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Citation/Publisher Attribution
Austin Becker (2020) Climate change impacts to ports and maritime supply chains, Maritime Policy & Management, 47:7, 849-852, DOI: 10.1080/03088839.2020.1800854

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Special Issue in *Maritime Policy & Management* (MPM)

CLIMATE CHANGE IMPACTS TO PORTS AND MARITIME SUPPLY CHAINS

Cite as: Becker, A. (2020) Climate change impacts to ports and maritime supply chains. Maritime Policy & Management 47, 849-852.

Climate change poses significant threats to global security and trade. This special issue identifies key challenges faced by ports and supply chains from climate change over the next century, with perspectives from researchers, practitioners, and decision-makers who have expertise in ports, supply chains, and natural hazards.

Many ports regularly experience natural hazard events and about a third of the world's ports lie in the path of tropical storms (Becker et al. 2012). Climate change will likely amplify the impacts of future coastal hazards for many of the world's 3,700 maritime ports (Verschuur, Koks, and Hall 2020) and their supply chains that enable global and local commerce. Indeed, ports fulfill a wide variety of critical functions for the local, regional, and global economy (Hall 2007, Baird 2004, Goss 1990). They provide jobs, facilitate trade, and serve as links between the hinterlands (back region) and the forelands (seaward region) of their markets. Most coastal cities grew around a port hub and global trade routes then evolved into a network that now connects port cities across the world. This 'inter-connectedness' means that even a short-term loss of port capacity (e.g., due to a natural disaster) can cause local and global ripple effects in logistics and trade-dependent industries (Becker et al. 2018, Lim-Camacho et al. 2017, Levermann 2014), such as imported food, energy, and assembled products.

Projected climate changes include an increase in the frequency and intensity of 'extreme' atmospheric events - shocks such as storms, heavy precipitation, and heat waves (USGCRP 2017, NCA 2014); as well as longer-term changes to climatic variables resulting in 'slow onset' changes like sea level rise, wave climatology, and sea-surface salinity (leading to higher rates of corrosion). In the last 15 years, attention to these issues has increased in both the academic and practioner spheres. However, as recently as the late 2000's, most ports primarily considered climate change to be a call to reduce their emissions and go green. To provide a resource for best practices, the World Port Climate Initiative formed to help ports quantify their carbon footprint and implement various emissions-reduction strategies. In the US, the Environmental Protection Agency developed new programs to help ports offset some of the costs for these new clean investments.

These efforts may help reduce the rate of global warming, but as awareness of the implications of climate change has grown and the science has evolved, ports and supply chains have begun to recognize the dire situation they will face in the coming decades. A number of maritime industry groups have thus added "climate adaption" to their agenda. Guidance documents have emerged, with lessons learned and best practices highlighted. The World Association for Waterborne Transport Infrastructure (PIANC), for example, recently released the *Resilience of the Maritime and Inland Waterborne Transport System*, to "provide a summary of the state of knowledge concerning the short- and long-term stressors affecting safe and efficient operation of the Marine and Inland Waterways Transportation System, now and into the future, and the best practices that have been learned and applied throughout both developing and advanced countries within the international community" (PIANC 2020, 5). The United Nations Conference on Trade and

Development has also published guidance for conducting vulnerability assessments of ports and airports (UNCTAD 2018). Many ports (e.g., Manzanillo, Mexico; Cartagena, Columbia; and many in Australia) have undertaken full resilience assessments either on their own or through a hired consultant. Some, like the Port of Boston (MA, USA), have taken steps to shore up their infrastructure and office space (MassPort 2014). Others, like the Port of NYNJ (NY, USA), have begun elevation projects to relocate utilities out of the floodplain.

Though progress is being made, adaptation for ports and supply chains is still in a nascent stage. There are many issues for ports and supply chains to address, including the development of new infrastructure or retrofit of existing infrastructure, the lack of clear incentives or leadership, the problem of resilience free-riders who benefit from the actions of other actors without paying their fair share, and more.

This special issue addresses these and other questions by bringing together academic researchers and key personnel from other sectors, who possess expertise in the various modes of transportation, in the regulatory and jurisdictional areas that affect each mode, in the impacts of economic development on local communities, and in the policy implications for shipping, transportation and regional management of the increasing access engendered by climate change. This special issue sets aside the question of mitigation of climate change through reducing emissions or other means, and takes as its starting point that climate change is occurring, that it cannot be, in the near term, reversed, and that, due to impacts such as sea level change, increased storm intensities and rising temperatures, ports and supply chains will need to adapt.

To set the tone for seriousness of these issues, the special issue begins with a paper by Moinos and Wilmsmeier which broadly argues that the climate change challenge for maritime transport will require “deep adaptation” at a systems-level. The disruptions to the global and local economy may be so severe that a fundamental restructuring may be required due to a cascade of failures brought on by climate change.

In the second paper, Ng et al. take stock of the present attitudes of port practioners and present one of the first analysis of Chinese port organizations perceptions of climate adaptation. Of the 18 respondents representing five ports, 84% reported having an awareness and involvement in climate change planning. These findings reinforce other studies that likewise suggest port operators are beginning to face the challenges that climate change will pose for coastal infrastructure (McLean and Becker 2019, Ng et al. 2018, Ng et al. 2016). And, like other studies, Ng et al. find that more regulations, stronger policies, and better education can all go a long way toward helping such organizations prepare.

Through the next three papers, the Special Issues explores some of the unique technical and operational challenges (and opportunities) that climate change poses for ports. Ryan-Henry & Becker and Chhetri et al. both offer a more nuanced understanding of the complexity of the climate change challenge for ports. In the first instance, the Ryan-Henry & Becker use the case of Hurricane Sandy and Red Hook (NY, USA) to illustrate how intangible and indirect impacts from storms can ripple across a port stakeholder system. Preplanning, coordination and communication between key interests, such as between the port authority and the electrical grid operator, can reduce recovery times. Through three case studies in Australia, Chhetri et al. explore how climate-

related weather events could impact port workers and port efficiency. Weather-related delays from extreme heat, intense rainfall, fog, or large swell can pose a variety of problems for port operations. Findings suggest that the three ports are already coping with many of these challenges, but they have opportunities to increase training, especially at the executive level. In the third paper exploring challenges and opportunities, Meyers & Luther shed light on another potential issue, that of sea level rise changes to the navigational channels that ships depend on to access port facilities. In a case study of Tampa Bay (FL, USA), the authors find sea level rise may result in deeper draft vessels having access to tidally-restricted ports. Changes to the speed of the current and the duration of slack tide could expand safe transit windows and reduce the need for harbor tugs, resulting in cost savings.

The final two papers in the special issue discuss a variety of approaches to solving these complex challenges. First, Esteban et al. offer a hopeful outlook for the feasibility of adapting ports to sea level change. Through case studies of five ports in Japan and Indonesia, the authors find that many ports have successfully raised their infrastructure to keep pace with relative sea level rise. Though port lands, of course, rely on the resilience of their interconnected infrastructure (e.g., bridges, tunnels, rail lines) most of which typically lies outside of the port terminal itself, these case studies show that from a cost and engineering perspective it is certainly feasible for some ports to incrementally elevate portions of their infrastructure over time.

In the last paper of the special issue, Morris provides an overview of approaches to climate adaptation for coastal ports, with an emphasis on the value of stakeholder collaboration. She argues that successful adaptation requires not only improvements to physical infrastructure, but also changes to organizational, operational, and community elements for ports and the maritime transportation systems of which they are a part. She provides a case study from the Port of Hampton to underscore the valuable role of a broad coalition of stakeholders plays in the adaptation process.

This special issue is intended to catalyze the creation of long-term, self-sustaining research networks that will provide the ability to share developing knowledge, experience and insight climate change to researchers, policymakers, and practitioners around the world. There is much work still to be done.

The guest editor of this Special Issue would like to thank the Editor-in-Chief Professor Kevin X. Li, Administrative Editors Dr Sally Martin and Dr Wendy Wenming Shi for being helpful throughout the whole editing of this Special Issue. The guest editor would like to express his sincere gratitude to all authors for their contributions and to reviewers for their enlightening comments on these papers.

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