COASTAL RESILIENCE CENTER

A U.S. Department of Homeland Security Center of Excellence

Integrating Maritime and Coastal Resilience

Report from the 7th Annual Maritime Resilience Symposium

November 14-15, 2016

The University of North Carolina at Chapel Hill

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I. Introduction

On November 14-15, 2016 the Department of Homeland Security Coastal Resilience Center of Excellence [CRC], in collaboration with the U.S. Coast Guard, hosted the 7th Annual Maritime Risk Symposium [MRS] on the campus of the University of North Carolina at Chapel Hill. The theme of MRS 2016 was "***Integrating Maritime and Coastal Resilience***," in keeping with the CRC's mission to, "conduct research and education to enhance the resilience of the Nation's people, infrastructure, economies, and the natural environment to the impacts of coastal hazards such as floods and hurricanes, including the effects of future climate trends" (Coastal Resilience Center 2015). Academia, government agencies, and private sector companies offer many definitions of resilience, but the key concepts are the capacity or ability of a system, whether physical or human, to prepare for disruption, absorb or resist stress from disturbance, recover from impact in a timely manner, and adapt for future disruptive events (Holling 2001; Cox, Prager, and Rose 2011; National Academies 2012; Rosati, Touzinsky, and Lillycrop 2015; PIANC 2016).

Structured in a workshop format, the event consisted of a series of panel presentations, plenary sessions, and breakout discussions that tackled some of the most challenging issues associated with resilience in the maritime and coastal sectors. Topics included: enhancing resilience of the Nation's ports and maritime facilities, including the Houston-Galveston complex; vulnerable coastal and maritime infrastructure; resilience in the coastal system of the Norfolk/Hampton Roads communities; and cyber resilience concerns in the Maritime Transportation System [MTS]. The primary goals of the 2016 Symposium were to expose gaps in current knowledge and areas of operational inefficiencies, and to identify innovative research opportunities that might be pursued via the Department of Homeland Security Science & Technology Centers of Excellence. A complete description of the 2016 MRS, including agenda and list of participants can be found in the appendices. Many of the presentations are available at the CRC's website: coastalresiliencecenter.unc.edu.

MRS 2016 follows in the footsteps of recent Maritime Risk Symposia hosted by other DHS Centers of Excellence. The Center for Risk and Economic Analysis of Terrorism Events [CREATE] at the University of Southern California hosted the 2014 MRS focused on the subject "Worldwide Chokepoints and Maritime Risks." The 2015 MRS was hosted by the Maritime Security Center located at Stevens Institute of Technology and focused on "Risk in the Western Hemisphere and Southern Border Approaches." The 2017 MRS will be hosted by Tiffin University in Tiffin Ohio, and will focus on "Maritime Cyber Security."

This report presents the research recommendations and questions synthesized from MRS 2016 followed by a survey of the academic literature and informational resources from federal agencies and practitioner organizations to provide broader context and background for the recommendations. A recurring theme is the linkages between the MST and the physical, ecological, built and human systems found in many coastal regions. Thus an overall conclusion to this report is: ***in many cases resilience will not be achieved independently in the maritime and the coastal sectors, but rather requires an integrated consideration of both***.

Guiding recommendations for designing resilience studies across the maritime and coastal sectors identified during MRS 2016 include:

- consider projects that take a regional approach and rather than attempting to address national or international scales;
- seek interdisciplinary research project teams (e.g., engineering, ecology, planning & design, social and behavioral sciences – geography, economics) working with mixed-methods approaches (quantitative and qualitative);
- seek participation or partnership with stakeholder-driven end user groups, that represent important sectors of the coastal and maritime community (federal agencies, port authorities, shippers, tenants, local government, environmental groups, community groups); and
- ensure that representatives from any projects funded as the result of this Symposium report convene to share results and experiences/lessons learned at a future CRC Project Meeting, a future Maritime Risk Symposium or a professional meeting such as the annual Global Resilience Summit RES/CON.

II. Research Questions

The MRS speakers and discussions supplemented by our review of the current state of knowledge provided numerous examples of operational needs and research questions related to resilience in the maritime–coastal system. Synthesis of the symposium material resulted in the following nine questions for possible follow on research activities.

1. Consider the flows linking coastal systems and the MTS and how these flows interact with geographic boundaries, social networks, governance structures, ecosystems and other important physical, environmental and social systems.
    - How do natural and social drivers such as climate change, the energy economy, and globalization interact with these flows to influence human and ecological exposures and risk in areas of convergence such as port communities?
    - Develop an understanding of macro-level interdependency of the system of systems that creates the flows linking coastal systems and the MTS.

2. What are the threats to maritime-coastal systems? Identify acute and chronic hazard threats[1] that pose a risk to the operation of maritime shipping and that increase community vulnerability to environmental, economic, and social loss.
   - How can we incorporate future-oriented perspectives of climate change and its impacts on ports into planning for port resilience?
   - What are levels of protection needed for both human infrastructure and the environment under different sea level rise scenarios?
   - What are the primary and secondary impacts of climate change on critical coastal and maritime infrastructure?
   - Are the costs of sea level rise understood?
   - How can we quantify cyber risk and the value of cyber resilience?
3. What are the environmental, economic, and social impacts of disruption (e.g., sea level rise) in the maritime-coastal system? Develop a hazard scenario planning exercise to quantify and qualify risk (e.g., loss of port assets and community assets) and identify "tipping points" or points of failure to determine scales of economic loss across the maritime-coastal system.
   - Identify social, economic, environmental, and health consequences of port disruptions.
   - Where are the choke points in the maritime logistics chain?
   - What are tipping points when ports will lose jobs and lose infrastructure. How do these tipping points translate to loss in the coastal system? What level of disruption will the market stand?
4. What are the environmental, economic, and social costs of implementing resilience? Identify and prioritize criteria for resilience[2] and evaluate the environmental, economic, and social costs and benefits of hard and soft approaches[3] to implementing resilience, at varying spatial scales (e.g., from an individual port to the broader maritime-coastal system).

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[1] Acute hazard threats might include episodic disturbances, such as hurricanes, tsunamis, storm surge flooding, drought, channel disruptions, or a breach in cyber security. Chronic hazard threats might include slow-moving hazards, such as sea level rise, shoreline erosion, fluctuations in port congestion, and changes in labor and workforce.

[2] Criteria would be defined by stakeholders but might be environmental mitigation, minimal business interruption, time to post-event recovery, climate change adaptation, or cyber security resilience.

[3] Hard approaches to implementing resilience include structural mitigation or infrastructure improvements. Soft approaches to mitigation include strategies for insurance, planning and design, operations and management, and business continuity.

- Develop criteria for prioritizing resilience actions, especially in regards to systems within ports and their surrounding coastal areas (e.g., over time, post-event recovery, adaptive capacity).
- What are some incentives to promote resilience across the maritime supply chain?
- How do redundancy and capacity reserves balance across ports and figure into resilience?
- What is the role of insurance in port resilience (e.g., incentives for behavior change vs. non-actuarial premiums)? How does this compare with the role of the NFIP in providing home owners in flood prone coastal areas?
- What combination of characteristics of the built and natural environment determine when or if port assets shift towards being vulnerabilities? Which characteristics best promote resilience capacity under dynamic conditions?

5. How are the environmental, economic, and social consequences of risk transferred across stakeholders in the maritime-coastal system, at varying spatial and temporal scales? Conversely, how is the effort to implement resilient solutions distributed across stakeholders of the maritime-coastal system?
    - Look at the distribution of social, economic, environmental, and health consequences of port disruptions across stakeholders, from the individual port to a system of ports.
    - Who owns the risk? Consider experimental public/private ventures and adjustments to the current insurance business model to better address risk.

6. What is the value of infrastructure across the maritime-coastal system? Develop an inventory of the economic value of existing assets, considering both public and private infrastructure.
    - Conduct an inventory of infrastructure across the supply chain, beyond public property to include private property and beyond port boundaries to include the entire logistics path.
    - What are the methodologies for quantifying total national economic benefits of maritime infrastructure and the risks to maritime infrastructure?

7. What data and tools currently exist to help identify areas of investment for resilient maritime-coastal systems? Establish a catalogue for existing data, models, and visualization tools to identify hazard threats, assess vulnerability and risk, and incorporate principles of resilience across the maritime-coastal system.
    - Develop enterprise capabilities to access and share data within the USACE, project stakeholders, and the public.

- Develop a repository for decision-support tools that incorporate planning, design, and social engineering disciplines to help quantify resilience and guide community leaders when making resiliency investment decisions.

8. How are existing data and tools unable to help to identify areas of investment for resilient maritime-coastal systems? Identify and develop data, models, and visualization tools to fill information gaps (e.g., to identify hazard threats, assess vulnerability and risk) to incorporate principles of resilience across maritime-coastal systems.
    - How can we build on existing tools to identify hazard threats, prioritize investment and incorporate resilience principles into design?
    - What are underpinning informational needs for planners and decision makers to improve situational awareness of current resiliency, vulnerabilities, and resiliency investment decisions?

9. Where are examples of success and lessons learned for implementing resilience in maritime-coastal systems? Establish a collection / repository of case studies of successful planning efforts that resulted in positive return-on-investment for implementing resilience in addition to lessons learned and areas for improvement.
    - Are there consistent resiliency planning scenarios and preparedness actions by all levels of government and community that might improve the understanding of infrastructure and socio-economic impacts that may result from a hazard event?
    - Improve community awareness and understanding of infusing resilience into design standards by developing links to Return-on-Investment incentives and case studies where notable ROIs have been realized by the implementation of resilient systems.

III. A Case for Research in Coastal and Maritime Resilience

Over the past decade there has been growing interest in studying and applying the principle of resilience in the context of natural and human-caused hazards. As noted in the introduction there are many definitions of resilience, but the key concepts are the capacity or ability of a system, whether physical or human, to prepare for disruption, absorb or resist stress from disturbance, recover from impact in a timely manner, and adapt for future disruptive events (Holling 2001; Cox, Prager, and Rose 2011; National Academies 2012; Rosati, Touzinsky, and Lillycrop 2015; PIANC 2016). Arguably, there is no region on earth that more urgently calls for the application of resilience than the coastal zone. The coastlines of the United States – including the Atlantic and Pacific Oceans, the Gulf of Mexico and the Great Lakes – are exceptionally vulnerable to adverse impacts resulting from both natural and human-caused hazards. This vulnerability is due to numerous factors, including:

- increasing risk of flooding, storm surge, high winds, erosion, subsidence, and other natural hazards;
- rapid population growth and accompanying development;
- increasing social vulnerability due to demographic and economic changes;
- deteriorating coastal infrastructure, including roads, bridges, rail lines, ports, marinas and other water-dependent uses;
- limited or non-existent incentives to refrain from building along or retreating from the shoreline;
- lack of implementation or enforcement of hazard mitigation and risk-reduction policies and regulations; and
- increasingly stressed natural features and ecosystems.

(ASCE 2013; Hallegatte et al 2013; Knight 2015; NOAA 2013; The Heinz Center 2009; U.S. Commission on Ocean Policy 2004; Beatley, Brower and Schwab 2002).

These factors are common to a significant number of coastal communities, and have led to the heightened level of property damage, disruption of social networks, interruptions in commerce and trade, and tragic loss of life that we have experienced in the aftermath of large-scale disasters such as Hurricanes Katrina and Sandy, as well as from smaller but more frequent events. These challenges will only be compounded by the effects of climate change (Intergovernmental Panel on Climate Change [IPCC] 2014), a phenomenon that disproportionately impacts coastal areas through sea level rise, an increased number and intensity of tropical storms, as well as other shifting dynamics within the complex natural systems found at the coast.

As compelling as the arguments are for increasing our efforts to enhance resilience in the coastal region, there are equally pressing motives for endorsing a resilience framework in the maritime areas of our nation. While the coast encompasses a relatively narrow swath of land / water at the interface of the ocean or lake and the shoreline, the reach of the United States' maritime jurisdiction extends outward to encompass the territorial seas. The maritime region also reaches extensively landward, and includes navigable channels in the interior of the country.

The maritime sector of the U.S., and in particular the Maritime Transportation System is essential for our nation's security and economic viability. For convenience we include waters from the inland river regions to the open ocean in the MTS. We are dependent on the entire network of the MTS, comprised of the waterways, ports, and inter-modal land-side connections that allow the various modes of transportation to move people and goods to, from, and on the water. The extensive reach of the MTS makes trade and commerce possible throughout the country, as it connects all 48 contiguous States, as well as Canada and Mexico. According to

U.S. Department of Transportation statistics, waterborne cargo and associated activities contribute more than $649 billion annually to the U.S. GDP, sustaining more than 13 million jobs (U.S. DOT MARAD). The total value of marine freight is estimated to increase by 40 percent domestically and 67 percent internationally between 2010 and 2020 (U.S. DOT MARAD). A disruption in any portion of the MTS can have far-reaching consequences for the rest of the network, potentially interrupting supply chains both up- and down-stream.

Many hazard threats, both predictable and unknown, challenge the uninterrupted operation of the maritime transportation system across multiple temporal and spatial scales. Hazard threats include: climate-change associated impacts (e.g., higher temperatures; drought; flooding; extreme precipitation, tidal conditions, and storms; changes to water level and quality; ice; sea-level change; new shipping routes); other environmental impacts (e.g., invasive species, seismic disruptions, tsunamis, chemical spills); economic impacts (e.g., fluctuating markets, aging infrastructure, port congestion); and social impacts (e.g., labor strikes, population dynamics, and automation of cargo handling) (PIANC 2016). Unpredictable disruptions, such as breaches of cyber security and terrorist attacks, also pose threats to the MTS.

It is clear that a critical aspect of our nation's overall resiliency is the level of resilience in the maritime and coastal sectors, each of which must be able to withstand and recover effectively from external shocks and continue to provide the services we rely upon for our economic viability and homeland security. However, despite the clear dependencies, the interface between the maritime and coastal regions has not been an area of significant research to date. The following points highlight the gap in the current body of knowledge about maritime and coastal resilience:

- there is a paucity of published peer-reviewed research on maritime resilience, and in particular MTS resilience;
- the measures of coastal resilience most critical to maritime and MTS operations have not been well defined;
- the impact of coastal resilience on the MTS and oceanic commerce is not well understood;
- the existence of tipping points in the MTS and coastal systems are largely unexplored;
- there is minimal guidance on how to distribute investment in the coastal versus the maritime / MTS sectors to maximize the resilience of both; and
- there is little event- or scenario-based evidence as to how coastal hazard risks affect maritime operations.

Approaches to understanding and measuring resilience in the context of the MTS and coastal communities are described in the next section of this report. As a way to frame the discussion, we focus primarily on ports, both in their role as a critical node within the MTS, and because of the interplay between ports and their host communities.

IV. Setting the Stage: Port and Local Governance

A brief overview of governance is important for understanding both the authority and limitations of ports to regulate and oversee port operations, and the corresponding authority of local communities to control the use of land within their jurisdiction. These powers and limitations present both obstacles and opportunities for increasing resilience within a particular port itself and in relation to the surrounding community.

Port Governance

Under the Commerce Clause of the U.S. Constitution (U.S. Const., art. I, § 8, cl. 3), the federal government has exclusive jurisdiction over the navigable waters of the United States. Authority to carry out certain functions with regard to navigation has been delegated to the U.S. Coast Guard and U.S. Army Corps of Engineers, among other federal agencies. However, unlike many other countries, there is no national port authority in the United States, although the Committee on the Marine Transportation System [CTMS] acts as a coordinating body among federal agencies that have a role in MTS governance. Some ports operate as autonomous port authorities, or self-governing public bodies, operating under a delegation of power from the state or local government within defined geographic districts. Other ports are variously governed by local, state and federal regulatory bodies. Some commercial ports, such as many of those on the Great Lakes, are privately owned and operated as part of a larger industry enterprise (Sherman n.d.).

Like other types of special districts, port authorities are governed by a board, commission, or council, but their governance structures vary; some boards may be elected by the public, while others are appointed by the state, county or municipality that authorized creation of the port authority. No matter the type or structure of governance, port authorities do not control private terminals, industrial facilities, or military operations located in or around port facilities, although some private tenants in ports may be subject to controls written into their lease agreements (EPA 2016). The primary distinction between a port and a port authority is that a port is a geo-economic entity whereas a port authority is a government or quasi-government entity (Sherman n.d.).

Generally speaking, a port authority is an administrative device that acts outside the framework of conventional government departments, with adequate jurisdiction and authority to construct facilities, promote the port, and administer its operations in the interest of the whole community (Fair 1961). Even when explicitly established as a governmental entity that serves the public, the degree of power that a port authority can exercise varies widely (Sherman n.d.). Powers delegated to port authorities may include: eminent domain; conducting studies and plans; levying facility charges; issuing bonds; applying for grants; entering contracts; etc. Some port authorities may exercise regulatory powers, such as enforcement of local or state environmental and land-use regulations, and management of submerged or tidal lands within the port's jurisdiction, an important power for controlling water-dependent uses.

Local Land Use Governance

Many of the challenges that face coastal communities are a factor of planning and policy decisions about where and how to build homes, businesses, public facilities, infrastructure, and other types of development. Local governments do not have inherent power to deal with these challenges. Counties, municipalities and other units of government may act only through a delegation of power from the state for the purpose of protecting the public's health, safety, and general welfare. Fundamental powers delegated to most local governments by their states include regulation, acquisition, taxation, spending, education, as well as the function of planning. These powers can be used separately or in tandem to manage the characteristics of land use, growth, and development in the community to help mitigate the impacts of natural hazards by deterring development in identified hazard areas, while steering growth into less vulnerable locations within the jurisdiction. Among the regulatory powers that can be effectively used to reduce hazard vulnerability in this manner are zoning ordinances, subdivision regulations, building codes, and flood damage prevention ordinances.

V. Interdependence in the MTS and Coastal Communities

As discussed previously, the MTS includes navigable waterways, vessels, ports, terminals, and intermodal connections. Ports represent a critical link in the maritime transportation system and provide an important nexus to connect regional economies to each other and to global trade networks. Individual ports are also integrally connected to their host communities, and are dependent upon the surrounding population as a source of employment, as well as the local ancillary businesses and services that support port operations. Therefore, resilience is a desirable property within and throughout the MTS and coastal communities.

Achieving resilience, in ports and near-port communities, requires understanding of the interdependency and interconnectedness between ports, communities, and businesses, both physically and socio-economically (Figure 1). A resilient MTS requires physical infrastructure resilience as well as organizational and operational resilience, both which emphasize anticipatory action and pre-event planning. The following section provides a very brief overview of where these topics sit in the academic literature, how the federal government plans to approach MTS

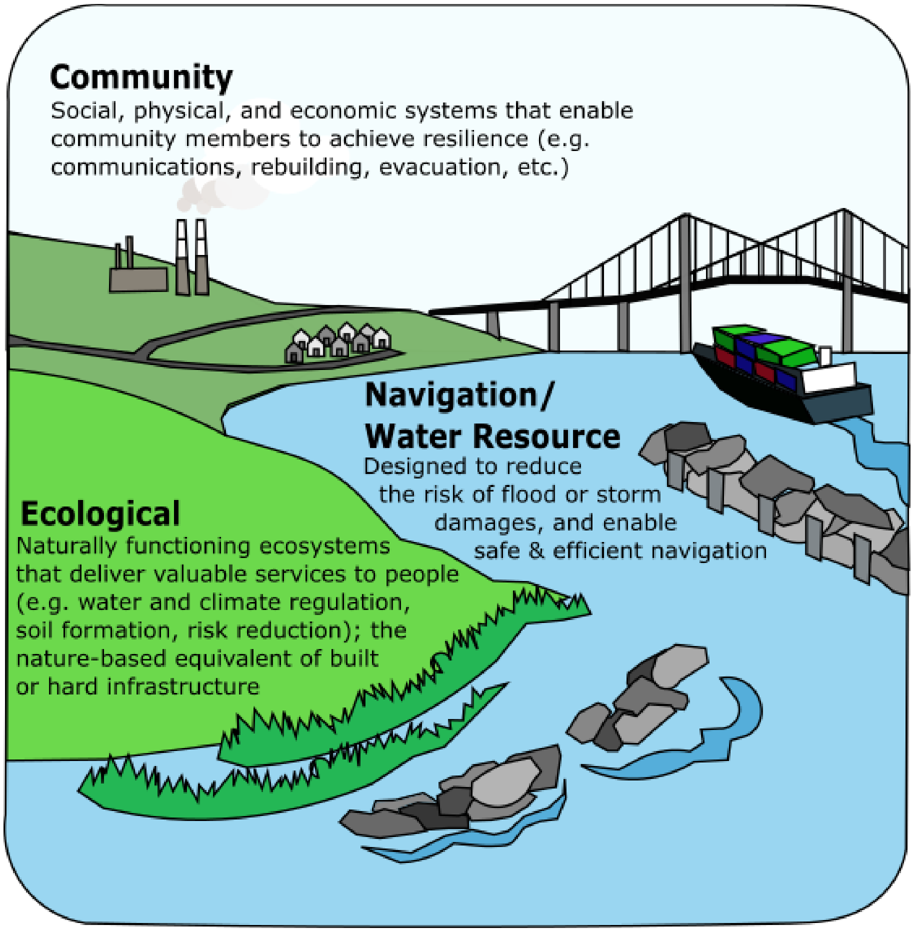

Figure 1. Maritime Transportation System, juxtaposed with ecological and community systems. (Image Credit: Touzinsky, U.S. Army Corps of Engineers, Resilience Integrated Action Team, http://www.cmts.gov/Activities/ActionTeams.aspx).

resilience, and what questions need to be explored further, as identified by participants of the 2016 Maritime Risk Symposium.

At the intersection of maritime transportation, port, and physical hazards studies, much of the academic research addresses the impacts on and physical resilience of ports to earthquakes, tsunamis, and terrorist attacks (Werner, Dickenson, and Taylor 1997; Chang 2000; Martagan et al. 2009; Mansouri, Nilchiani, and Mostashari 2010; Madhusudan and Ganapathy 2011; Barberopoulou et al. 2011; Gregory et al. 2012). MTS resilience should be studied as part of a greater network of integrated and interdependent systems (Little 2003). Since multiple supply chains pass through a single port, understanding the role of operators across the supply chain enhances resilience planning by understanding the linkages up and down the chain and across the network.

Presentations at the 2016 MRS highlighted relationships between ports and port communities. For example job creation, infrastructure, higher local and state tax revenues, and port-community partnerships related to the existence of a port provide opportunities to protect the environment, coordinate land use planning, and promote community amenities. Potential challenges facing port communities might include inequitable distribution of economic benefits, adverse impacts on human health due to impaired air and water quality, increased traffic congestion, noise and light pollution, loss of environmental resources and ecosystems, and a decline in property values. Issues of environmental justice may also arise, as when ports and related industry operations disproportionately impact low income and/or communities of color (EPA 2016). A noteworthy presentation described efforts by the EPA to provide assistance to near-port communities by building capacity so that community members are empowered to participate more effectively in the decision-making processes of port activities that may impact local land use, the environment and quality of life.

VI. Assessing Vulnerability at Port and Community Levels

Vulnerability assessments and simulation models specific to supply chain relationships in maritime networks focus on large scale impacts to large commercial ports (Martagan et al. 2009; Berle, Asbjørnslett, and Rice 2011). For example, Martagan et al. (2009) developed a computerized simulation model that tests the impacts of adjusting the amount of time that freight spends in transit on the flexibility, agility, and adaptability of entire supply chains during a natural or human-caused disruption. In addition, supply chains generally do not have plans developed for unpredictable threats or for low-frequency, high-impact events, such as hurricanes and other natural hazards (Berle, Asbjørnslett, and Rice 2011; Berle, Rice, and Asbjørnslett 2011).

In 2007, the U.S. Government Accountability Office [GAO] released a report titled Port Risk Management: Additional Federal Guidance Would Aid Ports in Disaster Planning and Recovery (U.S. GAO, 2007). As a response to Hurricane Katrina, the GAO interviewed port stakeholders and reviewed relevant planning and emergency operations documents for seventeen major U.S. ports to assess the status of preparing for and reducing damages from natural hazards, specifically earthquakes and hurricanes. Ports reported experiencing challenges with damage to port infrastructure, debris clogging the waterways, and delivery of utility services, such as electricity and water. The most reported challenges, however, included problems with communication, personnel, and coordination with local, state, and federal stakeholders, both in the response phase and for days to weeks after an event.

At the community level, a risk assessment is an integral part of the hazard mitigation and climate change adaptation planning process. Data about the hazards facing the community that are obtained during a risk assessment serve as a solid fact base that can help direct and justify mitigation policies, strategies, and incentives to reduce vulnerability (FEMA 2013).

A risk assessment undertaken as part of the local planning process allows the community to identify its level of vulnerability to identified hazards. Physical vulnerability refers to buildings, structures, and infrastructure that are exposed to hazards, while social vulnerability refers to the people that are exposed to hazards (Berke 2016). Together, these vulnerability factors can shed light on the level of community resilience, that is, the ability of people, structures, systems and networks to "bounce back" following a disaster.

VII. Measuring Resilience

Port stakeholders have a vested interest in the long-term function and viability of ports, but no standardized measures for resilience currently exist for ports or the broader MTS. With increased frequency of hazards, both natural, technological and human-caused, port stakeholders should take a proactive stance in identifying risks and planning accordingly, rather than waiting until after an event. The academic literature emphasizes macroscale impacts of disruption to entire supply chains, physical resilience to disruption, and the importance of pre-event planning. This need for pre-event planning is equally critical to the sustainability of coastal communities. Following a disaster, investments in recovery and repair are often focused on returning to the status quo, i.e., the pre-event landscape re-emerges and residents return to "business as usual." While this approach may result in actions that help maintain a certain level of function (for example, avoiding major business interruption), it can still leave the community vulnerable to future disaster impacts.

Putting together a port risk management plan, under the uncertainty associated with natural hazards and severe weather, creates a complicated process for managers because of all the opportunities for interruption with cargo, ships, port infrastructure, personnel, and port geographic location. Previous research efforts have developed conceptual frameworks for risk management to assess the effects of severe weather on port operations (Athanasatos, Michaelides, and Papadakis 2014), to compare policy and investment strategies to increase physical infrastructure resilience (Mansouri, Nilchiani, and Mostashari 2010), and to assess and quantify risk and risk mitigation (Kleindorfer and Saad 2005).

Decision makers in the MTS can use simulation models to evaluate different resilience-building strategies to attempt to develop a cost of resilience. The difficulty of quantifying disturbance impact before an event takes place transfers to difficulty in predicting impacts of disruptions to nodes along the MTS. At the University of Southern California, the Center for Risk and Economic Analysis of Terrorism Events seeks to "improve the Nation's security through the development of advanced models and tools for the evaluation of the risks, costs and consequences of terrorism" (http://create.usc.edu). One research effort developed port service disruption models to understand the possible economic impact of terrorist attacks on port operation (Rose and Wei 2013). In their methodology, Rose and Wei included certain resilience actions to observe the adjustment to economic impact, using an input-output modeling approach to show interdependencies across the supply chain (2013). Adjustments to the model included strategies for resilience, such as ship re-routing, export diversion, and import substitution, which reduced impacts to regional gross output by 70% in a model of a 90-day disruption to Port of Beaumont and Port Arthur, Texas (Rose and Wei 2013).

Outside of academia, seeking to understand and measure the mechanisms of MTS resilience has recently generated new research efforts at the federal government level. The Committee on Marine Transportation Systems [CMTS] has a Resilience Integrated Action Team [RIAT] whose purpose is to coordinate information and activities across federal government agencies to incorporate resilience into operation and management of the U.S. MTS. The task is complicated, which justifies doing more applied research in order to understand the nature of resilience throughout the MTS and the integration of coastal and maritime resilience.

At this time, the CMTS RIAT has prioritized defining metrics for physical infrastructure resilience but has acknowledged the importance of considering social factors as well. The final report from the 4th biennial meeting of the CMTS (held in June 2016), in collaboration with the Transportation Research Board, stated "[t]he MTS should consider and evaluate social vulnerability factors alongside the physical risk factors that shape port resilience" (U.S. CMTS 2016, 5). CMTS RIAT objectives for fall 2016 included developing a compendium and gap analysis of tools, metrics, and indices in federal agencies and NGOs related to MTS infrastructure resilience; and evaluating ports for best practices and vulnerabilities associated with infrastructure.

The U.S. Army Corps of Engineers [USACE] serves as the lead agency for the CMTS Data Integrated Action Team and is leading the effort to create a database of federal datasets that might be used for analyzing and understanding maritime performance and resilience (publicly available on www.data.gov/maritime). As of December 2016, fifty-two available data sets represent agencies such as DHS USCG, DOC NOAA, DOT, DOD, USDA, MARAD, DOI BOEM, EPA, USACE, and USGS. Datasets that might specifically apply to the intersection of coastal and maritime resilience include NOAA's Digital Coast and nowCOAST web mapping portal, NOAA's Sea Levels Online, DOT's Water Levels and Environmental Data, and NOAA's worldwide historical hurricane tracks.

The USACE is "examining MTS performance as an interconnected system and within a larger intermodal supply chain network" and is looking to develop an operational intermodal freight network model to determine the performance of critical aspects of the MTS (Kress et al. 2016, ii). Categories of major indicators of MTS performance, defined by USCE, include economic benefits, capacity and reliability, safety and security, environmental stewardship, and resilience. According to Kress et al., the dataset that USACE has identified as currently available for MTS resilience is the physical condition ratings of critical coastal navigation infrastructure (e.g., piers, groins, jetties, dikes, breakwaters, and revetments). USACE acknowledges that this data set provides a physical assessment, not a functional assessment, of infrastructure. The authors acknowledge the difficulty of defining quantitative measures for resilience: "resilience is ultimately location and event-specific…[and]…is unlikely to be reduced to a single measurement, but a relevant suite of measures through time will provide important insight into infrastructure performance under a variety of conditions" (Kress et al. 2016, 50, 52).

The USACE Engineer Research and Development Center [ERDC] plans to develop outreach and communication tools on a risk assessment approach, using federal datasets and assets. While the risk assessment approach is being developed, USACE ERDC is also developing individual case studies to assess average port performance and post-disaster performance and to identify potential resilience indicators, using data from USACE's Channel Portfolio Tool, which provides analysis on how the commercial shipping industry uses federally maintained navigation channels, and the AIS (Automatic Identification System) Analysis Package, which provides movement information and vessel characteristics for commercial vessels.

At the international level, PIANC (World Association for Waterborne Transport Infrastructure) assembled a Resilience Working Group in 2016 with objectives including development of a working definition for resilience for the maritime and inland waterborne transport system and identification of resilience indicators and methods to quantify resilience (PIANC 2016). Similar to USACE, PIANC focuses on physical infrastructure and hard approaches to resilience but from an international perspective.

For coastal communities, the identification of standards and metrics for measuring disaster resilience is one of the challenges faced by local, state, and federal agencies (Cutter 2008), but meeting the challenge is "essential if communities want to track their progress toward resiliency" and "target efforts where they most need to improve" (NRC 2014, p.12). At the community level, advances have been made in measuring resilience (Peacock et al. 2008; Cutter et al. 2008; 2010; Rose et al. 2009; Cox et al. 2011), but more remains to be done.

Among the approaches for measuring community resilience is the disaster resilience of place (DROP) model developed by Cutter et al. (2008) "to improve comparative assessments of disaster resilience at the local or community level". Berke et al. (2015) has developed a draft "Plan Integration for Resilience Scorecard" that assesses the degree to which community-wide plans and policies reveal plan conflicts and alignments that either increase or decrease disaster vulnerability within hazard zones. Other resilience tools, indicators and scorecards focus on community capacity, economies, infrastructure and the built environment, mitigation actions, and other community variables. When assessing resilience of the community, it is important to note that "any scorecard development and use must … involve the community and its leadership. Building a scorecard or assessment can provide an opportunity to raise awareness and educate the public about resilience" (Knight 2015, p.13). The ultimate purpose of an assessment of resilience is to incentivize actions to reduce risk to hazards. (For a comprehensive list of additional resilience indicators and scorecards, both quantitative and qualitative, see Cutter 2016).

VIII. Planning for Resilience

MTS Resilience Planning

Due to the long list of possible operational risks (i.e., equipment failure, labor strikes, personnel challenges, etc.), supply chain managers typically focus on maximizing profit, rather than preparing for risks, through strategies like adding inventory and having redundant suppliers (Chopra and Sodhi 2004). Strategies to build port resilience generally focus on emergency response planning rather than long-range resilience planning. MTS operators have to strategize how to manage the push-pull effect of preparing for and preventing risk without reducing profits. A recurring theme of the MRS was the value of redundancy built into the system. MTS stakeholders will be more willing to adopt strategies that improve operational efficiency and resilience, guaranteeing profitability and business continuity after a disruption (Tang 2006).

Port Resilience Planning

A key step in port planning includes understanding assets available for response. Increasing visibility and communication among all players of supply and demand relationships might increase resilience across the entire supply chain. By understanding assets and assembling a preparedness plan in the pre-disaster planning phase, maritime industry members and public stakeholders with maritime interests will know the availability of resources to deploy in order to increase efficiency of disaster response and aid after an event (Stewart et al. 2009; Mileski and Honeycutt 2013). Federal legislation requires that ports prepare and plan for security threats and terrorist attacks. Since no specific federal requirements exist for natural disaster planning at ports, time and resources get devoted to security planning, and any existing disaster preparedness plans show wide variation from port to port (U.S. GAO 2007).

After Hurricane Katrina in 2005, the American Association for Port Authorities [AAPA] developed a disaster manual, Emergency Preparedness and Continuity of Operations Planning Manual for Best Practices, that encourages ports to develop alternative communication plans, establish emergency operations centers, and identify federal resources for recovery efforts (Saathoff 2006). To go a step further, the Ports Resilience Index, developed with port practitioner input from across the Gulf of Mexico, offers a self-assessment questionnaire for port management organizations to assess their resilience and ability to reach an acceptable level of functioning after an event and to adapt and prepare for the next hazard event (Morris 2016). The PRI guides port and maritime industry leaders in identifying actions to take to improve resilience. In the Great Lakes region, the Great Lakes Resilience Planning Guide (http://greatlakesresilience.org/case-studies/infrastructure/economic-valuation-port-infrastructure) offers case studies and a matrix to evaluate the economic value of port assets.

Challenges still exist for the ports and maritime industry in terms of disaster response and recovery, such as hazard mitigation for waterfront buildings (Smythe 2013). In addition, port administrators feel that climate change impacts, such as sea-level rise, might pose a threat to port operations but these impacts will not affect current port authority administrative entities in this century, (Becker et al. 2012). In terms of climate change projections and adaptation planning, ports typically use time horizons that do not adequately account for impacts that will become evident several decades from now as a frame of reference. Instead, ports tend to plan for the short- and medium-term range, and rarely develop strategies for infrastructure development beyond 25 years. This continues to be the norm, despite the observation that climate change, and the accompanying increase in risk from extreme events, requires a longer planning horizon (Becker 2014).

For hazards, ports need to account for direct damages (i.e. the cost of structural damage to property), indirect damages (i.e. the cost of reduced production of goods and services), and intangible consequences (i.e. the non-market consequences of disaster, including ecosystem damages or cultural damages), Becker and Caldwell (2015). After Katrina, port planning documents initially focused on recovery and future hazard planning, but the focus soon shifted to job creation (Becker et al. 2013). Future interactions with port stakeholders should emphasize how different stakeholders perceive environmental impacts and how port resilience planning documents should account for those impacts to members of the community beyond the physical boundaries of the port (Becker et al. 2015).

Community Resilience Planning

Under the federal Disaster Mitigation Act of 2000 (DMA), states, local governments, and native American tribes are required to develop and adopt a FEMA-approved all-hazards mitigation plan to be eligible for pre- and post-disaster mitigation funding. Guidance materials produced by FEMA to help states and local governments meet DMA regulatory planning requirements note that “mitigation is most effective when it is based on a comprehensive, long-term plan that is developed before a disaster occurs. The purpose of mitigation planning is to identify local policies and actions that can be implemented over the long term to reduce risk and future losses from hazards” (FEMA 2013).

Over the last few decades, land use planning and regulation have become well-established in the literature as viable approaches for communities to reduce their vulnerability to natural hazards (Burby et al. 1999; Burby, French, Cigler, Kaiser, & Moreau, 1985; Godschalk, Kaiser & Berke 1998; Milleti 1999). In particular, local hazard mitigation plans that incorporate a land-use approach are “essential for building disaster resilient communities” (Burby 2000).

When adopted through a local community's planning process, mitigation strategies can help guide development to locate people and property out of harm's way. Mitigation strategies also include efforts to build new construction and retrofit existing buildings so that hazard reduction is maximized. In addition, federal, state and local environmental regulations, such as protection and enhancement of wetlands, marshes, mangrove forests, and other "green infrastructure" can provide protection to communities against flooding, storm surge and other coastal hazards (Beatley, Brower & Schwab 2002).

Many of the same short-term biases that face port operators are evident in community-level resilience planning. Often the time horizon for community-wide planning efforts is only as long as the next election cycle, since many of the policies that affect land-use and infrastructure planning can be fraught with local politics. Despite these challenges, an increasing number of communities are addressing the impacts of climate change in their land use and comprehensive plans by incorporating future-oriented assessment of natural hazard risks into the planning process, particularly in coastal areas that are already experiencing climate impacts such as increases in tide-related / nuisance flooding.

While planning, design and siting of development can be effective in reducing hazard vulnerability in coastal communities, as part of the MTS network, many ports are constrained to environmentally sensitive and high-risk locations (Becker 2015). This siting constraint often leads to increased vulnerability, particularly as climate-related changes, including sea level rise, increased storminess and more frequent flooding impact ports and their surrounding communities directly. Many of the challenges associated with risk reduction and climate adaptation are common to both ports and communities, which can provide an opportunity for ports and near-port communities to engage in collaborative mitigation and climate adaptation planning (EPA 2016).

IX. Conclusion

The recent development of government efforts to define and quantify MTS resilience supports the fact that the topic is complex and largely unexplored. While several efforts are underway to define metrics for physical infrastructure resilience, questions of social and economic resilience of the MTS still remain. While efforts to define community hazards and vulnerabilities in coastal areas are more mature, methodology for measuring and advancing resilience in this area remain nascent. MTS and coastal resilience converge most clearly in and around ports.

Understanding how environmental, economic, and social risks are distributed across the MTS and throughout coastal communities, and how to implement resilience at both small and large spatial scales requires further research and action. Themes discussed at the Maritime Risk

Symposium included interdependencies within systems of the MTS; capabilities associated with redundancies within the MTS; bottlenecks and tipping points within the MTS; distribution of risk among all MTS stakeholders; relationships between ports and near-port communities; and challenges for climate change planning common to both the MTS and coastal communities. It is clear that the integration of maritime resilience with coastal resilience is more of an undertone in the literature ***in many cases resilience will not be achieved independently in the maritime and the coastal sectors, but rather requires an integrated consideration of both***.

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Appendix A

Maritime Risk Symposium 2016 Agenda

7th Annual Maritime Risk Symposium: Integrating Maritime and Coastal Resilience

Agenda
November 14-15, 2017
The Carolina Club, George Watts Hill Alumni Center
The University of North Carolina at Chapel Hill
150 Stadium Drive, Chapel Hill, NC 27514

Day One: November 14, 2016

7:15 a.m. Light Breakfast/Registration (Alumni Hall I)

8:15 a.m. **Welcome:**

Co-Chairs:

- **Dr. Rick Luettich**, Lead Principal Investigator, DHS Coastal Resilience Center of Excellence
- **Dr. Joseph DiRenzo, III**, Director of Research Partnerships, U.S. Coast Guard Research and Development Center

Master of Ceremonies: **VADM Rob Parker**, USCG (Ret.)

8:30 a.m. **Keynote Speaker: Donald Hornstein**, Aubrey L. Brooks Professor of Law, UNC-Chapel Hill School of Law; Member, Board of Directors, NC Insurance Underwriting Association: *"Resilience, Actuarially"*

9:00 a.m. **Session 1: Enhancing Resilience of Coastal and Maritime Systems: Port Resilience**

Moderators:

- **Dr. Gavin Smith**, Director, DHS Coastal Resilience Center of Excellence
- **Todd Davison**, Manager, Gulf, Southeast and Caribbean Region, NOAA Office for Coastal Management

Panelists:

- **Dr. Rachel Willis**, Professor of American Studies, University of North Carolina at Chapel Hill
- **Dr. Betsy Smith**, Senior Research Scientist, national Exposure Research Lab, Environmental Protection Agency
- **Dr. Robert Twilley**, Executive Director, Louisiana Sea Grant College Program
- **Lauren Morris**, Ph.D. candidate, Geography and Anthropology, Louisiana State University
- **Dr. Austin Becker**, Assistant Professor of Coastal Planning, Policy, and Design, University of Rhode Island
- **Dr. Adam Rose**, Research Professor, University of Southern California Sol Price School of Public Policy

10:30 a.m. BREAK

11:00 a.m. **Session 2: Enhancing Resilience of Coastal & Maritime Systems: Houston/Galveston,TX**

Moderators:

- **Tom Richardson**, Transition Director, DHS Coastal Resilience Center of Excellence
- **Jeff Lillycrop**, Technical Director, Navigation R&D, U.S. Army Corps of Engineers Research and Development Center

Panelists:

- **Dr. William Merrell**, Chair of Marine Sciences, Texas A&M University at Galveston
- **Len Waterworth**, Col (Ret.); Executive Professor, Maritime Administration, Texas A&M University at Galveston
- **John Kennedy**, Commissioner, Port of Houston
- **Sheri Willey**, Civil Engineer/Project Manager, U.S. Army Corps of Engineers – Galveston District

12:15 p.m. LUNCH

1:00 p.m. **Lunch Speaker: U.S. Rep. David Price**

1:45 p.m. **Keynote Speaker: Devon Streit**, Deputy Asst. Secretary, Infrastructure Security and Energy Restoration, U.S. Department of Energy

2:15 p.m. **Session 3: Enhancing Resilience of Coastal Infrastructure**

Moderators:

- **Dr. Hudson Jackson**, Section Chief & Program Chair, Civil Engineering, U.S. Coast Guard Academy
- **CDR Brian Maggi**, Teaching Staff, Engineering Department, U.S. Coast Guard Academy
- **Brian Hill**, Director, Western Gulf Gateway, U.S. Maritime Administration

Panelists:

- **Dr. Melissa Allen**, Post-Doctoral Research Associate, Computational Science and Engineering Division, Oak Ridge National Laboratory
- **Lisa Dickson**, Associate Principal, Climate Risk and Resiliency, Arup
- **Randy Kee**, Maj. Gen., USAF (Ret.), Executive Director, Artic Domain Awareness Center
- **LCDR Mark Braxton**, Construction Director, U.S. Coast Guard

3:30 p.m. BREAK

4:00 p.m. **Session 4: Resilience in a Complex Coastal System: Norfolk/Hampton Roads**

Moderators:

- **Dr. Michelle Covi**, Asst. Professor of Practice, Ocean, Earth & Atmospheric Sciences, Old Dominion University
- **LCDR Blair Sweigart**, Operations Research Analyst, U.S. Coast Guard Atlantic Area
- **Dr. Larry Atkinson**, Professor of Oceanography, Old Dominion University

Panelists:

- **Jim Redick**, Director of Emergency Management, City of Norfolk, VA
- **Ann Phillips**, Rear Admiral, U.S. Navy (Ret.)
- **Kit Chope**, Vice President, Sustainability, The Port of Virginia
- **CAPT Richard Wester**, Commander, U.S. Coast Guard Sector Hampton Roads

5:15 p.m. **Day 1 – ADJOURN**

6:30 p.m. **Dinner**—The Great Room at Top of the Hill, 100 East Franklin St., Chapel Hill, NC

AGENDA Day 2: November 15, 2016

7:00 a.m. **American Public University System Student Breakfast** (Alumni Hall II)

7:30 a.m. Light Breakfast (Alumni Hall I)

8:15 a.m. **Day 2 Welcome: Dr. Rick Luettich / Dr. Joe DiRenzo**

8:30 a.m. **Keynote Speaker: Dr. Stephen Flynn**, Director, Center for Resilience Studies, Northwestern University

9:15 a.m. **Session 5: Cyber Resilience in the Maritime Transportation System**

Moderators:

- **CAPT David Moskoff**, Professor, Marine Transportation, U.S. Merchant Marine Academy
- **Scott Blough**, Assistant Professor of Criminal Justice & Security Studies, Tiffin University

Panelists:

- **CAPT Alex Soukhanov**, Vice President, U.S. Maritime Resource Center
- **CAPT Drew Tucci**, Commander, U.S. Coast Guard Sector Long Island Sound
- **Kate Belmont**, Associate, Blank Rome, LLP
- **Dr. Cliff Wang**, U.S. Army Research Office

10:30 a.m. **Breakout Sessions:** Held in Alumni Hall I and II, Dowd, Harris and Royall Rooms
See handout for room locations

11:30 a.m. **Report out from Breakout Sessions** (Alumni Hall I)

12:00 p.m. **Symposium Wrap-up and Adjourn**

Appendix B

Maritime Risk Symposium 2016

Committee Members

Co-Chairs
Dr. Rick Luettich, Lead Principal Investigator, DHS Coastal Resilience Center of Excellence
Dr. Joseph DiRenzo, III, Director of Research Partnerships, Research & Development Center, USCG

Senior Advisors
VADM Rob Parker, USCG (ret.)
Dr. Isaac Maya
Eleanore Hajian

Vice-Chair of 2017 Maritime Risk Symposium
Dr. Scott Blough, Tiffin University

Symposium Program Committee
David Boyd, Chair
Dr. Gavin Smith
Timothy Hughes
Dr. Nicole Drumhiller
Dr. Scott Blough
Chris Doane
LCDR Blair Sweigart
Dr. Michael Plumley
LCDR Brian Maggi
Dr. Hudson Jackson
CAPT David Moskoff
Dr. Scott Savitz
Todd Davison
Jeff Lillycrop
Dr. Robert Whalin
Thomas Richardson
Dr. Julie Pullen
Dr. Fred Roberts
Dr. Michelle Covi
Dr. Larry Atkinson
Anna Schwab
Josh Kastrinsky
Rebekah Sturgess