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Evaluating a "wicked problem": A conceptual framework on seaport resiliency in the event of weather disruptions

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ABSTRACT

Seaport infrastructure by virtue of its location can be severely impacted from disruptive adverse weather events. Disruptive adverse events range from long-term changes such as sea level rise caused by climate change to short-term impacts such as hurricanes. This paper proposes a new conceptual framework for evaluating how ports currently strategize against the risks associated with these potential events and how they plan to ensure port resiliency. Resiliency is defined as the port's ability to resume normal operations at pre-disruptive performance levels after a disruptive adverse event. Further, port resiliency also includes a port's ability to maintain normal operations and performance over a long period of disruptive adverse change. Protecting ports from the impact of adverse weather events is a "wicked problem." A wicked problem is one where the planning for adverse events is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. This "wicked problem" context helps port managers to view decisions made on port resiliency in terms of mitigation and minimization of the extent and duration of the negative consequences associated with major disruptions rather than a solution mindset. To achieve this goal, we propose a four step framework: (1) collecting and analyzing historical records on past events, (2) recognizing and managing stakeholders' expectations, (3) developing ever changing resilience strategies, and (4) implementing these strategies with flexibility.

1. Introduction

Oceanic transportation is the main mode of international freight transportation which places a substantial amount of pressure on seaports to consistently perform at optimal levels. According to the United Nations Conference on Trade and Development (UNCTAD), seaborne trade reached 9.84 billion tons in 2014, divided across bulk, dry, and containerized cargo (UNCTAD, 2015). Developing countries contribute an ever growing share of international seaborne trade. Currently, developing countries contribute 60% of global exports and 61% of imports, measured by the volume of goods unloaded. This huge amount of seaborne freight results in the handling of between 200 and 700 million tons of cargo per year in the busiest global ports (AAPA, 2016). The economic impact of ports and their infrastructure is significant to global and local economies. For example, according to Martin and Associates (2015), Houston Ship Channel-related businesses in 2014 contributed 1,174,567 jobs throughout Texas. This activity helped generate more than $264.9 billion in statewide economic impact, up from nearly $182.6 billion in 2012. Additionally, more than $5 billion in state and local tax revenues were generated by business activities related to the port, up from $4.5 billion in 2012.

Smooth operations within ports are challenged by various adverse events and disasters. Complying with the definition established by Fritz (1961), we define a disaster as an event, concentrated in time and space, in which a port undergoes severe danger and incurs such losses to its stakeholders and physical appurtenances that the normal operations are disrupted and the fulfillment of all or some the essential functions of the port is prevented. Mileski and Honeycutt (2013) categorize disasters as natural and non-natural (human-made); a differentiation is made between the two because usually there exists historical records to view regarding natural disasters. Because of researchers' ability to analyze historical data, most natural disasters can be anticipated, and sometimes preventative steps may occur at organizational, local, and regional levels (Tierney et al., 2001). Since ports are located in areas most vulnerable to catastrophic weather events (Becker et al., 2012; Ng et al., 2013, 2016), in this study, we focus on natural disasters with significant disruptions including storms, hurricanes, and flooding. Long-term changes, caused by the climate change, such as sea level rise falls also within our scope. Note that the findings and framework can be generalized to include human-made disasters.

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As key nodes linking transportation and supply chains, ports affected by these changes can have broad implications on the global economy and human welfare (Ng and Becker, 2015). An example is the five-day shutdown of the Port of Houston after Hurricane Ike. It is estimated every day the Port of Houston is closed, it costs $322 million (Texas Ports Association, 2011). In Table 1, we summarize some of the major weather events impacting U.S. ports in the past decade. A quick review of the table reveals that the overwhelming costs requires a nationwide attention for this wicked problem of protecting the port and port resiliency. Becker et al. (2012) come to the same conclusion based on a survey from the port authorities around the world.

Protecting ports from the impact of adverse events, considering all stakeholders and variables involved, is a "wicked problem." A wicked problem is one where the planning to address adverse events is difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often difficult to recognize. Wicked problems are generally seen as complex, open-ended, and intractable (Head, 2008). They can be defined in several ways, and have multiple characteristics (Camillus, 2008). Past decisions, historical trends, and current industry knowledge may not be useful in addressing wicked problems compared to other events (Koelsch, 2014; Rittel and Webber, 1973). Wicked problems are influenced by many economic, social, and political factors, and biophysical complexities: and the cause and effect of these factors and complexities are difficult to determine (Batie, 2008; Koelsch, 2014).

The wicked problem context has not been widely adopted in management. This may be due to the fact that wicked problems are viewed as unsolvable because of their complexity (Rittel and Webber, 1973). However, wicked problems can become better mitigated with proper identification of issues, requirements, and constraints (Koelsch, 2014). The port is a conglomeration of many stakeholders in an ever changing environment. According to Roberts (2000), in such a situation, the helpful mitigations to cope with the wicked problem are collaborative, authoritative (vesting responsibility), and completive (pitting different points of view). Generally, the problem of protecting the port is mitigated through the measure of resilience which has become an essential concept in the field of crisis management and critical infrastructure protection (Boin and McConnell, 2007; De Bruijne, 2006; De Bruijne and Van Eeten, 2007). Multiple definitions exist regarding the concept of resilience (Manyena, 2006; Moteff, 2012). Some authors break resilience down into four dimensions (Bruneau et al., 2003; Gibson and Tarrant, 2010; MCEER, 2008; Zobel, 2010): (1) Technical resilience, the ability of the organization's physical system; (2) Organizational resilience, the capacity of crisis managers to make decisions and take actions; (3) Economic resilience, the ability of the entity to face the extra costs; (4) Social resilience, the ability of society to lessen the impact of a crisis. Alternatively, others set the following characteristics as the main features of resilience (Bruneau et al., 2003; MCEER, 2008; Zobel, 2010): robustness, redundancy, resourcefulness, and rapidity. Finally, Labaka et al. (2013) define resilience as the system's ability to reduce the probability of failure, the consequences from failure and the response and recovery time. Following these studies, we define resiliency as the port's ability to resume normal operations at pre-disruptive performance levels after a disruptive adverse event. In addition, port resiliency includes a port's ability to maintain normal operations and performance over a long period of change such as sea level rise. One of the key elements in this regard is learning from past experience.

Port decision-makers require quality theoretical analysis, highly innovative assessment methodologies, and insightful empirical experiences to identify the best practices, plans, and appropriate policies to effectively develop and adopt resilience measures to minimize adverse impacts on ports (Ng and Becker, 2015). In order to address port resilience planning, this research proposes a conceptual framework addressing this wicked problem which focuses on 1) understanding the complex driver of risks to ports; 2) understanding core infrastructure vulnerability of ports; 3) understanding the functional vulnerability of ports including broad risk elements such as workforce and other economic elements and 4) addressing mitigation strategies. Using the framework, to mitigate the wicked problem of port protection: first, the frequency of events or anticipated events and the severity of related consequences based on experience will be discussed. Second, the economic impact of a disruption or potential disruption to facilities, services, and systems will be described. Third, perceptions of timeframes and costs of mitigation to enhance resiliency will also be measured. The objective is to help port authorities, regional transportation agencies in which ports are located, and other associated stakeholders minimize the extent and duration of major disruptions, and to bring the ports' operating systems back to pre-event levels. Further, this research will aid in planning for long-term events such as sea level rise mitigations and to determining whether current port investment provides for lower costs, avoiding major, additional investments in the future.

In this study, we focus on providing the wicked problem lens to protecting ports and making them resilient. Decision-making and policy-making approaches must be altered under the "wicked problem" context, emphasizing that the problem cannot be solved overnight but can be mitigated overtime with the collaboration of stakeholders. Following this idea, we propose a conceptual framework to mitigate the impact of adverse weather events and improve port resiliency. The benefits of this framework include immediate, short, medium, and long-term outcomes. In developing this framework, we have contributed to the maritime transportation industry's ability to perform at optimal levels as rapidly as possible after a disruptive event. This impact will ripple through all transportation nodes, as most rely on

Table 1
Major adverse events caused by nature in U.S. in the past several decades.

Location and year	Type of response	Days	Cost of damages	Reference	Explanation of event
New York/New Jersey ports 2016	State	>5	NA	Weather advisory (2016)	New York/New Jersey port area to receive 30 in. of snow making moving cargo too risky.
New York/New Jersey 2012	National	>5	$2b	Sturgis et al. (2014), Strunsky (2013)	Hurricane Sandy hit the north eastern U.S. with a 14 ft storm surge and 90 knots.
Mississippi, Gulf port & surrounding MS ports 2005	National	<25	$99.9m (port damages)	PEER (2013)	Hurricane Katrina wipes out the City of Gulfport and most of the coast of the state. Several years later they are/were in the restoration project.
Texas, Houston 2005	State	>5	$1.6b	Grenzeback (n.d.)	Hurricane Rita came and did minimal damage to port structure but cluttered water and damaged boats.
Mississippi, Pascagoula 2005	National	<25	$15.73m	PEER (2006), Alexander and Irwin (2005)	Hurricane Katrina whipped everything out.
Louisiana, New Orleans 2005	National	<25	$200b+	Sayre (2006), Moore (2010)	Hurricane Katrina wipes out the city of New Orleans and the majority of the port. 6 months afterwards they were only at 50% operating capacity.

*Facility indicates that the level of response was limited to the facility.