Chapter 3

Storm resilience and sustainability at the Port of Providence, USA

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1 Introduction

Sustainable seaports must be resilient seaports. Resilient systems withstand shocks like storms. In its most basic form, resilience is the ability of a linked human and natural system to absorb disturbance, while at the same time retaining its basic structure and function (Walker and Salt, 2006). Further, it is the ability of a system and its component parts to anticipate, absorb, accommodate, or recover from the effects of a potentially hazardous event in a timely and efficient manner, including through ensuring preservation, restoration, or improvement of its essential basic structures and functions (IPCC, 2013). Resilience to hurricane events can be achieved not only through physical improvements to property but also through planning, policy adaptation, and cultivating public support (Becker and Caldwell, 2015; Raub and Cotti-Rausch, 2019).

Seaports, while shaped by the natural land and seascape, are ultimately human systems. Sustainability, the state of meeting current needs without compromising the ability of individuals to meet their needs in the future (Brundtland et al., 1987), demands that resilience to hurricanes, and ultimately climate change, should be a part of port planning. Ports and port cities grew synergistically, with the port facilitating commerce and the city developing in lock step. Hall's (2007) focus on cities favors the goal of improving social and economic conditions during urbanization while maintaining environmental quality. In this study, we examined aspects of this relationship for the Port of Providence, Rhode Island, United States with a focus on the role of stakeholders in responding to the likely impacts of hurricanes in ways that produce greater resilience and sustainability. Stakeholders responded both to surveys and to 3-D visualizations of a hurricane striking the port (for more information, see www.portofprovidenceresilience.org).

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Coastal flooding arises from a combination of sea level rise, storm surge, and rain. The recent climate assessment (IPCC, 2018) of a +1.5°C to 2°C world has medium confidence for increased extreme precipitation events eastern North America where Providence is located (IPCC, 2018; Nicholls et al., 2018). The IPCC (2013) estimates a global mean sea level rise of 0.72 m (2.4 feet) over the 1986–2005 average by 2100 if there is no mitigation from carbon release (RCP8.5) in the future. Additionally, Rhode Island state government has adopted a NOAA (2017) high estimate of 9.6 feet by 2100 (2.9 m) for some state planning purposes (CRMC, 2018). While these sea level projections vary greatly, both enforce the need for port preparedness. Hurricane futures are also difficult to predict, with one group finding that greenhouse gas-induced warming does not increase the frequency of either tropical storm or overall hurricane numbers in the Atlantic (GFDL, 2019) and others finding that overall intensity of storms is likely to increase (Kutson et al., 2010). Nonetheless the storm surges associated with historical hurricanes in Providence, RI have been particularly severe. For example in the hurricane of 1938 the water level reached 5 m above normal high tide (NWS, 2019). Anticipating a sea level rise of 0.72–2.9 m, a medium confidence for increased extreme precipitation, and historical hurricane patterns will produce significant flooding at the port in the future.

With that threat in mind many dimensions of sustainability can be affected. They include nature, life support, and human community as well as individual, social, and economic needs NRC, 1999). In explaining sustainability science Kates et al. (2001, p. 641) focus attention on interactions between society and nature as well as "society's capacity to guide those interactions along more sustainable trajectories." Key to guiding an urban port in this manner will be the perceptions and actions of primary stakeholders. Kates (2012) further elaborates this theme by noting the integrative demands across social, natural, and engineering domains as well as the environmental, health, and economic development communities. Ultimately sustainability successes require knowledge to be transformed into actions (Kates et al., 2012), an approach that we consider in this chapter.

Hiranandani (2014) examined port sustainability in the context of development and environment. A multipage table in his article summarizes focal issues across four major global ports. They include pollution (air, water, and ballast water), waste disposal (dredging, solid, and hazardous wastes), and land/resource use. Hiranandani (2014) lays out principal areas where port activities affect the environment. However, storms and sea level rise also produce direct physical impacts on port functioning (Becker et al., 2014). And as Schipper et al. (2017, Table 2) find in a global study that most ports have sustainability as a part of master plans ports, but they find limited to no awareness of flooding risk in the documents.

We apply the sustainability paradigm to the social dimensions of ports. Following Burroughs (2012) we propose that in a positive sustainability trajectory, individuals in a geographic region make decisions and implement programs that assure continuity and improvement of one or more of the dimensions of sustainability as noted in the NRC report above. A sustainability trajectory sequence includes identification of a target and societal values related to it, engaging science to create feasible solutions, selecting and implementing authoritative means to 7 meet targets, and assessing results. Stakeholders are instrumental in successful trajectories. In the case of ports, stakeholders include a wide range of individuals, organizations, and agencies, such as shippers, tenants, government agencies, neighborhood groups, insurers, and, of course, the port operator itself (Becker et al., 2014). In practice, sustainability decision-making consists of iterative analysis, as society grapples with both new information from sustainability science and new values, which collectively create new targets. For the case of the Port of Providence described in this chapter, we further limit the scope to hurricanes. Storms disrupt sustainability by causing direct, indirect, and intangible impacts on the port stakeholders. Preparing for and recovering from storms is a primary challenge for ports. A positive trajectory has the potential to limit damage, to restore a system such as cargo flow in a port after a storm, or create new but affirmative values as a new situation arises for the port. In either case, the target includes meeting individual needs, building human communities, and accumulating social capital as well as respecting environmental limits. A sustainable future for a port rests on taking resilience-enhancing actions.

2 Planning for inundation

Inundation, whether temporary due to a storm event or permanent due to sea level rise, forces port sustainability considerations. Because ports must be located in areas subject to rising sea levels and storm surge, port resilience should be a focus of future planning.

Although resilience planning progress has been made, particularly with respect to changes in residential land use and building codes (Melillo 2014), few actions have yet been taken to protect the complex system of ports and shipping that facilitate the nation's maritime-based freight economy (Becker et al., 2012; Ng et al. 2016). Indeed, while port operators themselves acknowledge the important role that climate change will play in future operations (Becker et al., 2012, 2014), there are still few examples of plans, let alone implementation actions.

Complicating the response is the fact that ports consist of complex and interdependent public/private decision-making governance structures (Notteboom and Winkelmans, 2002, 2003), thus making general or universal recommendations difficult. Natural hazards associated with climate change threaten the system as a whole, as well as the infrastructure that individual organizations depend upon. Individual organizations and agencies often do not have the proper incentives or understanding of the system's interconnectedness to justify investment in long-term resilience (Becker and Caldwell, 2015). Despite the availability of impacts assessment tools and established methods for stakeholder engagement, overcoming barriers to resilience investments for complex systems such as ports remains a significant challenge. Conflicting timescales, institutional uncertainties, and lack of resources make the process more difficult (Ekstrom and Moser, 2014; Eisenack et al., 2014; Tompkins and Eakin, 2012).

3 The Port of Providence, Rhode Island

To inform planning and develop deeper knowledge of storm issues for port stakeholders, we undertook a year-long study that culminated in a workshop with representatives of the private and public sectors of the port (Becker et al., 2017). Together, the businesses that make up the port of Providence supply Connecticut, Massachusetts, and Rhode Island with petroleum products and handle bulk and break-bulk imports and exports. Many businesses depend on the port's functionality, including trucking companies, Providence and Worcester Rail, dredging firms, tug companies, marine pilots, and cargo handling services. Hospitals and educational institutions with power plants, manufacturing companies, gas users, electricity generation plants, and aviation fuel consumers among others benefit from fossil fuel trade at the port. The hinterland for fuel distribution extends well into Massachusetts.

The study area for this project includes ProvPort, the main port terminal, and number of other waterfront businesses and industries, which together take up nearly 93 ha of waterfront in Providence and East Providence (Becker et al., 2010). ProvPort itself is about 42 ha of land that are owned by the City of Providence and operated by a nonprofit organization with five board members. ProvPort contracts the services of Waterson Terminals LLC to operate and maintain the port. In 2015 the public and private terminals at the port handled a total of 8,043,000 short tons (U.S. Army Corps of Engineers, 2016).

The port is located at the northern end of Narragansett Bay, an ecologically sensitive estuary that provides breeding grounds for marine life in the region. The length and orientation of Rhode Island's Narragansett Bay, and its proximity to the Atlantic hurricane zone, make it susceptible to extreme storm surges from the southerly winds that are generated when a hurricane passes to the west of the Bay. The most recent major storm, Hurricane Carol in 1954, produced 4.4 m of storm surge in Providence. Most of the port lands in the study area are 1–3 m above mean high water. A 7.6 m hurricane barrier north of the port protects the downtown City area, but the port is located seaward of this barrier.

To further define the perceived impacts of a storm with stakeholders, we selected a 111–129 mph hurricane traveling at 40 mph and approaching Rhode Island from the south at high tide which would be equivalent to the 1938 hurricane but shifted 80 miles east (Becker et al., 2017). Modeling such a storm using Sea, Lake, and Overland Surges from Hurricanes model (SLOSH) produced a maximum total water level of ~6.4 m above NAVD 88. With this hypothetical storm 198 ha or 86% of the study area would be covered by one foot of water or more. Three-dimensional visualizations of the storm surge inundation were used to inform stakeholders about the impacts on various waterfront parcels.

Vulnerability is defined as the degree to which physical, biological, and socio-economic systems are susceptible to, and unable to cope with, adverse impacts. Clearly this port is vulnerable. To understand the degree of vulnerability as perceived by port businesses and the resilience-building actions they had taken, we interviewed many of them, conducted a workshop, and undertook a survey.

4 Survey

We conducted online surveys of port businesses to determine what actions had been taken at the firm level to create a more resilient and hence sustainable port. We were able to involve totally 17 private firms in our work. They included seven handling petroleum, five recycled metal, and four salt. In 2015 these categories of cargoes accounted for 90% of the cargo volume for the port (U.S. Army Corps of Engineers, 2016).

Eleven businesses reported owning their property and six reported their operations as independently operated. Seven businesses stated they have 1–19 employees, five businesses stated 20–99 employees, and two businesses reported over 100. Based on stakeholder responses total employment of the businesses surveyed is ~600 to as many as ~2000 workers.

Nine businesses have more than 100 unique customers (individual purchasers), while 12 stated 100 or more businesses rely on their services. This suggests a sizeable supply chain effect if port businesses were impacted, with port products reaching many customers and businesses throughout the hinterland.

Businesses require access to land and sea corridors to be effective participants in the supply chain (Fig. 1). Nine of our respondents to the initial survey depend on access to the shipping channel and of those six require the channel to be maintained as deep draft or 35 (10.7 m) to 40 feet (12.2 m). Seven require

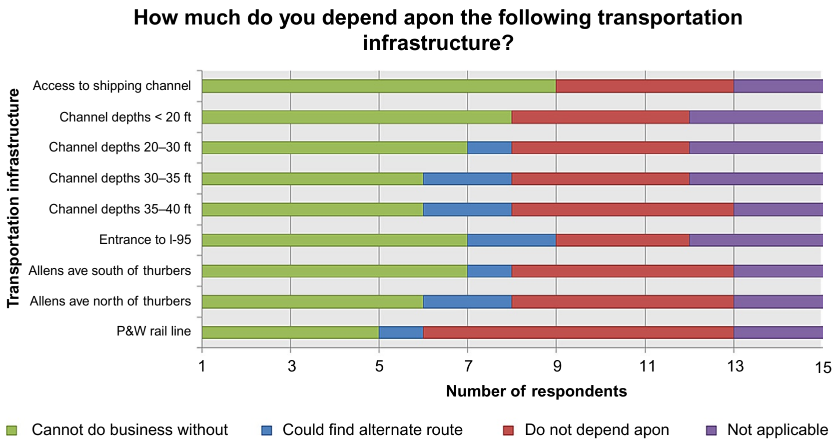

FIG. 1 This figure shows that 9 out of 15 businesses state that they could not do business without access to the 40-foot-deep shipping channel.

access to route I-95 and five the railroad line to move cargo into and out of the port area. Annual vessel calls per business range from 15 to 250 per year. At least one representative stated if the 40 ft channel were lowered (to 30 or 20 ft) business could be facilitated with smaller vessels, but at a higher cost to the business.

Storm preparedness can be measured by individual firm investments in physical reconfiguration at the business. Fig. 2 shows that many firms have backed up computer systems, installed emergency generators, and taken wind/flood proofing actions on site. Less common firms invest in raising electrical systems or moving to less flood-prone areas.

Planning by individual firms (Fig. 2) includes identifying offsite locations for equipment and cargoes, and developing hazardous material as well as business recovery plans. Only two firms have created structure stability analyses. Structural stability of piers must be maintained if cargo is to be handled after a storm. In addition firms have completed meetings, inundation maps, and prestorm contracting. In prestorm contracting waterfront businesses can identify debris removal and other needed activities in advance of the event.

Subsequent to the survey we completed a workshop to gain further insights on stakeholders that included businesses as well as government (Becker et al., 2017; Becker, 2017, see also www.portofprovidence resilience.org).

5 Discussion

All coastal ports are *vulnerable* to storm impacts because land/sea cargo transport almost always occurs at or just above sea level where storm surge, tide, and wave action can damage infrastructure. Since almost all cargo enters the port of Providence by ship or barge and leaves by truck, the viability of these land and sea arteries determines port function.

Unlike most other ports in the United States, the Providence does not have a central port authority that is responsible for operations and planning. Instead, the port includes a variety of private businesses, each responsible for its own sustainability efforts. Because the mandate for public port authorities typically includes prioritization of the local, state, or regional economy and the "public good" more generally, they may be more likely to invest in long range resilience planning (see, e.g., MassPort). The Port of Providence has grown considerably over the last century, with the expansion of Allens Avenue, the construction of the Interstate 95 highway, and landfill along the edges of the harbor to accommodate new maritime uses. Much of this infrastructure lies within the floodplain, but has not been tested by a major storm event since 1954.

When considering *resilient* infrastructure most generally, Husdon et al. (2012) focus on anticipation of the event like a hurricane that builds in ability to resist, absorb, and adapt while recovering rapidly. Actions of individual firms can build resilient ports, and we have assessed the extent to which individual firms had taken actions (Fig. 2). Since in 25% of the companies in a national

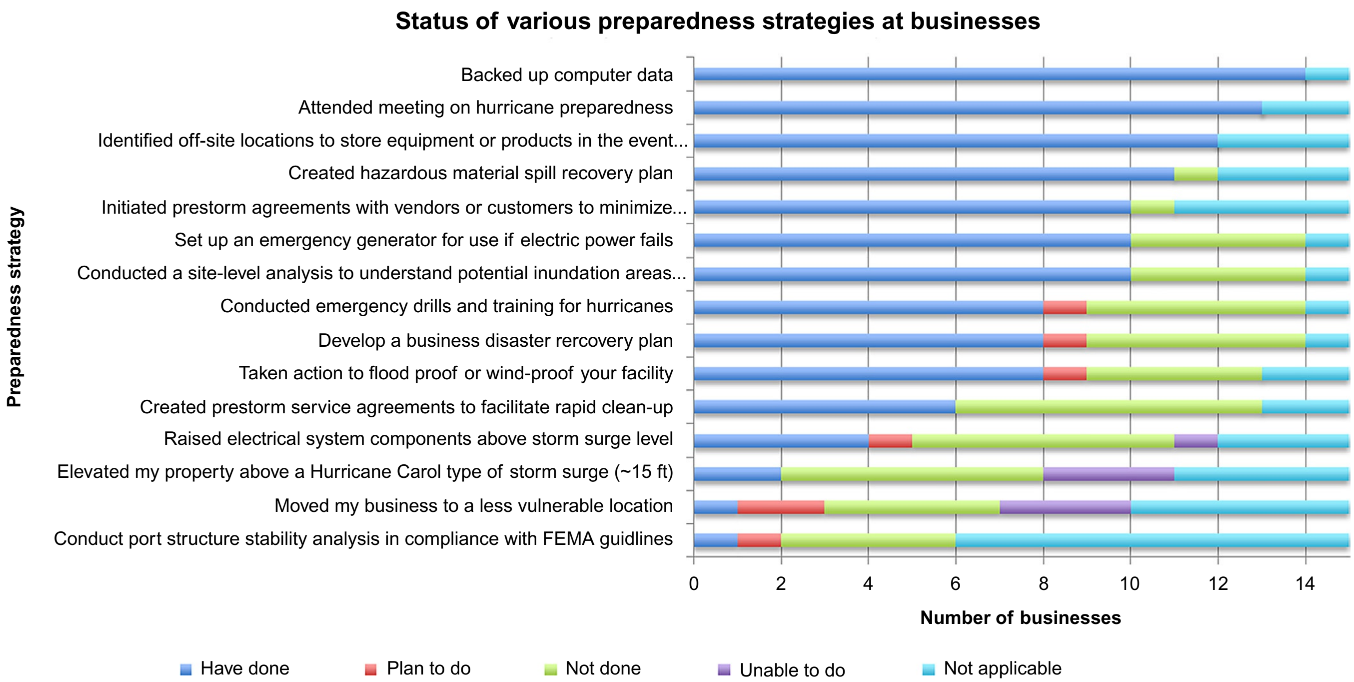

FIG. 2 Most business have backed up computer data, attended a meeting on hurricane preparedness, and identified an off-site location to store equipment or products; however, business has in general not created prestorm service agreements to facilitate rapid clean up and raised electrical systems above storm surge levels (~15 ft).

survey suffering an information technology outage of 2–6 days went bankrupt immediately (Husdon et al., 2012); this aspect of port businesses could be particularly important. Our early survey found that computer back-ups were nearly ubiquitous among the Providence respondents. This addresses an important part of information technology in our setting.

A *sustainable* port maintains system perturbations within tolerable limits such that long-term operations are assured. In the spirit of the Bruntland commission and focused on human systems, actions taken now would control storm impacts such that continued operations in the future would be feasible. An easily recognized objective is continued cargo flow, but allied to that are employment, community economic, and environmental health as well as continued effective linkage to global manufacturers and the port hinterland. Storms alone do not control sustainability as many other factors related to trade also intervene. Pressures include changes in values about waterfront use, altered lands due to changing sea level, shifts in cargo demands or technologies, and urban gentrification. For example the shift away from coal has reduced the volume of a formerly common cargo handled in Providence.

Resilient and sustainable in the context of ports implies for O'Keeffe et al. (2016) that scientific information is coupled with stakeholder involvement since effective adaptation measures will best be informed by tacit knowledge of port workers. However as they note, when ports engage in adaptation, it is often as a result of legislative or policy directives, which suggests that port managers are not convinced that bottom-up approaches should be encouraged. Our work was designed to alter this mindset by using visualization of storm impacts to bring inundation realities to individuals most directly connected to port operations and record their impressions as an entry point to informed responses and broad adoption of needed measures.

Visualizations can test both knowledge obtained and response to it (Lieske et al., 2014; Rickard et al., 2017), but we are most interested in results that cause collective action to reduce risk. One ultimate test of the effectiveness of a visualization is the extent to which individuals or groups are effectively informed and choose to constructively act to address the threat (Portman, 2014). Thus, testing individual responses to inundation of an urban area beyond the port can be instructive (Lindner et al., 2019). A combination of the ability to recognize individual flooded locations and for many direct experience with storms resulted in demographic groups varying between 46% and 62% higher likelihood of evacuation for a category 4 storm. Our sample, while directed toward port businesses, suggests high willingness to act: intention to implement individual preparedness strategies ranged from one to as many as 14 adopters out of a total of 15 businesses. While the buy-in for businesses is promising, much more remains to be done by individual firms and, most importantly, at the port-wide collaborative level. Without a robust organizational home for collective action, progress is expected to be slow until the next crisis.

As noted earlier, Providence does not have a port authority. This raises the question of the extent to which responding to storms is best considered as a collective action or a property owner/lessee individual action. Earlier work in Providence identified over 120 potential resilience strategies that could be implemented by various stakeholders of the port (Becker and Caldwell 2015). In fact, as Fig. 2 demonstrates, over one dozen individual actions have been taken by many Providence waterfront businesses. These individual actions could be taken by businesses in many US ports and to that extent the Providence case is broadly instructive.

However, protecting the port through the construction of a new storm barrier was found to be the best way to accomplish participants' resilience goals (Becker et al., 2017, Fig. 15). A new hurricane barrier seaward of the port could protect all port businesses. With protection clearly favored, implementation, in the eyes of the participants, rested on public-private collaboration or government initiatives (Becker et al., 2017, Fig. 18). Importantly, meeting individual goals requires collective action, especially when the costs are in the hundreds of millions of dollars. Thus while the need is identified for the Port of Providence, the organizational structure to accomplish it remains uncertain.

At local government level, both the Providence Harbor Management Committee and the Providence Emergency Management Agency could facilitate more resilience discussions. The former was recently created by the city to draft a new harbor management plan. The latter has recently completed a City of Providence Hazard Mitigation Plan update, which explicitly assesses hurricane readiness. Federal government through the US Army Corps of Engineers built the current Fox Point hurricane barrier and will be involved should another structure serving the community be created.

Missing from the Providence waterfront is a port authority, a common feature of large ports such as the Port of Seattle or Port of San Diego, CA. A port authority could become a strong advocate for a new more seaward barrier, if existing entities do not do so. The storm we have proposed and the responses to it make clear that a combination of collective and individual actions is appropriate. Port authorities can perform that function and other organizations can also.

At the base of this discussion is a consideration of the mix of collective (across firms, property owners, public entities) or individual actions to advance sustainability trajectories. To the extent that resilience preparedness is a function of individual action the Providence case applies to multiple settings around the United States where private entities are best positioned to make investments that matter. However, when collective action supported by government, such as the construction of a hurricane barrier is called for, a different organizational structure may be more appropriate.

6 Conclusions

This study represents a practical application of the terms vulnerability, resilience, and sustainability in port operations. While some aspects of maritime industry can be physically relocated out of the flood plain (e.g., tank farms can be located on elevated areas and product piped from the shorefront berth facility), we recognize that retreating from the shorefront is not a realistic option for most port activities. The inevitability of future maritime commerce in such vulnerable areas brings sustainability questions into clear focus here.

In our setting, impacts of hurricanes on port operations force firms and ports to respond before, during, and after the storm to assure sustainability. The context for urban port sustainability extends beyond business interruptions to include environmental impacts, gentrification of port area due to changing values, changes in cargo handling technology, and shifting port hinterlands among other influences, which are subjects for future research.

Sustainability trajectories (Kates et al., 2001; Burroughs 2012) require the assessment of multiple stakeholder actions in aggregate to determine whether a system is becoming more or less resilient over time. Applied to ports, trajectories enable one to assess the importance of actions taken in terms of the overall sustainability. In Providence individual firms have taken steps to become more sustainable in the face of hurricanes and need to take many additional actions. Missing, so far, is an institutional setting to assess and, where warranted, advance protection measures that could be taken for the port system. Further research will profitably engage both the appropriate designs for protective action and the collective will to make it happen.

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