6-3-2021

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Citation/Publisher Attribution

Mclean EL and Becker A (2021) Advancing Seaport Resilience to Natural Hazards Due to Climate Change: Strategies to Overcome Decision Making Barriers. *Front. Sustain.* 2:673630. doi: 10.3389/frsus.2021.673630

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frontiers in Sustainability

ORIGINAL RESEARCH
published: 23 June 2021
doi: 10.3389/frsus.2021.673630

Advancing Seaport Resilience to Natural Hazards Due to Climate Change: Strategies to Overcome Decision Making Barriers

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Climate change and extreme weather events put in peril the critical coastal infrastructure that is vital to economies, livelihoods, and sustainability. However, for a variety of reasons, decision makers often do not implement potential adaptation strategies to plan and adjust to climate and extreme weather events. To respond to the question of how seaport decision makers perceive strategies to overcome the barriers to adaptation we used semi-structured interviews of 30 seaport directors/managers, environmental specialists, and safety managers from 15 medium- and high-use ports of the U.S. North Atlantic. This paper contributes four broad strategies identified by seaport decision makers as necessary to help them advance on this challenge: funding, better planning or guidance, research and education, and advocacy/lobbying. We coded these strategies parallel to our partner paper that identified seven key barriers faced by the same set of decision makers. Results can help direct resources in ways targeted to the needs of seaport decision makers. The proposed framework contributes to theories of resilience building and barriers to decision making. Being strategic about change facilitates effective adaptation, decreasing risk, and enables continuity of safe, and sustainable, operations of U.S. seaports in the face of climate and extreme weather events.

Keywords: resilience, climate change adaptation, natural hazards, decision making, seaports

OPEN ACCESS

Edited by:
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Reviewed by:
Peggy Chen,
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Specialty section:
This article was submitted to Sustainable Organizations, a section of the journal Frontiers in Sustainability

Received: *28 February 2021*
Accepted: *03 May 2021*
Published: *23 June 2021*

Citation:
Mclean EL and Becker A (2021) Advancing Seaport Resilience to Natural Hazards Due to Climate Change: Strategies to Overcome Decision Making Barriers. Front. Sustain. 2:673630. doi: 10.3389/frsus.2021.673630

INTRODUCTION

Seaports face increasing risk from climatic changes that will result in sea level rise and increased frequency and intensity of storm events (Izaguirre et al., 2020). Seaport infrastructure plays a key role in global and national economies, as it enables the transfer of goods (Bookman, 1996; Fusco, 2013). Disruption to seaport operations can result in significant losses at the local and national scales (Zhang and Lam, 2015), as well as damage to seaport infrastructure and working areas (Takagi and Esteban, 2013; Esteban et al., 2017; Jiang et al., 2020). Seaport decision makers will need to prepare for issues associated with extreme weather and chronic flooding from sea level rise (Hallegatte et al., 2011).

Although, planning for adaptation is more prevalent today than a decade ago (Jiang et al., 2020; O'Keeffe et al., 2020), overall, the implementation of adaptation measures in coastal communities is still scarce (O'Keeffe et al., 2020; Roozbeh et al., 2020; Wilbanks et al., 2020). In 2010, the National Resilience Center, noted that effective adaptations for climate change will require all

types of decision makers and stakeholders to participate (National Research Council, 2010). Through the selection and implementation of adaptation strategies, seaport operators play a key role in resilience building (Becker and Caldwell, 2015) to reduce vulnerability to extreme weather and climate events (Nicholls et al., 2008; Esteban et al., 2020; United Nations Conference on Trade Development (UNCTAD), 2020). Many studies on climate adaptation have focused on the development of frameworks to identify barriers to implementing resilience measures (Moser and Ekstrom, 2010; Ekstrom and Moser, 2014), on reviewing methods used to describe the nature of climate change barriers (Biesbroek et al., 2013; Eisenack et al., 2014), or explaining stakeholders awareness of climate adaptation (O'Keeffe et al., 2020). This study takes an empirical approach to identify decision makers' perceptions around strategies to help them overcome the barriers to making resilience investments at their seaports.

The paper begins with a review of the pertinent literature on resilience barriers and resilience building in the seaport context. Next, the Methods section outlines the sampling and data collection and analysis approach. In the Results and Discussion section, the main findings are outlined, including the four broad strategic approaches to overcoming decision barriers for resilience investments. Finally, the main Implications for policy and practice are addressed.

LITERATURE REVIEW

The Intergovernmental Panel on Climate Change (IPCC) defines resilience as: "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation" (IPCC, 2014; pg. 40). Resilience building is difficult due to barriers that obstruct plans and processes (Moser and Ekstrom, 2010; Biesbroek et al., 2011). We define barriers as "… obstacles that can be overcome with concerted effort, creative management, change of thinking, and the related shift in resources, land uses, institutions, etc." (Moser and Ekstrom, 2010, p. 22027). Barriers hinder decision makers from moving forward on resilience enhancement actions. In this study, we distinguish a "limit" from and a "barrier," in that a barrier can be overcome, while a limit is seen as an unsurmountable obstacle (Hulme et al., 2007; Moser and Ekstrom, 2010; Dow et al., 2013). Earlier studies suggest many barriers challenge seaport infrastructure managers when it comes to resilience building (Becker and Caldwell, 2015; Kretsch, 2016; Ng et al., 2018; Mclean and Becker, 2020). In 2020, Mclean and Becker identified seven key barriers to planning for resilience building, these include:

1. Lack of understanding of the risks. This is explained by a lack of awareness of the risks or confusion over the level of risk. Decision makers find it difficult to predict an impact or do not understand associated consequences.
2. Lack of funding. This was described as a major obstacle given the high cost of adaptation.
3. Perceived levels of risks do not exceed the action threshold. Under this premise, awareness of the potential risks exists but it does not exceed a magnitude or intensity to prompt an action.
4. Physical constraints at the seaport. Because some seaport facilities are under-designed for present and future conditions, the implementation of climate change adaptations is challenged by the growth and development of other sectors on or near the coast. The ability to expand is reduced, restricting the seaport's aging infrastructure to their current locations.
5. Governance disconnects. This is explained by a lack of direction from above; the lack of clarity over who pays for resilience, and who maintains or controls the resilience of infrastructures. Respondents raised concerns that even when rebuilding after a disaster, the federal aid received through the U.S. Federal Emergency Management Agency (FEMA)[1] limits how seaports can spend funding to enhance resilience.
6. Lack of communication. Adapting and planning for resilience requires that staff and stakeholders are well-informed about adaptation strategies.
7. The problem of adaptation is overwhelming. Some find that the enormity of the climate change problem is overwhelming to the point of causing decision paralysis.

Resilience building requires decision makers to overcome these barriers in order to reduce risk (Kates et al., 2012; Esteban et al., 2020) by implementing "resilience enhancement options" (Wang and Zhang, 2018; Dong et al., 2020). For coastal infrastructure, this might include elevating piers and facilities, designing for submersion, or, in some cases, abandoning infrastructure entirely (Becker et al., 2013).

Although this study does not seek to identify such "resilience building strategies" *per se*, the topic warrants discussion in the context of the empirical research undertaken herein. Approaches to reducing natural hazards risk are well-documented in other studies (Chhetri et al., 2014; Jiang et al., 2020; O'Keeffe et al., 2020). Becker and Caldwell found seaport stakeholder's strategies for resilience building clustered into seven categories: (1) building codes and land use regulations; (2) long-range planning; (3) construction and design strategies (on and off port lands); (4) private sector and insurance policies; (5) emergency preparations, response, and recovery; (6) research; and (7) networks and new ways of thinking. Some ports could benefit from the acquisition of adjacent lands and properties or the acquisition of insurance coverage (Becker and Caldwell, 2015). Policy approaches could include the development of vulnerability assessment plans or incorporating resilience goals into the standard operations and management programs. More and more, organizations such as seaports have been conducting vulnerability or resilience assessments in order to identify key areas that need improvement in the face of present and future conditions. Indeed, seaport adaptation measures can be a non-trivial investment of resources (Molino et al., 2020; Morris, 2020; O'Keeffe et al., 2020).

[1]This challenge regards the Federal Emergency Management Agency reconstruction regulations.

Different from previous work that looks at society's adaptive capacity to SLR (Hinkel, 2011; Huang, 2012; Chhetri et al., 2014) or stakeholders' perceptions of seaport's resilience strategies (Becker and Caldwell, 2015), this study investigated how decision makers perceive the strategies that can help them overcome the barriers that they themselves identified as preventing resilience building (Mclean and Becker, 2020). In this study, seaport adaptation addresses incremental climatic change from sea level rise (SLR), as well as increased frequency and intensity of extreme weather events. Strategy here is defined as an approach to overcome a decision-making barrier. Overcoming said barrier ideally leads to more resilient seaport operations.

METHODS

Data Collection and Analysis

In consultation with the U.S. Army Engineer Research and Development Center (ERDC), our research team invited all 22 medium- and high-use ports of the United States Army Corps of Engineers (USACE) North Atlantic Division (CENAD) (**Figure 1**) seaports on the North Atlantic Coast to participate in this study. These represent seaports with a varying degree of risk to SLR, floods, and/or major hurricanes. ERDC was interested in piloting seaport resilience and vulnerability assessment methods with high-use seaports (Rosati et al., 2015). By adding medium-use seaports and restricting the selection to the North Atlantic

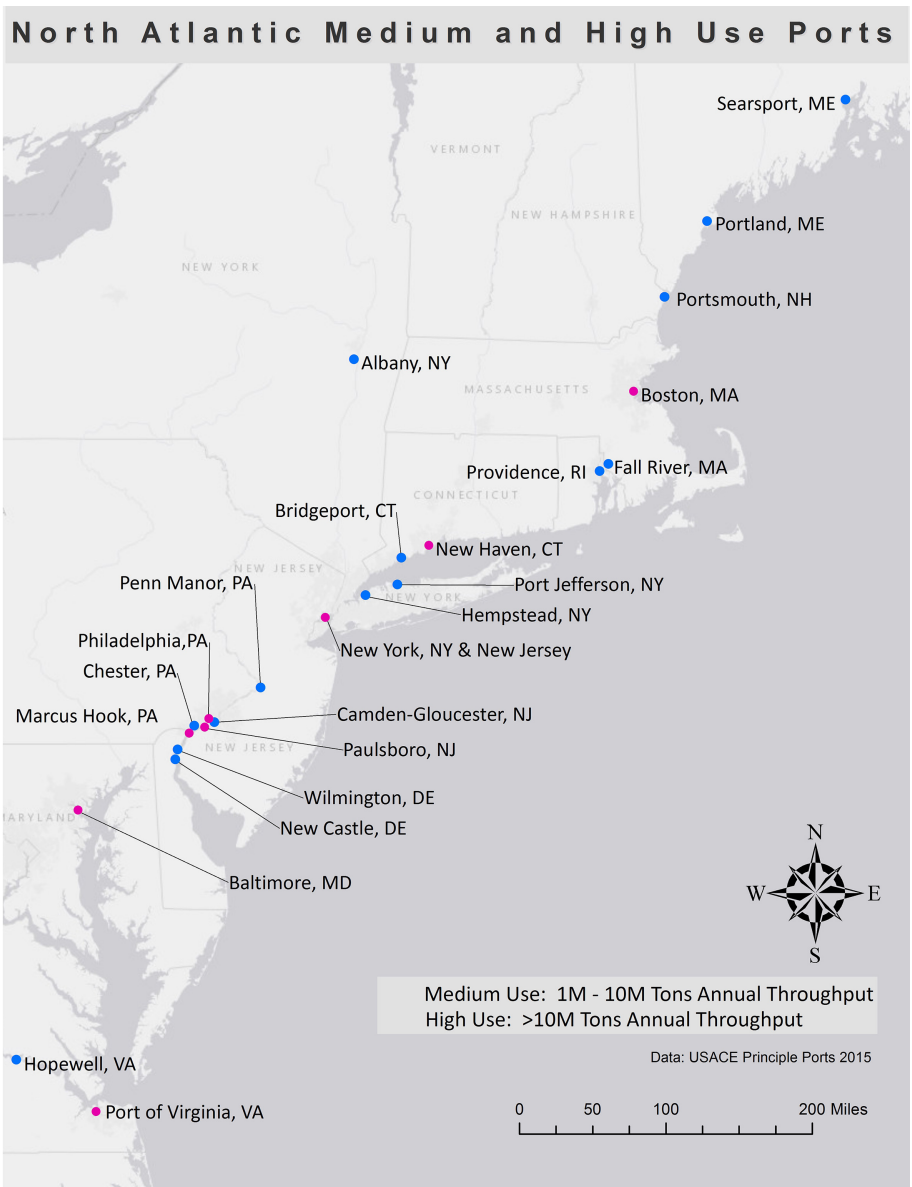

FIGURE 1 | The 22 medium-use (light blue dots) and high-use seaports (magenta dots).

TABLE 1 | Description of responsibilities of decision maker positions and number interviewed in each category.

Position (Number interviewed)	Example responsibilities
	• Run port operations and systems (short or long term)
Directors or managers (17) *Common titles:* - executive director - director of operations - project manager	• Perform maintenance of vessels and facilities Supervise employees • Manage specific functions of port facilities • Plan efficient use of port resources, with attention to security, safety, and health of personnel
Environmental specialists (8) *Common titles:* - marine environment and civil engineering consultant - manager of strategic planning - harbor master - environmental manager - project manager - climate mitigation and resilience manager	• Monitor related environmental regulations • Oversee environmental protection and other social responsibility functions
Safety managers (5) *Common titles:* - vice president of sustainability (consultant) - chief harbor safety strategist and operations assistant	• Monitor and assess hazardous and unsafe situations • Develop guidelines for personnel safety

TABLE 2 | Demographics representing the study's participating decision makers.

Number of ports invited to participate	22
Number of participating ports	15
Ports with port authority	9
Total participants interviewed	30
Types of decision makers	
Directors and managers	17
Safety managers	8
Environmental specialists	5
Years of experience	
<5	7
5–10	7
11–20	8
>20	8
Range of experience	1–46 (years)
Gender of decision makers	
Female	8/30
Male	22/30

region, researchers could create a manageable sample size. The proximity of these seaports to the University of Rhode Island allowed for site visits and interviews.

Of 22 invited seaports, 15 agreed to take part in the study. For each port, we invited the equivalent of three staff positions: seaport directors/managers, environmental specialists and safety managers who have the responsibility for decision making related not only to standard seaport operations, but also for climate and extreme weather resilience (**Table 1**). In sum, we interviewed 30 decision makers from across the 15 ports. We conducted interviews in person or over the phone and took around 1 h each; these were completed in accordance with Institutional Review Board protocols[2].

For five of the 15 seaports, we were able to interview all three types of decision maker (i.e., directors/manager, environmental specialist, and safety managers). For the remaining 10 seaports, one or two of the types of decision makers participated. In most areas of the U.S., harbor masters and the U.S. Coast Guard have additional responsibility for the safety planning of coastal infrastructure in a region. However, this study was limited to employees of the port authorities or port organizations who are charged with leadership and decision making within the studied ports (**Table 2**).

The semi-structured interviews captured barriers to climate and extreme weather adaptation (Mclean and Becker, 2020) and identified the strategies to overcome them, as described in this paper. Questions were open-ended, hence, the absence of a mention of a given strategy to remove barriers to adaptation does not mean that the seaport decision makers have not considered this, rather that other plans or actions were more palpable to the interviewee (Survey instrument is presented in **Supplementary Materials**).

Respondents were prompted to identify the barriers to resilience investments (Mclean and Becker, 2020) and the strategies to overcome these barriers. Both were coded using a grounded theory analysis approach (Charmaz, 2006; Glaser and Strauss, 2017) that allows for views and concepts to emerge and be grouped into unique themes or categories. After the transcription of the interviews, researchers coded the transcripts line-by-line using the NVivo qualitative data analysis software package (NVivo, 2014). Reviewing the transcripts, researchers identified and classified strategies for overcoming barriers independently, and resolved differences where necessary following the coding validation process laid out by Ekstrom and Moser (2014).

Each statement characterized as a potential plan or action that could reduce the constraints of an adaptation process, was coded as a strategy. Strategies were then clustered by theme. Note: if a decision maker mentioned more than a singular challenge, sometimes, he/she responded with more than one strategy. The results of interviews helped develop a framework of strategies for overcoming the barriers to implementing climate and extreme weather adaptation for these 15 ports.

[2]Interview protocol and procedures were approved by the Institute of Review Board at the University of Rhode Island (IRB Approved 894694-8). Interviewees were informed of the purpose of the study and that they give a written or oral consent to being interviewed and being recorded (for transcription purposes only).

The majority of interviews (73%, 22/30) were conducted in person, 27% were conducted over the phone, 10 of the seaports were visited.

RESULTS AND DISCUSSION

As detailed in our earlier publication (Mclean and Becker, 2020), the identified barriers to the implementation of climate change adaptations are the following seven: (1) governance disconnect, (2) lack of communication, (3) lack of funding, (4) lack of understanding of the risks, (5) perceived risks do not exceed action threshold, (6) physical constraints limits options, and (7) the problem is overwhelming. This section describes specific strategies to overcome these barriers and clusters them into one of four major categories that emerged from the grounded theory approach, as follows: (1) Funding (73% of respondents mentioned), (2) Better planning/guidance (27% of respondents mentioned), (3) Research and education (17% of respondents mentioned), and (4) Advocacy/lobbying (3.3% of respondents mentioned). We also include the instances when no strategy was mentioned (23%). **Figure 2** provides an overview of how respondents perceived the various strategies in relation to the barriers they identified in the same interview process (see also **Supplementary Materials**).

For context, we also probed interviewees about the perceived risks of climate change and the vulnerability of their seaports. Decision makers were asked what "seaport vulnerability to extreme weather impacts" meant to them, to which hazards their facilities were most vulnerable, and the ramifications of taking no action to build resilience. The respondents described the vulnerability of their seaports in terms of floods during a storm event (47%), or their facilities being vulnerable to storms (40%), surge/tidal flood (40%), high wind (27%), and/or sea level rise (SLR) (27%). In some cases, the respondents described the seaports vulnerability in terms of the costly outcomes of these events, such as increased coastal erosion, followed by the need for channel maintenance, or impaired critical seaport operations that delayed timely winter gas delivery (see **Supplementary Materials**). We note that a number of decision makers also mentioned short-term

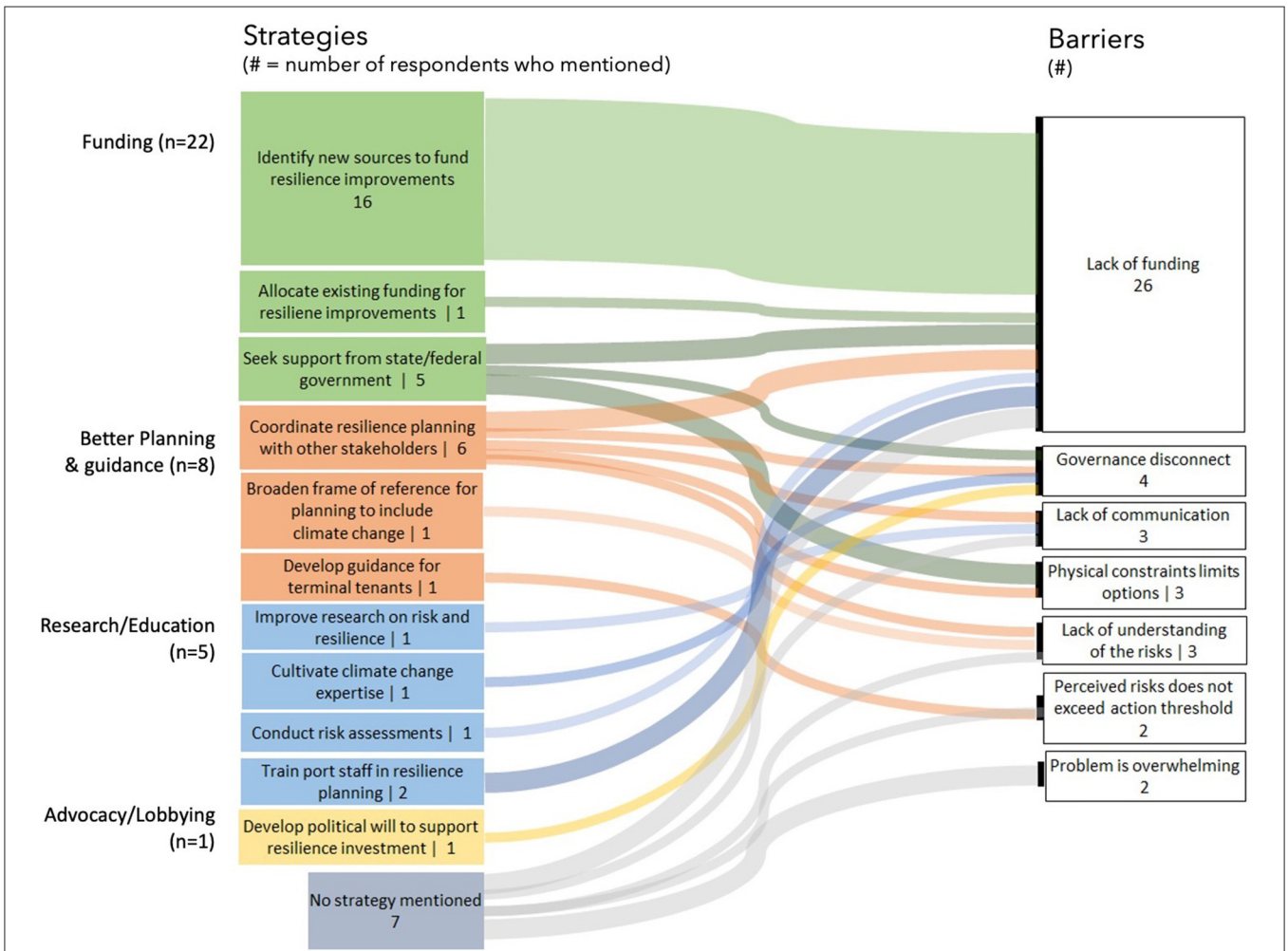

FIGURE 2 | Seven barriers connected to the identified distinct strategies: Funding (3) (green); Better Planning/guidance (3) (blue); Research/Education (4) (yellow); Advocacy and lobbying (1) (orange); No strategy mentioned (gray). The diagram shows how each of these strategy categories was discussed as a way to overcome the seven major barriers identified by interviews, depicted on the right.

actions that were already being implemented to increase the resilience of their seaports to natural hazards. These included implementing best management practices and updating seaport management plans to include risk assessments or putting in place a Risk Assessment of Critical Infrastructure document. Other short-term actions include implementing pier rehabilitation projects, raising the pier to FEMA standards (or above when resources are available), and conducting flood mitigation projects.

The description that follows consist of the four major strategy categories, and the sub-categories or context in which these are mentioned as ways to overcome the seven major barriers identified in earlier work.

Strategy 1 - Funding-Related Strategies

One of the most commonly cited barriers to resilience building is "Lack of funding." Efforts to implement climate adaptation, or to reduce the impacts of hazards will require planning and investment of limited resources. Sustaining seaport operations and staying competitive also requires upgrades and maintenance. Here, we discuss a variety of funding-related strategies mentioned to overcome the barriers noted in our earlier publication (**Figure 3**). The need for financial capital or financial incentives was stated by 20/30 respondents as a key strategy to overcome barriers to implementing resilience initiatives. Three sub-categories were clustered within this strategy, as follows: (1) Identify new sources to fund resilience improvements, (2) Allocate existing funding for resilience improvements, and (3) Seek support from state/federal government. Funding was mentioned as a strategy to overcome "Lack of funding," of course, but also mentioned as a way to help overcome governance disconnects and even the physical constraints that may limit the types of resilience investments that respondents considered feasible.

Identify New Sources to Fund Resilience Improvements

Seaport directors talked about the importance of acquiring more capital resources or funds for investment in the terminals. Notably, this strategy was mentioned only as a way to overcome the "Lack of funding" barrier. They foresee that, for older terminals, the seaports have to be prepared to disrupt service to their customers when upgrades and construction begins. One director expressed his concern in the context of not being able to compete with other seaports due to the lack of resources:

> "… money is the main constraint to do anything in a state facility. We can't necessarily compete with some of the private companies, or private terminals, because of their equipment [etc.], everything is just always a challenge to be cutting edge because of that." (DIR26)

The need to identify new sources of funding, as a strategy, is a generic (and perhaps less than constructive) strategy. While there is no doubt that funding is needed to carry out most, if not all, resilience projects, identifying this as a need is not as useful as identifying specific funding-related strategies noted below. Nevertheless, it is noteworthy that 16 of 30 respondents stated that the way to overcome barriers was to identify new funding sources.

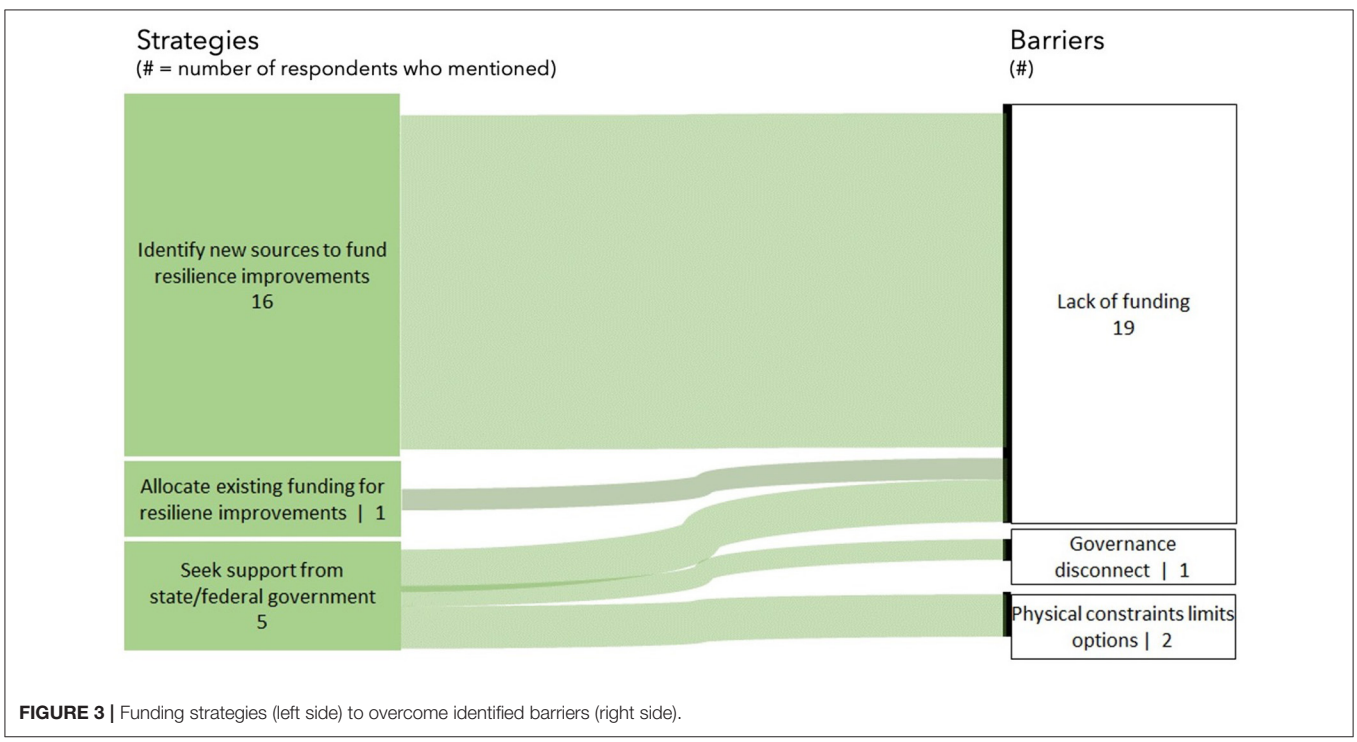

FIGURE 3 | Funding strategies (left side) to overcome identified barriers (right side).

Allocate Existing Funding for Resilience Improvements

Though most respondents spoke of the need to find additional funding, two did acknowledge that efforts could be made to reallocate existing funding to enhance resilience. This strategy was mentioned as a way to overcome the general "Lack of funding" barrier. One noted that capital was typically invested into standard upgrades and maintenance, as opposed to increasing the current level of resilience. One director said:

> "[One] has a fixed pool of resources [and] how you apply those resources represents the biggest challenge to finding the ways to make the seaport more resilient to extreme weather." (DIR17)

Others acknowledged that resources were also essential for the research that would support and determine the need for the seaports' adaptation. Furthermore, one safety manager said that even after finances were secured, justifying the adaptation investment required political will. "You have to almost lobby for it," he said.

> "The primary challenges are fiscal and monetary, in securing the funding at being able to allocate the funding for those things... you'll see as facilities are renovated, or new facilities are constructed that they will factor in SLR. And they have been doing that for quite some time." (SM13)

One respondent emphasized that by allocating existing funds to build up the resilience, the seaport would be better prepared for SLR and climate change. These measures would also ensure that future operations that facilitate trade and relief materials are not interrupted. Examples of resilient improvements include:

> "Raising the short cranes higher than the originally planned [so] that if SLR does continue at the rates that are predicted by some of the models, we should be protected long-term." (ENV22).

Seek Support From State/Federal Government

The political nature of local government means that all decisions, including climate adaptation, are affected by political interests and competing preferences vying for support at the municipal scales (Keen et al., 2006). Hence, for many decision makers the ability to address resilience begins with a fundamental need for local or state government support. This strategy was noted by five respondents as a way to overcome all the major funding-related barriers. They acknowledge that to succeed in their seaport resilience projects, their state funds need to be matched by federal funding. It can be also easier to persuade seaport tenants and other stakeholders that adaptation is worthwhile with financial incentives for adaption(s). Incentives can come from grants or federal or state government agencies. As one respondent stated:

> "The only way that we have been able to achieve [an adaptation] is through getting funding through the 'federal government'." (DIR18)

Since seaport infrastructure supports local and regional economies, public funding is often used to maintain and update critical infrastructure. Planning can make a difference when pursuing government aid. Decision makers sometimes wait many years to see their projects materialize because of insufficient funds. One noted that:

> "All is on who decides to pull the strings on any given time where they are going to push the money... Decisionmakers wait and see what the new mid-term will bring." (SM16).

Strategy 2—Better Planning/Guidance

In order to anticipate and prepare for potential impacts, decision makers need to consider information at hand, to examine and prioritize some measures of response. The need for better planning and/or guidance was recorded for 8/30 of the respondents as a key strategy. Four sub-categories were clustered within this broader strategy, as follows: (1) Coordinate resilience building with other stakeholders, (2) Broaden frame of reference for planning to include climate change and (3) Develop guidance for terminal tenants (**Figure 4**).

Coordinate Resilience Building With Other Stakeholders

Many stakeholders are impacted by an interruption in seaport operations, including tenants, clients, seaport operators, and private companies. Social scientists highlight the importance of collaborations in promoting strategic thinking, resourcefulness and effective communication (Moser and Ekstrom, 2010). According to six respondents, stakeholder collaboration can help reduce risk to the system as a whole in order to overcome many of the barriers they face to resilience enhancement. In the context of responding to storms and natural hazards due to climate change, seaports collaborate with state emergency response and management entities, federal emergency management agencies, the U.S. Coast Guard, the Department of Transportation, as well as the Department of Homeland Security. Respondents mentioned that they benefit from these collaborations both in terms of emergency response and longer-term planning for infrastructure improvements, as stated by one of the environmental specialists:

> "We will participate with anybody who wants to do anything on the climate resilience topic. We have participated with the Department of Homeland Security on critical infrastructures assessment, and I think that that helped us understand our own infrastructure better." (ENV30)

Respondents also noted that public/private partnerships help them contribute to the sustainability of other stakeholders outside of the seaport itself. One stated:

> "One of the things that we are doing in our pier rehabilitation project, because we have an aquaculture facility just to the north of our pier, we are working with the owners of an aquaculture farm to relocate them—at our expense—to make sure that they can continue to harvest clams … and keep their business alive and keep people working so that there is no harm to the environment. Then we will move them back [when we finish our construction project]." (DIR1).

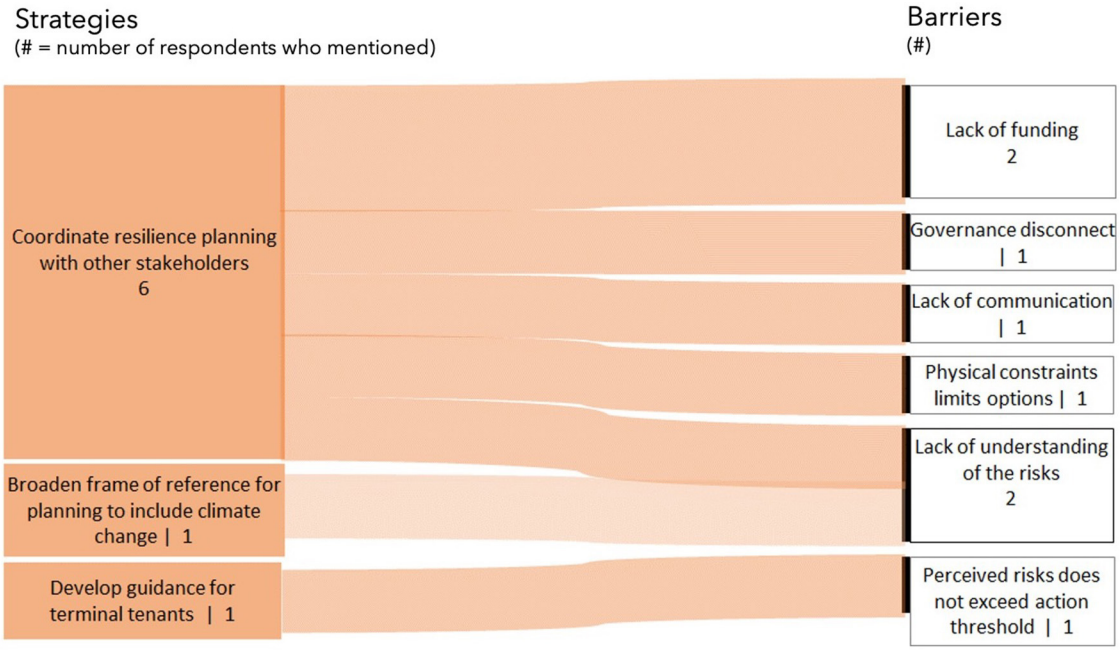

FIGURE 4 | Better planning and guidance strategies (left side) to overcome identified barriers (right side).

Broaden Frame of Reference for Planning to Include Climate Change

Although this study was not focused explicitly on climate change, many respondents mentioned this challenge when speaking more broadly about natural hazards resilience. Only one, however, explicitly mentioned the need to broaden the frame of reference for planning to include climate change. This need for climate change specific planning emerged in the context of more general planning needs for both emergency response and long-term resilience efforts. Here, the respondent said that the seaport should consider climate impacts to their own property, but also for the adjacent transportation network. From their experience, even when the seaport itself can bounce back and operate after a severe storm—seaport operations remain disrupted when the rail and/or the roads are flooded.

Develop Guidance for Terminal Tenants

Some seaports had already established internal resilience policy guidelines, but the guidance did not necessarily extend to their tenants. Often, upgrades and betterment of the seaport facilities occur when a terminal or facility transitions from an (old) tenant to a (new) tenant. One director mentioned in order to persuade tenants to take actions (even if the risk did not exceed their perception of a threshold for such action), the seaport as a landlord should provide better guidelines. He said:

> "Financial incentive is always an easy driver for a lot of the tenants and people within agencies... to convince them that [adaptation measures] are worthwhile... tenants come to us requesting what guidelines they should follow since they are working and operating on our facilities... I have prescribed to them that they discuss [with their insurance provider] whatever requirements are pertinent... a lot of times the cost saving can be dramatic, even just by going up... half a foot more in elevation." (DIR23).

Strategy 3—Research and Education

Five respondents mentioned strategies that fall into the broad category of "Research and education." These four strategies were suggested to overcome the barriers of "Lack of funding," Governance disconnects," and "Lack of communication" (**Figure 5**). To solve for the challenges of government disconnect, the lack of communication and/or the lack of funding, respondents drew connections between "better guidance" and "research and education" strategies to solve for these challenges. When seaport stakeholders establish collaborations, they gain opportunities that facilitate and promote knowledge transfer. For instance, collaborations with the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Services and other agencies, provide real time local weather data, or modeled projections that increase seaport decision makers' ability to predict in advance and prepare for a given weather condition.

Four sub-categories were clustered within this strategy, as follows: (1) Improve research on risk and resilience, (2) Cultivate climate change expertise, (3) Conduct risk assessment, and (4) Train and educate seaport staff. These included four environmental specialists and one seaport director.

Improve Research on Risk and Resilience

There are many ways to advance the knowledge and understanding of risks to grow the seaports resilience. One

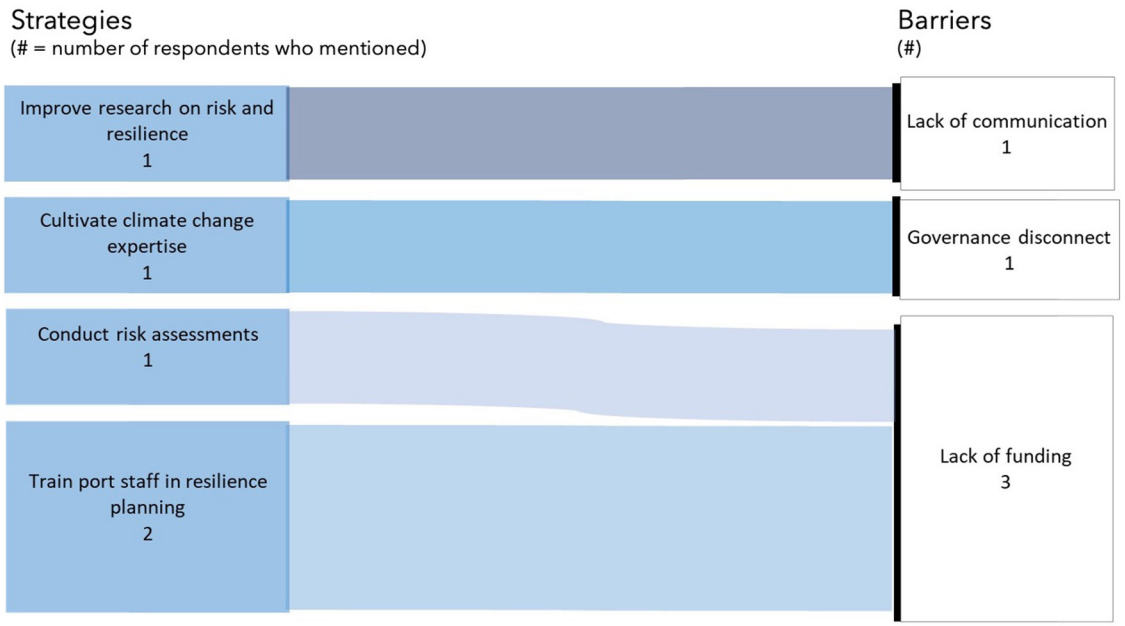

FIGURE 5 | Research and education strategies (left side) to overcome identified barriers (right side).

environmental specialist indicated that the city where the seaport is located was trying to tap into research resources, so that they could make progress in benchmarking their facility and bringing it up to standards. This strategy was noted as a way to improve communications. The seaport was described as a resource for the state, and as an actor that could muster appropriate intellectual resources needed to address climate and extreme weather events.

Cultivate Climate Change Expertise

Today progress is being made in seaports and research institutions that are studying climate change and its impacts. Closely related to the other subcategories mentioned, seaport stakeholders cultivate climate change expertise by increasing their awareness of risks and improving their capacity to respond. In one of the seaports, the emergency response is orchestrated through a marine instant response team that coordinates different sides of seaport operations and seaport safety personnel, connecting with agencies both outside and inside of the seaport. This was seen as a way to improve knowledge, but also as a way to overcome governance disconnects.

> "We are a team of folks, and we have a marine instant response team on the terminal that coordinates with our safety folks and operations folks. I get involved from time to time as well. Our development coordinator gets involved... Basically, you have some representatives there from each terminal, representing each department for the most part. Then they coordinate with outside entities like the USCG or the Department of Emergency Management (DEM) at the state level." (ENV12).

Conduct Risk Assessments

This strategy includes documenting and acknowledging the risk factors at a seaport—a fundamental step in understanding the vulnerability of a seaport and its facilities and subsequently identifying funding to support resilience investments. Decision makers that had experienced Hurricane Sandy in 2012 highlighted the importance of the lessons learned, the and the need to not only focus on similar impacts they had experienced, but to undertake a more holistic risk assessment. Participants discussed concepts from engineering perspectives and highlighted the need for more data to run risk models and cost-benefit analysis. They also discussed a three-prong approach which includes: (1) relocate non-essential activity out of the flood plain, (2) if that was not possible, elevate structures and sensitive infrastructure two feet above the 100-year flood plain for their basin, and (3) if that is not possible, then make sure that moving forward, new upgrades were better, and used non-corrosive, stronger materials that can hold up to extreme weather.

From different experiences, they understood that even new equipment would be challenging, or could potentially fail when stressed beyond a threshold, as expressed by a seaport director:

> "… [We will need to] procure equipment that is modified to have the brains - the electronics– higher up on the equipment than it would normally be, which makes it more expensive and sometimes, more difficult to maintain. It might also take more space." (DIR11).

Train and Educate Seaport Staff in Resilience Building

Training and educational opportunities help stakeholders understand the risk and be better prepared for a storm or extreme weather event. Decision makers understand that having access to more information and developing multiple approaches to serve a variety of audiences is of great benefit to them, as stated by one of the environmental specialists:

> "The potential for impact has been presented to leaders in the city's staff, and we now have a better idea of how to talk about adaptation... Taking a three-pronged approach at a concept level, we now have a better understanding of the engineering and what we need to do; we have a better understanding of what the impacts will be, and we are more conversant in the process." (ENV30).

Strategy 4—Advocacy/Lobbying

Although this strategy was only mentioned by one safety manager in response to the challenge of "governance disconnect," there is connection between strategy one of "funding" and the need for seaport decision makers to prioritize already limited resources **Figure 6**. Hence, seaports would benefit from resilience advocacy, or lobbying state representatives and public official at the governance level for funds that ensure and support advances in resilience investments. This strategy was framed in the context of the need for political will.

Develop Political Will to Support Resilience Investment

This strategy calls for political interest in creating or enforcing the legal frameworks that would support or pressure seaport decision makers to adapt seaports to climate and extreme weather events. The difficulty that seaport decision makers face is described by a safety manager in the following words:

> "If we get the finances, we have to play politics to get the finances. It is not just 'put together a performance to support and justify what you are doing [to make the seaport more resilient] and then the funding comes,' there is more to it than that. You got to almost lobby for it". (SM26)

Lastly, there were instances when a barrier to adaptation was described, but no strategy to overcome the barrier was mentioned. This was true for lack of communication, lack of understanding of the risks, perceived risks do not meet the action threshold, and the problem of adaptation is overwhelming. As noted by the assessment of the barrier, having a strategy to solve for the problem, required that the decision makers understood the problem (or the risk) in the first place (**Figure 2**).

IMPLICATIONS

The motivation behind this study began with the need to better understand the "adaptive capacity" to climate and extreme weather events for medium- and high-use seaports in North Atlantic. Our earlier study identified "seaport vulnerability indicators" in order to inform metrics for seaport resilience (McIntosh et al., 2019). In that study, vulnerability consists of three key components: exposure, sensitivity, and adaptive capacity. Adaptive capacity refers to features of a system that enable it to "modify or change its characteristics or behavior so as to cope better with existing or emerging external stresses" (Adger and Agnew, 2004, p. 34). This proved to be exceptionally difficult to measure, leading us to explore the barriers to adaptive capacity and climate and extreme weather adaptation (Mclean and Becker, 2020). Subsequently, once a core set of barriers were identified, the question of "how do we overcome these barriers?" followed. This study builds on this body of previous work (Mclean and Becker, 2020) and provides a framework, based on empirical data from interviews at 15 ports, that outlines how seaport decision makers perceive strategies that could help them overcome these barriers.

This study found four broad categories of strategies, as follows: funding, better planning or guidance, research and education, and advocacy/lobbying. In practical terms, these strategies can be used to help target capacity-building activities,

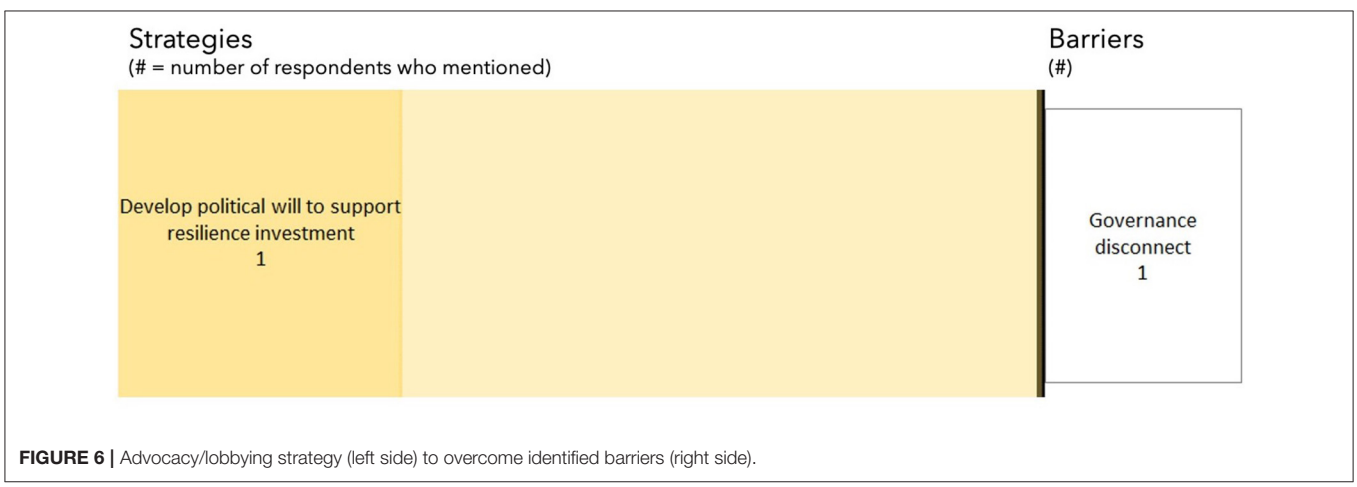

FIGURE 6 | Advocacy/lobbying strategy (left side) to overcome identified barriers (right side).

such as for the USACE or other government agencies that play a role in protecting public welfare and the economy. In the U.S. and elsewhere, attention to resilience needs has been growing. For example, the USACE and the Department of Homeland Security are collaborating to produce a *Resilience Assessment Guide for Ports and the Maritime Transportation System*, slated for release in late 2021. The international waterways organization, PIANC, published a *Climate Change Adaptation Planning for Ports and Inland Waterways* guide in 2020 [The World Association for Waterborne Transport Infrastructure (PIANC), 2020]. Many of these efforts focus on specific best practices for either conducting an assessment or specific recommendations for resilience building. Less attention, however, has been given to the challenges decision makers face to simply get resilience onto their organizational agenda. This has been the focus of the current work and some of the key implications of these for policy and practice are discussed in this section.

Identifying and Allocating Funding Is Key to Overcoming Nearly All Identified Barriers

As expected, funding was identified as a key barrier and a "identifying new funding streams" as a key strategy for overcoming that barrier. This may be considered a bit simplistic, as the reasons for a lack of funding for resilience are nuanced and more germane than the stated problem of, "we have no money, therefore we need to find more money." Resilience enhancements can be expensive and hard to justify, as the benefit of "damage avoided" can be hard to quantify. A lack of resources can be a significant barrier to climate adaptation (Füssel, 2007), but the problem may lie in a governance void (Hajer, 2003), the absence of leadership (Kretsch, 2016; Ng et al., 2016; Becker and Kretsch, 2019), or the lack of will to invest (Barnett et al., 2013). Delay in adaptations can also be political when elected officials avoid adaptation due to their high costs (Vine, 2012). However, seaports need to keep their competitive edge –looking into the future, the investments of today depended on the investments of the past (Crabbé and Robin, 2006; Hallegatte, 2009; Pechan, 2014). Seaports need to understand that financial constraints can become more of a burden over time as they address shortages in budgets and other priorities (Ekstrom and Moser, 2014). Furthermore, the problem may lie in the allocation of resources, as opposed to a simple lack thereof. In other words, if resilience building was a real priority, it would take the place of other important investments. Thus, the challenge for future researchers and practitioners is to tease this problem apart in order to determine why resilience is not a higher priority, how to raise its importance (if warranted), and then how new monies may be found or existing monies reallocated. Many of the strategies identified in this study can contribute to this goal and respondents mentioned ideas in all four of the major strategy areas of funding, better planning or guidance, research and education, and advocacy/lobbying. Better planning and guidance can lead to an easier path for investments. Through research and education initiatives, decision makers can learn to maximize future investments and become aware of best available data to support informed decisions. Finally, advocacy and lobbying can identify or allocate government funding to support such investments at the seaport level.

Leadership and Social Frameworks Are Important for Laying the Groundwork for Seaport Resilience

Consistent with other studies, respondents in the study noted that resilience building benefits from stakeholder engagement and participation (Wilbanks and Kates, 1999; Eakin and Luers, 2006). In particular, *Strategy 2 – Better planning/guidance* emphasizes the value of collaborative approaches to facilitate and support needed adaptation strategies at the state and national levels (Mukheibir et al., 2013; O'Keeffe et al., 2020). Collaborations underscore the necessity to share resources, time investments, and expertise (Zambrano-Barragán et al., 2010). Without doubt, strong public engagement can bring stakeholders to the forefront. Such involvement in participatory forums and programs is key to early identifying local concerns. Participatory processes strengthen the social and political base for effective implementation of policies and decisions that consider general priorities of all, the short-term, long-term responses and tradeoffs of the decision-making processes (Zambrano-Barragán et al., 2010; Wachsmuth, 2014).

Strategy 3, Research and education – is intertwined with fostering collaborations and partnerships, as it can bring to the table numerous opportunities to leverage technology and innovation, as well as the use of existing tools. Studies acknowledge that local politics often dictates decisions, including climate adaptation, and competing preferences vie for support at the municipal scale (Keen et al., 2006). An inspired leadership, Burch writes, could significantly change the context of decision-making by establishing innovative governance models (Burch, 2010). An increase in the institutional capacity can pave the way for planning strategically. Addressing concerns and infrastructure vulnerabilities on a regular basis can make the problem of climate and extreme weather impacts less overwhelming. This requires both leadership and a stakeholder group that has a common understanding of the risks and the role that individual entities play in resilience enhancements. When decision-makers count on reliable forecasting data their incentive for adaptation is greater. In a study by Wang and Zhang, they found that a *higher expectation* of a natural disaster *occurrence probability* encouraged ports to implement adaptation, but a *high variance of the disaster occurrence*, actually discouraged adaptations. A second incentive that resulted in more adaptation was described as an inter-port competition effect, when within a port there is free riding on adaptations between the port authority and the terminal operators (2018). This is also in agreement with Zambrano-Barragán et al., who emphasized that strategies that include the development of flexible social institutional frameworks as a basis for decision making are key to addressing barriers to adaptation (2010). Hence, improving decision making processes, and institutional capacity in the seaports can promote the advancement of informed decision-making and further

the development of climate change adaptation guidelines that manage risks more proactively (Scott et al., 2013). More work is needed to integrate a larger number of seaport stakeholders in the conversation, to make clear connections not only on what the barriers are but also on who has the responsibility to remove them (Biesbroek et al., 2013; Morris, 2020). Efforts should expand to understand risk both at the seaport and their neighboring communities.

Understanding Decision Makers Perceptions Can Help to Develop Appropriate Education and Capacity Building Approaches

Understanding perceptions that link the barrier to adaptation (the problem), with the strategy to overcome the barrier (the solution) advances seaport resilience by outlining a pathway to addressing vulnerabilities. We could hypothesize that (1) by responding with a constructive strategy to overcome adaptation barriers, stakeholders in that seaport are actively thinking about the seaport's resilience, or that (2) by presenting coherent responses across all decision makers in a port, this could be interpreted as an indicator that decision makers are communicating and planning in a strategic manner. Alternatively, responses that are less than constructive, such as "we lack funding and we do not know how to address this," or no responses to "the problem is overwhelming," and/or "a lack of understanding of the risk"; these could signal that there is a need to educate and inform seaport stakeholders how they can advance seaport resilience. Some respondents had no clear ideas for overcoming many of the barriers they identified. For example, overcoming a lack of funding and or the overwhelming nature of the problem were two barriers for which respondents offered few strategies. This could signal a deficit in decision making or simply an opportunity for targeted education and capacity building. In some cases, reactive mitigation, rather than a planned response strategy (to a storm, etc.) becomes the dominant adaptation strategy (Measham et al., 2011). This leaves coastal communities at risk and threatens the stability of their economy, environment, and human safety.

LIMITATIONS

This study has several limitations that are worth noting. First, the sample size of 15 ports is small, as is the total number of respondents (30). Seaports, of course, are all very different from one another and generalizing about seaports or port decision makers can be difficult. As the saying goes, "if you've seen one seaport, you've seen one seaport." Our results are limited in the number of environmental specialists and safety officers, as these types of decision makers are often the ones "on the ground" implementing resilience building and investments. We had uneven participation given availability, but also some respondents were cautious about sharing data that could expose their vulnerabilities to their competitors. Future studies could help develop an outlook of the challenges and resources specific to each decision maker category, in order to help them implement adaptation strategies at the different levels in which they operate. Some stakeholders had experienced extreme weather events at their seaports and understood the implications of climate change, while others had not. Respondents from seaports in the northern part of the study areas were more concerned with Nor'easters, as opposed to hurricanes. We also recognize that our line of questioning may have been pushing respondents to consider topics that they had not considered before. We asked them not only to identify the challenges to resilience building, but also the ways they might overcome these challenges. Without sufficient background, this exercise may have been difficult for some respondents who tend to be much more focused on other, shorter term, priorities. Nevertheless, an actor-centered approach can help researchers understand how barriers can be overcome (Eisenack et al., 2014; Jiang et al., 2020) by understanding the decision makers own perceptions of where they may need assistance.

CONCLUSION

This study presents seaport decision makers' perception of strategies to overcome barriers to climate and extreme weather adaptations at the seaport level. Participating decision makers from 15 high- and medium-use seaports in the North Atlantic shared the challenges that prevent and delay their efforts to implement climate change and extreme weather adaptations in the face of increasing risk. The three groups representing directors and managers, environmental specialists, and safety planners reflected on strategies that could help them overcome the identified barriers. The results presented in this research, is representative of a wide range of seaports, some that have experienced extreme storms, or Nor'easters, and some that have not. Responses on climate and extreme weather adaptation barriers and strategies need to consider the location and geographical conditions as relates to the natural hazards that seaports are experiencing. We believe that an approach that engages decision makers on the issues related to barriers, strategies, what are potential solutions, or consequences of inaction is important to influence gradual changes toward more proactive actions. An integrated approach that observes differences across varying seaport actors (decision makers), is useful to improve understanding of knowledge and perceptions leading toward better capacity building efforts that address management, environmental, and safety concerns together. This in-depth understanding of strategies can help seaport stakeholders and decision makers in the development and implementation of adaptation efforts that increase the resilience of their seaports.

DATA AVAILABILITY STATEMENT

The raw data stripped of identifiers supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Rhode Island Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

EM is responsible for data collection and taking the lead in writing the manuscript. All authors contributed equally to the design and conception of the study, provided critical feedback and helped shape the research, analysis, and manuscript.

FUNDING

This study was supported by the USACE project grant (W912HZ-16-C-0019) entitled Measuring Vulnerability to Inform Resilience: Pilot study for North Atlantic Medium and High Use Maritime Freight Nodes.

ACKNOWLEDGMENTS

The authors thank the reviewers for their helpful comments and constructive criticisms of the manuscript. The categorization scheme of the strategies for the implementation of seaport adaptation presented were developed by the authors for this seaport study. We also thank Katherine Chambers (USACE), Josh Murphy (NOAA), and the Committee on the Marine Transportation System Resilience Interagency Task Force for their guidance during the research project.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsus.2021.673630/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.