Impacts, and two recent studies in Alaska.[15] A Canadian study focused on possible adaptation measures for navigation of the St. Lawrence River under scenarios of lower water levels due to climate change.[16] None of these studies have established probabilities of impacts on specific facilities, nor suggested specific adaptation measures to be implemented.

3. Likely Impacts of Climate Change on Ports

While individual ports do not know their probability of experiencing specific climate impacts and when, several studies have enumerated the possible types of impacts that ports will experience. Higher sea levels and storm surges are the most commonly citied potential impacts, but ports may be at risk from various other direct and indirect impacts from climate change.

3.1. Changes in Water Level

Climate models predict long-term increases in global sea levels, due to melting of glaciers and ice caps and thermal expansion of the seas. Located at or very near current sea levels, the United States' coastal ports will most likely have to adapt to this increase.

The most immediate concern related to rising sea levels is the need to raise the level of infrastructure to prevent flooding. Ports will need to consider anticipated sea levels when building new infrastructure. In cases where current infrastructure may not be high enough for its useful lifespan, ports will need to increase infrastructure heights.

Higher sea levels may threaten ports' environmental mitigation projects. Also, many ports have contaminated or potentially contaminated industrial land on their premises.[17] Higher water levels may require new containment methods to prevent leeching of contaminants.

Many climate models predict that climate change will cause water levels to drop in the Great Lakes and the Mississippi River Basin, which would make shipping there more difficult. When lake levels decreased from 1997-2001, ships in the Great Lakes were forced to carry less

[14] ICF International, The Potential Impacts of Global Sea Level Rise on Transportation Infrastructure, Phase I Final Report, December 2007. p. 6. Available at http://www.climate.dot.gov/publications/potential_impacts_of_global_sea_level_rise/index.html.

[15] Transportation Research Board (TRB), Potential Impacts of Climate Change on U.S. Transportation. Special Report 290. Washington, D.C. 2008. p. 70-79. Available at: http://onlinepubs.trb.org/onlinepubs/sr/sr290.pdf.

[16] Pierre D'Arcy, et al. Climate Change and Marine Transport on the St. Lawrence: Exploratory Study of Adaptation Options. St. Lawrence Action Plan, 2005. Executive summary available at: http://adaptation.nrcan.gc.ca/projdb/pdf/137a_e.pdf.

[17] Key Impacts and Issues for WA Coasts and Infrastructure: Preparation and Adaptation to Climate Change http://www.ecy.wa.gov/climatechange/PAWGdocs/ci/102307Climpacts.pdf

cargo.[18] Future decreases in water level would again require cargo restrictions or perhaps the redesign of vessels. Either one would increase the cost of shipping on interior waterways.[19] Decreased depths could be mitigated by increased dredging, but at a financial and environmental cost.

Changes in sea level will also affect the navigability of some ports. For example, rising sea levels could prevent bridge clearance for ships near the current limit. Lowering sea (or lake) levels would have the reverse impacts. For bridges, this effect could be mitigated by increasing the frequency of bridge openings and raising the clearance of new bridges.[20]

3.2. Storm Events and Precipitation

Globally, extreme precipitation events are expected to become more frequent, and severe storms are expected to become more intense.[21] Stronger wave action and higher storm surges, especially when coupled with higher sea levels, are the primary threat to ports. These impacts can damage bridges, wharfs, and piers, terminal buildings, ships, and cargo. Harbor infrastructure may need to be raised or reinforced to withstand these impacts.

In addition to contributing to storm surge, wind can also have its own damaging impacts. High winds particularly threaten unreinforced terminal structures. For example, Hurricane Katrina tore roofs and doors off warehouses at the Port of New Orleans.[22] One possible response to these threats is to change design standards for terminals, cranes, lighting systems, and other infrastructure to incorporate the risk of stronger storms.

Port security systems, such as video cameras, radar equipment, and perimeter fencing, could also be damaged by storm events. Damage to monitoring equipment could expose ports to additional security risks.

Increased amounts of precipitation and extreme precipitation events could require improving the capacity of stormwater facilities.[23] More and stronger precipitation could also affect harbor channels. Increased erosion and buildup of underwater silt and debris could decrease channel depth and require more dredging.

Finally, more severe weather events could result in more and longer delays to shipping operations. Ports may be required to suspend operations because of severe weather events more often. The resulting delays would reduce the overall reliability of marine shipping and have business impacts on shippers and receivers.

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[18] Quinn, Frank, "The Potential Impacts of Climate Change on Great Lakes Transportation." The Potential Impacts of Climate Change on Transportation: Workshop Summary and Proceedings. October 1-2, 2002. U.S. Department of Transportation. Available at http://climate.dot.gov/publications/workshop1002/quinn.pdf.

[19] TRB Special Report 290.

[20] USCCSP 2008, Table 1.

[21] USCCSP 2008, 1-3, 1-4

[22] USCCSP 2008, p. 4-29

[23] USCCSP 2008.

3.3. Higher Temperatures

Higher incidences of extreme high temperatures could also affect some auxiliary port infrastructure. For example, paved surfaces may deteriorate more quickly in hotter conditions. Cranes and warehouses made of metal may require design changes to withstand higher temperatures. Higher temperatures may also require more energy for cooling of goods stored at ports.

Higher temperatures could impact the human and natural environments associated with ports as well. Many employees at ports work primarily outdoors. Operational changes may be required to protect workers from extreme heat. Warmer temperatures may also increase the risk of transferring invasive species from region to region on cargo vessels.

For ports in northern states, including Alaska, higher temperatures could provide some benefits. Operating conditions may improve as ice accumulation on port infrastructure decreases. Shipping seasons would lengthen as more ports and waterways become ice free for more of the year. These effects could increase volume and reduce costs for northern shipping.

3.4. Indirect Impacts

In addition to the direct risks that climate change poses to the infrastructure on which ports rely, ports may also experience broader indirect impacts of climate change. For example, shifts in climate may induce changes in population concentrations and in patterns of consumption of goods and energy. Warming trends will likely decrease the amount of energy needed for heating in northern areas and increase the amount of energy needed for cooling in southern areas. This shift might in turn affect regional shipping patterns and volumes for fuel commodities, such as oil and gas.

One of the most highly anticipated effects of climate change is the potential opening of the Northwest Passage, a sea route connecting the Atlantic and Pacific Oceans along the northern coast of Alaska and Canada. The use of this passage – which is subject to significant international controversy – could provide an alternative to the Panama Canal. An open Northwest Passage would likely increase activity at northern ports.[24]

Ports are also likely to face changes in insurance coverage and possible higher insurance premiums because of climate change. The insurance industry is one of the leading commercial sectors expressing concern about and exploring adaptive responses to climate change. Several large companies that provide business insurance services are incorporating risk from climate change into insurance offerings. Strategies include shifting a greater share of risk onto customers and providing technical support and pricing incentives for customers to reduce their exposure to climate-related risks.[25]

[24] Brigham, Lawson and Ben Ellis, ed. "Arctic Marine Transport Workshop," Cambridge University, United Kingdom, 28-30 September 2004. Available at: http://www.arctic.gov/files/AMTW_book.pdf.

[25] Sussman, Frances and J. Randall Freed, Adapting to Climate Change: A Business Approach. Pew Center on Global Climate Change. April 2008. pp. 9, 23-24. Available at: http://www.pewclimate.org/docUploads/Business-Adaptation.pdf

4. Planning Responses and Challenges

United States ports will almost certainly experience some or all of the above impacts from climate change, but appropriate adaptation responses are unknown. Ports' typical planning processes are ill-equipped to respond to the high levels of uncertainty associated with climate change impacts, the timescales of climate change, and the geographical scale of climate change. [26]

Climate scientists tend to provide probabilities for various impact scenarios. Yet transportation planning tools tend to focus on what is known about the system and are not well adapted to incorporate estimates of risk. Ports are likely not able to use current planning practices to act upon information subject to a high degree of uncertainty. Ports are most likely to act on conditions that they can already observe or easily foresee. For example, at some ports typical water levels during storm events are already threatening to inundate infrastructure. Ports are likely to take steps to upgrade this infrastructure in response.

In contrast, the planning cycles of ports do not match well with the horizons of climate change forecasts. Climate scientists typically forecast impacts for periods many decades in the future. The IPCC's most recent forecast of sea level rise is provided for a date 80-90 years in the future. In contrast, the typical lifespan of major port infrastructure, including docks and port terminals, is around 40-50 years. Ports thus have little incentive to plan now for projected future climate change impacts. Existing infrastructure, and perhaps also the next generation of infrastructure, will expire before the IPCC's forecast point arrives. Ports' actual planning horizons are even shorter, at 5 to 10 years.[27] The highly competitive nature of ports requires that they adapt quickly to changing business circumstances. Ports may not foresee significant climate change impacts, beyond what they are already experiencing, within their planning horizons.

There is also a spatial mismatch between climate change impacts and port jurisdictions. The impacts of climate change will occur at global and regional scales. Ports comprise only a small part of the natural and man-made infrastructure that will be affected by climate change. In many cases, ports' operations depend on assets that they do not own or control, such as bridges and shipping channels. While ports can take steps to protect their own infrastructure, both planning and implementation of adaptation measures could also take place at broader scales, involving multiple jurisdictions.

Some preliminary tools are available to ports to help them overcome these challenges. In particular, several recent studies have begun to develop conceptual frameworks that ports can use to assess their risk from climate change. Risk is defined as "the product of the probability that a facility will be exposed to a climate stressor of destructive (or disruptive, at the systems level) force times the damage that would be done because of this exposure."[28] One study on the risk of climate change to businesses provides a simple flowchart for businesses to screen themselves for climate risk.[29] Using this flowchart, ports will most likely find their level of

[26] TRB Special Report 290, p. 95

[27] TRB Special Report 290, p. 98

[28] USCCSP 2008, p.5-19

[29] Sussman and Freed, April 2008. p. 16

risk to be in the highest category, with a suggested response of "Take action to assess risk in detail and respond."

A recent study from the Transportation Research Board (TRB) suggests a decision-making framework for transportation providers based on assessments of hazards, assets, and consequences. The framework includes a list of preliminary questions that ports and other transportation agencies could consider in relation to climate change adaptation. It also includes a six step framework for assessment and adaptation of transportation infrastructure.[30]

The Gulf Coast Study also includes a conceptual framework for adaptation, based on the IPCC's guidance. This framework for risk assessment is based on the concepts of exposure, vulnerability, and resilience. Adaptation responses are designed based on the need to increase the resilience of infrastructure. During Phase II of this study, researchers will further develop the risk assessment methodology and identify techniques to incorporate environmental and climate data into transportation decisions. For Phase III, researchers intend to develop tools for assessing adaptation and response strategies.[31]

Ports can adopt capital improvements, maintenance projects, or operational changes to adapt to climate change. For example, the construction of a protective sea wall would be a capital improvement. Reinforcing existing structures against stronger wind and waves would be a maintenance project. Reducing cargo loads in the face of lower water levels would be an operational change. Likewise adaptation measures can protect, adapt, or retreat. Raising docks and warehouses would protect those assets. Developing more robust emergency procedures for storms would accommodate climate change. Relocating a port operation, as the Port of New Orleans is considering, would be a retreat response.

5. State of Practice

U.S. ports are responding in a variety of ways to the threat of climate change. While some ports are adapting their facilities to changes that are occurring already, the overwhelming majority of ports are not taking any action to prepare for predicted future climate changes. Many ports have not even considered the threat that climate change poses to them, while other ports do not think that climate change poses any appreciable risk to their facilities or operations. Those ports that are taking action on climate change are in the very early stages. A few ports are participating on climate change action committees or are initiating research studies. Many ports rely on federal resources, including data from the Federal Emergency Management Administration (FEMA), the National Oceanic and Atmospheric Administration (NOAA), and the Army Corps of Engineers, to determine their engineering standards. These resources reflect only historical information on climate and sea level and do not take projected future climate changes into account.

The **Port of Miami**, a county agency, participates in the Miami-Dade Climate Change Advisory Task Force (CCATF). A representative of the Port sits on the Built Environment Committee of the CCATF. In a recent report, the CCATF recommended that all County agencies (including the Port) assess the impact of climate change on their responsibilities. The CCATF also recommended the creation of detailed elevation maps of the County, using best

[30] TRB Special Report 290, pp. 103-111

[31] USCCSP 2008, pp. ES-1 - ES-2.

known survey technologies, to allow agencies to assess the risk to their infrastructure from flooding. The report includes a Statement on Sea Level in the Coming Century. The Statement predicts global sea level rise of between 3 and 5 feet in the coming century, with dramatic impacts on Miami-Dade County. The Statement is intended to be used as a policy guide for planning adaptation responses.[32]

At the Port of Miami itself, adaptation responses to climate change are in the planning stages. The Port does have plans to raise the elevation of much of its property, during near-term redevelopment efforts, to meet a new ten foot minimum elevation. This elevation is based on FEMA flood maps, which nevertheless are based on historical data. Thus while the Port will be better protected from higher water levels during storm events, the new height threshold does not explicitly consider risk from future climate change. The Florida Department of Transportation, in partnership with Miami-Dade County, is also planning a new highway tunnel that will connect the Port, an island, to the mainland. The tunnel project will maintain the ten foot minimum elevation requirement. The tunnel's stormwater system will be designed for a 1-in-100 year storm and will contain flood gates. The CCATF has only recently suggested that the planning process for the tunnel incorporate sea level rise projections. The Port does plan to incorporate climate change forecasts in its next long range plan, which will have a horizon year of 2035.[33]

The **Port Authority of New York and New Jersey** is taking first steps to plan for climate change adaptation. At a meeting in March, the Commissioners adopted a Sustainability Policy that includes a resolution to reduce the risk to its facilities posed by climate change. The Commissioners further resolved to work with regional stakeholders to mitigate risk at the regional level.[34] The seaport's engineering department is not yet making design changes specifically to account for anticipated sea-level rise from global warming. At present the Port Authority is considering for what particular climate change hazards it needs to prepare. New York City's Office of Sustainability is taking the lead in studying the likely range of climate events that could impact the region's transportation systems. The Port Authority also plans to conduct its own study on the topic. The Port Authority's maritime facilities may be at relatively low risk compared to other facilities that the agency owns and operates, such as the PATH subway system.[35]

The **Massachusetts Port Authority (MassPort)** manages the Port of Boston, among other key transportation infrastructure components in the Boston region. MassPort considered the potential impacts of climate change as far back as 1992, when it commissioned a study on sea level rise in the area; however, the state of climate change science has changed dramatically since that time. MassPort's Chief Development Officer is now considering initiating a new study of potential climate change impacts. Current infrastructure projects at MassPort do not incorporate climate change forecasts. For example, the Army Corps of Engineers is planning a maintenance dredging project in Boston Harbor. The Corps has not incorporated

[32] Miami-Dade County Climate Change Task Force, "Second Report and Initial Recommendations, Presented to the Miami-Dade Board of County Commissioners," April 2008. Available at: http://www.miamidade.gov/derm/library/08-10-04_CCATF_BCC_Package.pdf.

[33] Conversation with Becky Hope, Port of Miami, May 2008

[34] The Port Authority of New York and New Jersey, Thursday March 27, 2008 Minutes. Available at: http://www.panynj.gov/AboutthePortAuthority/pdf/March08_PA_Minutes.pdf.

[35] Conversation with Chris Zeppie and Joe Monaco, Port Authority of NY/NJ, May 2008

climate change forecasts into its planning for the channel maintenance. While potential higher sea levels are unlikely to affect the short term need for a deeper shipping channel, other aspects of climate change, such as the potential for stronger and more frequent storms, may impact the dredging project further down the road.[36]

The **Port of Seattle** has several ongoing initiatives related to climate change adaptation. The Port recently formed an internal working group on climate change adaptation. The Port is also shifting to a lifecycle cost basis in its business planning. New cost elements that will be considered include ongoing maintenance costs and possible costs from climate change impacts. The engineering department at the Port also uses climate change forecasts in its planning processes.[37]

The **Port of Corpus Christi**, Texas, acts as a regional steward of water resources. As such, the Port has long considered the risks that climate change poses to the region. The Port's Coastal Environmental Planner commissioned a study in the 1990s of the potential impact of climate change on the region. Yet the Port does not account for potential changes in climate in its facility designs and engineering. The Port recently updated its mean sea level datum in response to an update from the Army Corps of Engineers, but this information is based solely on historical data.[38]

The **Georgia Ports Authority**, which manages several coastal and inland ports in Georgia, does not consider risk from long term climate change in its facility designs and planning processes. The Port has had to consider climate change impacts for the study of a proposed deepening project for which it is the local sponsor. The Army Corps of Engineers' evaluation of deepening the Savannah River will soon be in the stage of environmental review. At the request of resource agencies, the Environmental Impact Statement will consider the combined effect of the dredging and two scenarios of sea level rise on wetland habitats.[39]

In addition to local action by ports, some statewide bodies are also considering policies and initiatives to mitigate risk from climate change to coastal facilities including ports. In Washington State, a working group of the Climate Advisory Team (CAT) issued two relevant draft recommendations in its 2007 report. The group recommended that mapping of sea level rise vulnerability be improved and that the design of coastal facilities should include the best available data on sea level rise.[40] The Port of Vancouver, WA was an official member of the CAT. In Oregon, the Climate Change Integration Group included a recommendation in its report of January 2008 that all government agencies, which would include some ports, adopt plans to prepare for climate change.[41] The Oregon Transportation Plan also references the potential impact on ports of rising sea levels and increased wave heights due to climate change.[42] In

[36] Conversation with Deborah Hadden, MassPort, May 2008

[37] Conversation with Sarah Flagg, Port of Seattle, May 2008

[38] Conversation with Paul Carangelo, Port of Corpus Christi, May 2008

[39] Conversation with official at the Georgia Port Authority, May 2008

[40] Washington State Climate Action Team, "Draft Recommendations of the Preparation and Adaptation Working Groups." December 21, 2007. Available at: http://www.ecy.wa.gov/climatechange/CATdocs/122107_2_preparation.pdf.

[41] Climate Change Integration Group, A Framework for Addressing Rapid Climate Change. January 2008, State of Oregon. Available at: http://www.oregon.gov/ENERGY/GBLWRM/docs/CCIGReport08Web.pdf.

[42] Oregon Department of Transportation. Oregon Transportation Plan, Volume 1. Adopted September 2006. p. 23 . Available at: http://www.oregon.gov/ODOT/TD/TP/docs/ortransplanupdate/2007/OTPvol1.pdf.

Maryland, the state's Climate Action Plan references the vulnerability of the Port of Baltimore to sea level rise and the need for strategic planning efforts to address that vulnerability.[43] While the actual impact of these higher level initiatives on ports is unclear, such statements of intent are nonetheless important.

Regional and local governments are also taking action to prepare for climate change. In addition to action by the Miami-Dade CCATF, mentioned above, King County, Washington has implemented a climate preparedness plan. King County has also issued a step-by-step guidebook to help other state, regional, and local governments draft their own plans.[44] The guide provides tips on scoping of climate change impacts, communication techniques, building a stakeholder team, conducting vulnerability and risk assessments, and developing action strategies. The guide takes a multi-sector approach to climate change; ports are just one relatively small sector included. Still, the guide provides a model for a planning process in which ports could be involved. Ultimately, action to protect ports from climate change is at least as likely to originate from such multi-sector collaboration as it is from individual ports.

Though some ports are taking some very preliminary steps to prepare for future climate change, many ports are taking no action. A 2006 survey of U.S. ports found that only one third of a sample of twenty-seven ports have considered the potential impact of climate change on their facilities. Just over half of the sample anticipated impacts of climate change on their locations in the next fifty years.[45] While representatives of some ports are familiar with the resources and studies mentioned in this paper, others are not. Very few ports have any sort of formal effort or designated staff person to address climate change impacts. Some ports cite the slow rate of expected change in climate, relative to their short planning horizons, as a likely reason that they are not actively considering or planning for the impacts of climate change.

6. Ideas for Possible Action

As noted in the TRB Special Report 290, the decisions transportation professionals make today, particularly those related to design and retrofitting of existing transportation infrastructure or the location and design of new infrastructure, will affect how well the system adapts to climate change far into the future. This white paper has summarized the state of information and tools for climate change adaptation available to ports and briefly reviewed the current state of practice at some ports. It has highlighted some principal challenges and knowledge gaps in planning for climate change impacts at ports. Drawing on the information already presented, we offer a few possible immediate ideas for action by ports and/or agencies that support ports.

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[43] Maryland Commission on Climate Change, "Brief Description of Proposed Priority Options-DRAFT." Resources and Resource-Based Industries Technical Working Group. May 9, 2008. http://www.mdclimatechange.us/ewebeditpro/items/O40F17210.pdf

[44] The Climate Impacts Group, et al. "Preparing for Climate Change: A Guidebook for Local, Regional, and State Governments." King County, Washington. September 2007. Available at: http://www.cses.washington.edu/cig/fpt/planning/guidebook/gateway.php.

[45] Bierling, David and Paula Lorente Rodriguez, "Port Planning and Perceptions about Climate Change." 2nd Workshop on Impacts of Global Climate Change on Hydraulics, Hydrology and Transportation. Washington, D.C. March 29, 2006.

First, ports could consider incorporating climate change forecasts into short and long term plans, to the extent possible. New docks and piers are expected to last about fifty years, during which time significant shifts in climate may occur. Ports may also be involved in the planning of bridge, tunnel, and dredging projects. At present, the design process and construction standards for such infrastructure typically include only historical data. Ports could assess whether there is any appropriately specific forecast data available that can be incorporated into design plans. Looking at current and projected flood plain maps is one place to start. Ports may also have opportunities to update design specifications for cranes, lighting, or buildings to withstand more severe wind.

Second, ports could work to keep abreast of developments in climate science and climate change adaptation. Common sense suggests that ports are at particular risk from climate change due to their geographical locations. Representatives of some ports have looked at climate forecasts, read current studies, and considered the risk of various types of impacts. Other ports are slower to take in and process information on climate risk. If possible, all ports could review the basic resources quoted in this paper. Given the very real resource and time constraints of port staff, ports may consider designating a single point person to manage and distribute information on climate change impacts and to spearhead adaptation efforts. Insurance companies are certainly considering risk from climate change in coastal areas, and may be allies in helping ports assess their business interests and risks.

Third, ports could consider reaching out to other agencies, including local, regional, and statewide bodies, to form alliances to address climate change adaptation. Many stakeholder groups at regional and state levels are already attempting to reduce greenhouse gas emissions from transportation and other sectors, and some of these are now turning to the issue of protecting infrastructure from climate change impacts. These groups can help ports define specific research gaps, produce the studies and data that they need, and possibly also help with planning adaptation responses. Coordinated study efforts can lead to better coordinated response efforts. Thus far, ports that have the support of state and county level action groups appear to be making more progress on climate change adaptation than ports that do not.

Fourth, ports could also study the actions that other ports are taking to prepare for climate change, both within and beyond their immediate regions. There is a broad range of practice among ports of all sizes. While it may be too early to establish any best practices, ports can certainly learn from each others' experiences. Public port associations or other regional, national, or international associations or agencies might coordinate a broader research effort. In particular, agencies could research more specifically the types of data and planning tools that ports are currently using or would like to use.

Finally, a national study focused on ports' risk from climate change and their adaptation options could be useful. While several ongoing regional and national level studies are examining climate change impacts on multi-modal transportation systems, marine transportation receives less attention than other modes. Needs for climate change planning at ports are likely to be different than planning needs for highways. Unlike highway infrastructure, which is almost exclusively publicly owned and operated, many ports straddle the space between government agency and private enterprise. While highway planning cycles are regulated by state and federal laws and have many standard elements, there is far greater variety in planning activities among ports.

To initiate broad action on behalf of ports, EPA could sponsor a study of planning practices relevant to climate change at ports. Such a study could examine in more detail the data and planning models that ports use. It could also convene agencies that supply key data to ports, including NOAA, FEMA, U.S. DOT and the Army Corps of Engineers, to discuss how new or existing data products could incorporate climate change forecasts. EPA could convene meetings of senior port representatives and senior representatives from federal agencies to discuss the research needed to better quantify and qualify the impacts of climate changes on port planning and facilities. The deliverable from this series of meetings would be a research strategy that identifies areas of focus and potential funding sources.

Preparing for climate change impacts has not been a priority concern for most U.S. ports. Ports have neither the data nor the methods to plan for climate change. In addition, many ports are assuming that climate change will not affect them any time soon. But some ports will inevitably experience impacts from climate change. As such, ports and their allies need to consider appropriate actions sooner rather than later. While climate change forecasts are improving, and studies to improve planning methods are ongoing, ports need to actively enter the arena of climate change preparation. Ports have an important role to play in directing and assisting research efforts on climate change adaptation.