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**Port Stakeholder Perceptions of Sandy Impacts: A Case Study of Red Hook, New York**

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**Abstract**

Understanding the impacts of coastal storm hazards on all maritime port system stakeholders (e.g. operators, tenants, clients, workers, communities, governments) is essential to comprehensive climate change resilience planning. While direct damages and indirect impacts are quantifiable through economic data and modeling, qualitative data on the intangible consequences of storms are necessary to explicate interdependencies between stakeholders as well as conditions that substantially affect response and recovery capacities. This case study explores Hurricane Sandy storm impacts using evidence solicited from stakeholder representatives and extracted from contemporaneous and technical accounts of storm impacts on the port system at Red Hook Container Terminal, Brooklyn, New York, USA. Results highlight the wide range of direct damages, indirect costs, and intangible consequences impacting stakeholders across institutional boundaries and requiring coordination for recovery, providing insight into stakeholder relationships and dependencies in the post-disaster response and recovery process that are often not fully accounted for in current vulnerability assessment and response planning methodologies.

KEYWORDS: resilience planning, disaster recovery, externalized costs

## 1. Introduction

Maritime ports are critical to the national transportation infrastructure, providing access to an oceangoing international trade network which accounts for more than 80% of the global trade by volume, including critical imports ranging from vehicles and raw materials to food and medical supplies (UNCTAD 2018). Securing the resilience of the national port infrastructure is a primary economic and defense priority, necessitating robust resilience planning (CMTS 2017). However, ports are inherently exposed to significant risk of harm from coastal storm impacts, because they must operate at the vulnerable land-sea interface where wind, flood, and storm surge impacts are concentrated (Ng et al. 2016). As climate change leads to rising sea levels and intensified storm impacts in many parts of the globe (Melillo et al. 2014), ports must account for and adapt to these changes over both mid- and long-term planning horizons (Becker et al. 2018; USDOT 2014; EPA 2008).

The port stakeholder cluster (De Langan 2004) includes port owners and operators; tenants, shippers, and other port clients; government regulators responsible for the safety and economic vitality of the national port system; and surrounding communities which depend on ports for access to the global economy and for employment (Ward 2001; Becker et al. 2013). Different port stakeholders play different roles in the port's resilience decision-making, including through direct planning (in the case of internal stakeholders such as owners and operators) and through external economic or political influence (Zhang et al. 2017; Freeman 2010, Bryson 2004). In turn, different stakeholders bear the harms and costs of storm impacts to port operations differently as well. In some cases, the harms of a storm impact may not only affect a stakeholder that is directly damaged (e.g., a port operator that must repair damaged cranes), but may also be externalized to other stakeholders throughout the cluster that are do not have direct responsibility or capacity for repairing the damage, but that nevertheless depend on its recovery to resume normal operations (e.g., a shipper that must reroute cargo and defray lost revenue). These externalized harms propagate throughout the stakeholder cluster according to a network of economic and institutional inter-reliance among stakeholders that is not always necessarily fully accounted for or engaged by planning processes (Zhang et al. 2017; Becker et al. 2014; Messner et al. 2015).

A robust understanding of how all harms and costs of storm impacts are either internalized or else propagated throughout the stakeholder cluster is critical to achieve proactive, comprehensive resilience planning (Messner et al. 2015). So too is an understanding of how those impacts function differently in different ports according to each port's unique circumstances (Becker et al. 2014). Identifying port-specific impacts is a first step toward identifying and deciding between resilience strategies. However, impact assessment methods often do not allow for a detailed understanding of how storm impacts might have differential effects on different components of the stakeholder cluster, whether because the scale of analysis is too broad to capture effects on individual stakeholders (Lian et al. 2007; Hallegatte 2008), or because the scope of analysis is constrained to particular quantifiable impacts, such as insured losses (Grossi et al. 2005) or direct damage to structures (Curtis 2007; LADOT 2006). Because impacts may propagate through the stakeholder cluster as indirect or intangible impacts, not only quantitative but also qualitative data are necessary to comprehensively characterize storm impacts on a port. There is a need for improved integration of qualitative impact data with the quantitative impact modelling and data used in the vulnerability assessment methods that provide the basis for resilience planning and decision making (Aerts et al. 2018; Stempel et al. 2018; Becker et al. 2014; Di Baldassarre et al. 2015). This paper contributes to the field of port policy and management through a theory-based analysis of stakeholders' perceptions. The cascading impacts resulting from hurricanes have economic, social, and environmental effects on numerous stakeholders throughout a port system. These cascading consequences are still not well understood, nor are they properly accounted for in current port planning practice.

This case study builds on work conducted by Becker et al in the ports of Gulfport, Mississippi, USA and Providence, Rhode Island, USA, and seeks to expand and improve the information available to decision-makers regarding coastal storm impacts for ports confronting key policy decisions in resilience planning (Becker et al. 2014). There is a rich literature describing the value of the case study approach, especially in emerging areas such as climate adaptation and resilience. As Yin states, “The distinctive need for a case-study approach arises out of the desire to understand complex social phenomena” (2008). And, as further elaborated by Flyvbjerg, “a scientific discipline without a large number of thoroughly executed case studies is a discipline without systematic production of exemplars, and a discipline without exemplars is an ineffective one” (2006).

The subject of this case study is the Red Hook Container Terminal (RHCT; the Terminal) in Brooklyn, New York City, New York, USA, a small cargo port in the Port of New York and New Jersey. In October 2012, New York City suffered extensive damage and disruption from Hurricane Sandy. Through targeted interviews with representatives of internal and external stakeholder institutions, as well as assessment of reports on storm impacts to the Port, the case study catalogs stakeholder perceptions of the direct, indirect, and intangible impacts of that major coastal storm on the RHCT stakeholder cluster. Applying the methods used to analyze storm impacts for the ports of Gulfport and Providence in Becker et al. (2014) also allows comparison to the results from those other cities in different regions. The case of RHCT provides insight into the propagation of storm impacts through a dense urban port stakeholder cluster, provides empirical support for a typology of such impacts, identifies nontrivial and non-obvious interdependencies, and contributes to a growing body of evidence that provides the foundation of a nascent area of theory with direct practical applications to port management and policy.

## 2. Description of Red Hook Container Terminal

RHCT is a small port facility in the Port of New York and New Jersey, located one mile south of the Brooklyn Bridge along Buttermilk Channel (Figure 1). It is the only terminal in Brooklyn that serves container ships, handling 55,000 containers in 2016. RHCT handles container, break-bulk, ro-ro, and project cargo, transferring goods to trucks for local delivery throughout Brooklyn and Long Island, as well as for longer highway hauls (Red Hook Terminals 2019). Regular services include a CMA CGM round-the-world route that delivers Heineken beer from Europe, and a Seaboard service from the Caribbean and South America carrying bananas. The Terminal also hosts a container barge service across the Upper Bay to Port Newark/Elizabeth, adding an additional 20,000 containers to its annual throughput (Red Hook Terminals 2019).

*Insert Figure 1 – map of Brooklyn and map of terminals about here*

The Port Authority of New York and New Jersey (PANYNJ) own the terminal, including four piers and administrative facilities, and Red Hook Terminals LLC operates the facility. The PANYNJ Maritime Commerce Department sets building codes and provides engineering management for capital projects, but does not participate in day-to-day operations. There has been some form of cargo terminal on the site since the 1840's, and for most of that time, maritime commerce drove the development of the surrounding Red Hook community.

Sandy made landfall in Brooklyn on Monday, October 29, 2012 as a post-tropical cyclone. A great deal of the Red Hook neighborhood south and east of the Terminal is built on reclaimed land with very little topographic relief. The combined high tide and storm surge struck low-lying Red Hook with an 11.2ft storm tide, causing an estimated 4.1ft of inundation throughout most of the community (Blake et al. 2013). Because the Terminal naturally slopes down toward the water, inundation depths were even more severe in seaward parts of the facility; tenants at RHCT's Pier 7 reported almost 5ft of water in their warehouse. Throughout New York City, 44 deaths were directly attributable to the storm (Jaffe et al. 2015).

The U.S. Coast Guard (USCG) closed New York Harbor waterways and ordered the evacuation of all vessels the day before the storm's arrival, pursuant to the Heavy Weather Plan developed in collaboration with port stakeholders after Hurricanes Earl in 2010 and Irene in 2011. The Port remained closed after the storm until the USCG, in collaboration with the National Oceanographic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and Sandy Hook Pilots, could survey all waterways for obstructions to navigation, pollution, and shoaling from storm tides. Extended power outages and fuel shortages on land impacted the city for more than a week following the storm; this was compounded by temperatures dropping below freezing, stranding many residents without heat, power, or transportation in icy, slushy conditions. Although the USCG was able to progressively open waterways to municipal sewage scows, then fuel barges, then more traffic over the following days, the fuel terminals which processed and received home heating oil, diesel, and gasoline remained crippled by the power outage, prolonging the fuel shortage even after the Port resumed operation. RHCT received its first cargo vessel on November 6, eight days after the storm.

## 3. Methods

This case study was designed to provide qualitative and quantitative storm impact information that is useful to planners and decision-makers with responsibility for implementing resilience plans and policies in U.S. and international ports (Becker et al. 2014). In order to comprehensively capture the range of impacts to the full RHCT stakeholder cluster, 'impact' is defined broadly to encompass the full range of direct damages, indirect costs, and intangible consequences (IPCC 2012) which result from a major storm and which meaningfully disrupt the ability of a stakeholder to engage in normal operations. Direct damages are impacts with discrete costs, which are incurred by the action of flooding, wind, or waves on port facilities, equipment, and contents. Indirect costs to port stakeholder clusters are disruptions to the normal flow of goods and services caused by direct damages or by efforts to recover from them. Direct damages and indirect costs are impacts on the port as an economic system that can be expressed in terms of value lost to one or more stakeholders from the baseline of normal economic conditions. Intangible consequences for port stakeholder clusters encompass the range of impacts that are substantively significant and relevant to stakeholder decision-making but nevertheless are poorly described by economic valuation, such as loss of life, health impairments, or damage to the environment or to cultural heritage.

For the purposes of this research, the RHCT stakeholder cluster is defined broadly to include both internal and external stakeholders with an economic or institutional interest in the successful normal operation of the Terminal (Becker et al. 2014). Internal stakeholders include port owners (PANYNJ) and operators (Red Hook Terminals LLC). External stakeholders include economic stakeholders (stakeholders with interests defined through contractual relationships, e.g. tenants, shippers, insurers), public policy stakeholders (government institutions with jurisdictional responsibilities for the port, e.g. USCG, Department of Transportation, state and city agencies), community stakeholders (residents and institutions representing the cultural and economic interests of hinterland communities, e.g. Community Boards, environmental groups), and academic stakeholders (institutions which generate information or scholarship relevant to port decision-making).

The study was designed to elicit two related kinds of information: comprehensive cataloging of storm impacts to RHCT stakeholders, and identification of which stakeholder group(s) (internal, economic/contractual, public policy, and/or community) carried the 'burden of recovery' for each impact. The burden of recovery is defined broadly to encompass the investment of financial, human, and institutional resources (i.e., time, effort, and expense) in recovering from an impact; it is sensitive to stakeholders' perceptions of their own and other stakeholders' capacity (e.g. technically, financially) and responsibility or authority (e.g. legally, politically) to undertake such recovery activities.

The burden of recovery may be borne internally, or it may be externalized to other members of the stakeholder cluster. In the case of direct damages, the burden of recovery is generally borne internally by stakeholder institutions (Becker et al., 2014). For example, a tenant may write off the loss of water-damaged products from its warehouse, or the port operator may pay for replacement electrical equipment using an insurance payout. In the case of indirect costs, economic losses can often become externalized and may not be 'paid for' by any one stakeholder institution, but nevertheless may require the time and effort of one or more stakeholder institutions to recover from. For example, the economic impact of damage to USCG aids to navigation is felt by all economic stakeholders because of the disruption to vessel traffic until the waterway is reopened. In that example, the burden of paying for repairs to the navigation aids falls to the USCG (and, by extension, the federal taxpayer). In the case of intangible consequences, some impacts are articulated broadly as an impairment of response capacity (e.g., the challenge of learning new disaster recovery procedures on the fly), while others can be solved by the explicit efforts of particular stakeholder institutions (e.g., debris which blocks roads and impedes repair efforts for stakeholders across the cluster, but which must be addressed by the cleanup efforts of particular stakeholders, such as the city government or landowner).

Many of these indirect and intangible harms are externalized throughout the stakeholder cluster. For the purposes of recording and analyzing results, each impact was classified according to the stakeholder who held the burden of recovery only as perceived by the sources.

Data were gathered from two types of sources: interviews with port stakeholders and contemporaneous news and retrospective technical reports addressing port damage from the storm. Interviewees were identified through personal contacts, internet research, and referral by other participants. In total, five port stakeholders were interviewed: two representatives of PANYNJ, two representatives of USCG, and one representative of a community group (Table 1). As the Terminal is a small port with limited economic and institutional reach, this sample of the stakeholder cluster, taken in conjunction with the written reports, was considered adequate to capture the experiences of the stakeholder cluster. Interviews were conducted in-person and by telephone, using a semi-structured technique. In one case, two interviewees attended the same interview; their responses were coded individually. The interview instrument (Appendix A) was adapted from Becker et al. (2014) to elicit stakeholder impressions of what impacts from the storm affected their institutions and to what parts of the stakeholder cluster the burden of recovering from those impacts fell. The instrument was approved by the University of Rhode Island Institutional Board. The interviews were recorded and transcribed for coding.

*Insert Table 1 about here*

Reports on Sandy's impacts from academic literature and from contemporaneous news accounts were identified through internet searches and selected according to the criterion that they catalog storm impacts on Red Hook Container Terminal or the broader PNYNJ system, as reported by members of the port stakeholder cluster. Six scholarly articles and four contemporaneous news reports were collected and coded (Table 2).

*Insert Table 2 about here*

Coding procedures from Becker et al. (2014) were employed in this study using the NVivo qualitative data analysis software package to ensure that results were compatible. Interview transcripts and reports were reviewed line-by-line and impacts were provisionally identified. Once all potential impacts were highlighted, they were coded a second time to ensure there was no duplication or conflation, and assigned to common ‘main ideas.’ Finally, ‘main ideas’ were refined into explicit sub-types, and sub-type sets were coded into three top-level types (direct, indirect, intangible impacts). The three top-level impact types used by the International Panel on Climate Change were used for consistency and because they are conceptually comprehensive – any articulable impact fits into at least one impact type (IPCC 2012). However, sub-types were coded independently without consulting the Becker et al. results to avoid interpretive bias.

Impacts were articulated as specifically as possible to make the results comprehensive and holistic; for instance, the impact of *disruption to the flow of food supplies* was kept distinct both from the more general impact of *disruption of the flow of cargo*, and from the causally related impact of *waterway closures*, according to how the respondent specifically expressed the impact. Each impact mentioned in a written report was considered to have been mentioned only once in that report regardless of how often the words appear in the text itself.

Once coded, impacts were then assigned to stakeholder groups according to the burden of recovery. All impacts were parsed in this way, even where interviewees or reports were not explicit about who ended up bearing the burden, based on the authors' best interpretation of the contractual or jurisdictional obligations associated with each impact.

## 4. Results

Through analysis of five interviews and ten reports, 227 mentions of 82 distinct impacts were identified, including 23 unique direct damage, 31 indirect costs and 28 intangible consequences. The impacts are presented in Tables 3-5, divided into top-level impact types (direct damage, indirect cost, or intangible consequence) and sub-types. For each impact, the stakeholder group which carried the burden of recovering from the impact is identified.

### *4.1 Direct Damages*

Direct damages, or damages with discrete costs incurred by the direct action of flooding or wind on port facilities, equipment, and contents, are reported in Table 3. Damage to port facilities was severe and widespread. Several structures on the Terminal experienced basement and first floor flooding, and building contents across the Terminal including computer systems and records were extensively damaged. Underground infrastructure such as electric substations, storm drains, and fire pumps was destroyed.

*Insert Table 3 about here*

Port equipment was similarly hard hit, with cargo handling equipment disabled either by water damage to engines or salt corrosion of wheels and electrical systems. Six electric gantry cranes, which have their motors installed near ground level, were flooded out. Several of the gantry cranes at RHCT had not yet been converted from diesel to electric to conform to PANYNJ air quality guidance; these cranes were not disabled, while most of the rest of the Port's crane equipment had to be dismantled and shipped out for refurbishment, which one source reported cost about $160,000 per crane. Some minor damage was done to barges at the

Terminal, although elsewhere in the Port one barge was stranded on a pier. Cargo was seriously damaged, with numerous containers thrown around the Terminal and washed into the waterway. One tenant reported that flooding of its warehouse resulted in $10 million in write-offs.

### *4.2 Indirect Costs*

Indirect costs, or disruptions to the normal flow of goods and services caused by direct damages or by efforts to recover from them, are reported in Table 4. Key among these costs incidental costs to repairing damages expressed in Table 3, such as assessment, monitoring, security, and the provision of temporary replacement services.

*Insert Table 4 about here*

Apart from waterway closures and vessel evacuations, interruptions to operations also stemmed from damage to administrative buildings, which destroyed paper records and disabled computer systems. The interruption was felt by internal stakeholders, from the revenue gap for tenants to lost wages for workers.

### *4.3 Intangible Consequences*

Table 5 reports intangible consequences, encompassing a broad range of impacts that are relevant to stakeholder decision-making, but nevertheless are poorly constrained by economic valuation. This type includes a number of impacts which could feasibly be classified as direct costs, such as damage to traffic signals, but which were cited by sources as conditions which made recovery more difficult (i.e., the failure of traffic signals making travel to recovery sites harder) rather than simply costs to be paid. In these cases, the impacts were recorded as reported by the source.

*Insert Table 5 about here*

Sources strongly emphasized impacts, both on Terminal property and outside it, which impaired their ability to bring the Terminal back online. Impacts on the Terminal included damage to lighting and roads, debris on roads, and disruptions to communication systems. Not only did the system back up seawater into facilities and make direct drainage impossible, but also waste backed up through the storm drains because the City has a combined sewer system. This meant that all water damage remediation activities required environmental hazard abatement procedures as well.

Impacts outside the Terminal included severe cold weather during a fuel shortage, damage to personnel's homes and communities preventing them from participating in recovery, and the emotional toll of the widespread devastation. Finally, all interviewees discussed the complexity of coordinating disaster relief efforts and funds within their institutional contexts.

## 5. Discussion

The experience of RHCT stakeholders in the aftermath of Hurricane Sandy demonstrated the advantages and challenges of resilience planning to minimize the propagation of storm impacts through the stakeholder cluster. Ports are highly interconnected and inter-reliant systems. Stakeholders in the port stakeholder cluster rely on the goods and services of other stakeholders through contractual, institutional, and cultural relationships. In a disaster, direct damages to port facilities and resources propagate throughout the cluster along those reliant relationships as indirect costs and intangible consequences.

Resilience planning ahead of the disaster event serves to anticipate the propagation of impacts and develop working relationships between stakeholders that can be activated during the response phase to abate impacts. Where impacts were not fully anticipated or working relationships did not exist and had to be developed *ad hoc*, indirect and intangible impacts served to impede response and prolong recovery. The specific experiences reported by Red Hook stakeholders demonstrate the propagation of impacts through a port stakeholder cluster (section 5.1), and highlight both successes and failures of the port system's response and recovery attributable to pre-storm planning practices (section 5.2). Comparison to the reported outcomes in a separate case (Gulfport, MS, USA after Hurricane Katrina) provide the basis for discussing generalizable best practices for planning (section 5.3).

### *5.1 Direct damages propagate as indirect costs and intangible consequences*

Sources reported that before Sandy, hurricanes were considered, and planned for, primarily as wind hazard events. Hurricane Sandy was primarily a storm surge event rather than a wind event. All direct damages to port facilities highlighted in interviews and reports were the results of flooding. One report cited this as the primary reason damage was so extensive: 'The storm surge was the big issue. With a hurricane you might expect a wind event with some flooding. Instead we had a major flooding event with some wind damage' (Wakeman & Miller 2013, 12).

*Insert Table 6 around here*

The building codes for PANYNJ facilities had emphasized protection from wind damage, meaning that a great deal of critical port infrastructure – generators, transformers, motors, and computer systems – was at or below ground level (DesRoches & Murrell 2014). Likewise, the flat topography of the filled land in and around RHCT exposed the area to some of the most severe flooding in the city.

The economic impact of the disruption to port commerce propagated to economic dependents of the port in the hinterlands, ranging from clients of tug and barge, water taxi, and ferry services, to the wider consumer goods marketplace. As one interviewee said: 'there's a lot of things that sometimes people forget are on cargo containers, things like blood and food … things that are critical to emergency response. And it took a long time for that to get back up to a moving pace.'

Economic hardship was a major point of discussion, especially regarding the disruption of container traffic right at the opening of the holiday shopping season. Although interviewees emphasized that critical port operations such as fuel deliveries came online quickly, container operations took longer to reach pre-storm levels, both because they did not receive the same level of public health emergency prioritization, and because the necessary equipment (e.g., gantry cranes) took longer to repair.

The disruption of waiting on other members of the stakeholder cluster to resume operations before being able to conduct one's own recovery efforts was also discussed as an intangible but significant impact of the storm. One interviewee discussed how operators and tenants could not resume full operations until PANYNJ could bring their own operations fully online. Several sources discussed how all internal Terminal stakeholders relied on the USCG to clear and reopen waterways before resuming port operations. An interviewee reported that Customs and Border Patrol (CBP) lost critical hardware at the Manhattan Cruise Terminal for identifying and processing arriving passengers (e.g., scanning passports), which forced them to turn away a cruise ship which had weathered the storm at sea and subsequently had to be rerouted to Boston. All sources emphasized the reliance of the surrounding community on the port for fuel and for commerce.

***5.2 Resilience planning builds relational capacity to stem the propagation of impacts***

Resilience planning can provide a mechanism for stakeholders in the port stakeholder cluster to establish working relationships that can be activated to coordinate response and recovery. The experience of recovering the channel versus recovering the fuel system highlight the effect of resilience planning in building such institutional relationships. Port hazard planning with internal stakeholders, tenants and clients, and public policy stakeholders including the City and the USCG prepared the port system to abate navigational hazards and reopen the waterways efficiently, minimizing indirect costs and intangible impacts. By contrast, an enduring fuel shortage, which was prolonged and exacerbated by an inability to coordinate response operations, caused a significant portion of indirect costs and intangible consequences suffered by stakeholders across the cluster.

### 5.2.1 Waterway response and recovery

The waterways remained closed until impairments to navigation could be abated. Waterway closures were the initial cause of the port shutdown, as the USCG evacuated the harbor before the storm. Immediately after, USCG activated a pre-existing response network of government and non-government vessels to survey the waterways for navigational safety, including identifying debris and shoaling, and assessing the status of aids to navigation - an effort which was impaired by damage to their own equipment and facilities. This process involved repairing aids to navigation and clearing obstacles such as drifting vessels, containers, oil spills, and other various hazards. Floating containers were highlighted by multiple sources as a significant challenge, as they can severely damage a vessel in a collision, but can often float slightly below the water’s surface, making them difficult to avoid.

The burden of abating the container problem complicated response efforts. Although the USCG had jurisdictional responsibility to survey and identify containers that had floated off the terminals in the surge, the practical responsibility of who would pay to remove any given container was not always clear. For containers that were sufficiently intact to identify the owner by serial number, the owner had clear liability to cover the cost of removal. If the container was damaged such that the owner could not be ascertained, and it posed a risk of polluting the waterway, the Coast Guard had access to dedicated funds to cover removal. If the container was damaged and was found in the waterway, the USACE took responsibility for removing it as an obstacle to navigation. However, a great number of containers beached alongside the waterway did not fall into those categories – the Coast Guard surveyed and catalogued these containers but did not have clear guidance on how to obtain funds for their removal. An interviewee reported that in many cases, these containers ended up being removed at the expense of the landowner or the city.

Despite uncertainty regarding debris outside the channel, interviewees described that USCG was able to successfully collaborate within the port stakeholder cluster, including PANYNJ, tenants, and pilots, to accelerate waterway inspection and cleanup. USCG prioritized reopening the waterways to key fuel terminal facilities. Priority routes to fuel terminals were restored within days, making possible emergency fuel delivery operations to affected parts of the City. RHCT, as a container terminal, received lower priority but was navigable within eight days. Sources stated that this coordination was possible due to preexisting institutional relationships developed through the disaster recovery planning process.

### 5.2.2 Power system response and recovery

The response network developed through prior port resilience planning had not, however, developed similar lines of communication with regional electric utilities. Extensive damage to subterranean infrastructure across the city left the electric grid disabled for days, cutting off internet access and requiring stakeholders to obtain back-up generators. The huge demand for fuel for generators, combined with the power outage itself disabling otherwise operational fuel terminals, in turn created a severe fuel shortage.

As discussed above, USCG prioritized reopening deliveries to certain fuel terminals that had received less damage. This allowed the government to begin to make emergency fuel deliveries to shelters and hospitals. However, many fuel terminals were unable to resume operations due to damaged tanks, flooded pumps, and the ongoing electrical outage.

Because the port community was effectively left to sit on its hands waiting for electrical systems to recover, it was not able to stem the fuel shortage even once waterways and terminal facilities were otherwise ready to reactivate. With response and recovery delayed relative to the waterway navigability, sources across the stakeholder cluster reported indirect and intangible effects of the power shortage at a higher rate than those consequent to other direct impacts. As one interviewee reported, '[the surrounding communities] had no gas. Many needed gas to fill generators, to get power back up at their house and keep the heat on … As soon as power went out, a lot of people went to generator systems and the generators started to go out. Then at the same time, the temperature dropped pretty precipitously. And so you had this confluence of people needed fuel for heat, fuel for electricity, fuel for their cars, fuel for all sorts of things, and it wasn't readily available.'

Electricity, therefore, represented a bottleneck in the critical path to recovery, which an interviewee indicated was a consequence of the inability of stakeholders to coordinate ahead with the utilities through the resilience planning process. The knock-on, externalized burden of recovering under these circumstances fell to port tenants and operators (e.g., by using backup generators during the repair process) and to the public policy and community groups which offered emergency services to those without power (e.g., government fuel deliveries by truck, and community aid groups providing warm shelters).

5.2.3 Adaptivity in response and recovery

Across stakeholder groups, new systems and procedures for communicating, problem solving, and processing paperwork had to be innovated on the fly. One interviewee expressed that the mix of impaired roads, fuel shortages, and damage to personnel's homes severely short-staffed PANYNJ in the first days after the storm, necessitating that the personnel on hand step into inspection and decision-making roles that were outside their normal work responsibilities. For instance, one interviewee reported that road and rail inspections had to be performed by whoever could report to work on the day after the storm, because most of the regular inspectors lived in New Jersey and couldn't get into the city by car. This delayed the recuperation of the land transport network and cut off repair personnel and equipment.

Because of this complexity, interviewees strongly emphasized the importance of adaptivity and coordination among stakeholders during the recovery process. Several interviewees described coordinating major governmental response efforts using a daisy chain of officials' personal cell phones, depending on which carrier was online that day.

Strong institutional relationships also empowered stakeholders to respond adaptively. For instance, perimeter fences and cameras were destroyed throughout the Port; this brought the Terminal and other Port facilities out of compliance with the Maritime Transportation Security Act (MTSA), which requires terminal operator to continuously maintain security equipment and procedures (MTSA 2002). An interviewee reported that the USCG, which enforces the MTSA, worked with terminal operators across the Port in the hours after the storm to identify breaches and execute temporary plan amendments under USCG regulations to fill the breaches using hired security monitoring. As the interviewee put it, 'the minute the Facility Security Officer could get out to the facility and assess what was going on, most of them were on the horn with their corporate headquarters and within 12 hours you had privately hired sheriffs from Louisiana doing gate-guard duty.' No indirect costs or intangible consequences related to security issues (e.g. looting) were reported by any sources.

***5.3 Contrasting findings from Gulfport, MS***

. The Port of Gulfport, MS is Mississippi's largest port, and it experienced profound damage from Hurricane Katrina in 2005. Becker et al. (2014) reported impacts from Katrina on the port and surrounding community using the same methodology.

Nearly all Red Hook interviewees emphasized the rapid turnaround of port recovery. While community stakeholders in Red Hook have indicated that economic recovery in the community has been protracted and remains incomplete, the port system resumed critical operations within 10 days. This stands in sharp contrast with the severe, long-term shutdown at Gulfport and the associated intangible consequences identified, such as supply-side fluctuations in the labor market, complete facility destruction and reconstruction, and permanent loss of revenue or lines of business.

This distinction points to a disparity in the economic and institutional capacity of the two ports' different stakeholder clusters to recover, as well as the effectiveness of recovery activities coordination across those clusters. Becker et al. found that existing resilience planning processes in Gulfport revolved around the responsibilities and interests of internal and economic external stakeholders, without involving other external stakeholders, and that, as a consequence, planning processes failed to account for significant portions of the impacts experienced after Hurricane Katrina, especially indirect and intangible impacts which impaired long-term recovery. The experience of RHCT drives this point home by illustrating that, where resilience planning anticipated impacts and built institutional relationships that could be activated to coordinate response and recovery, response operations brought systems online quickly, such as in the case of waterway debris clearing, whereas unanticipated impacts led to lack of coordination and enduring impairment of recovery, such as in the case of the fuel shortage.

## 6. Conclusion

This case study of the Red Hook Container Terminal in Hurricane Sandy extends the methods of Becker et al. (2014) to the highly integrated, intermodal port system of New York City. Interviews with key stakeholders indicated clear interdependencies among stakeholders in ability to storm recovery activities, caused by indirect and intangible impacts which propagated across the stakeholder cluster. Where the disaster planning process had instituted post-disaster coordination frameworks for those interdependencies – such as in the case of regional fuel supplies – stakeholders were able to coordinate and rapidly recover. Where institutional lines of coordination did not exist – such as in the case of the electrical grid – the recovery process was impaired and secondary costs were incurred to endure the impact during the recovery process. The results from Red Hook emphasize that coordination between stakeholder institutions is an effective strategy for efficiently recovering from major storm events. Information like the stakeholder impacts solicited in this project can inform and support the capacity of resilience planning to comprehensively involve all relevant stakeholders in a port system in procedures and investments to build port resilience.

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## Appendix A – Interview Instrument

**INTERVIEW INSTRUMENT FOR RED HOOK, NEW YORK**
***Modified from Becker 2014***

INFO = Information to be given to informant
Blue = notes for interviewer

**OVERVIEW**
Respondent Name; Date; Interviewer; Organization; Position.

**Section I: Background on institutions and interviewees (5 minutes)**

INFO: There are 13 questions, concerned with your organization's relationship to Red Hook Terminal and to your organization's experiences in the aftermath of Sandy. I will record the interview. Your responses to these questions will be kept private, and neither your name nor your organization's name will be tied to any specific response, either in internal transcripts or in any publications. This should take about 30 minutes.

Please tell me about your organization's management responsibilities.
(Setting the stage here to have the scope of jurisdiction and mandate in their words, and get at interactions among stakeholders)
Follow up (FUP) A: Could you tell me a bit about the *current priorities* your organization has?
FUP B: Does your organization interact with other local, state, regional or even federal agencies or companies to do its work?

And what specifically does your work entail?
FUP A: So you manage …. What does that actually mean as far as your daily work is concerned?
FUP B: Who do you interact with regularly to accomplish this?
FUP C: How long have you been in this position?
FUP D: What is your education background (degrees and discipline)?

Can you describe the *decision-making process* for long-term planning and investing bit more?
These questions are likely to bring out issues of conflict, institutional cooperation or lack thereof. They are included for completeness.
FUP A: Who applies/proposes/initiates?....
FUP B: Who else is involved?
FUP C: Are your decisions reviewed by some higher authority?
FUP D: Can anyone appeal or supersede your decisions? How does that process work?
FUP E: What information is required so you can make an adequate assessment?
FUP F: How long does it take to complete one project/application? How often do you have to make these kinds of decisions?
FUP E: What are the most significant changes in your work in the last five years (assuming the person has been in this or similar position for this long)

This research is about the "port system." This includes all of the various functions, costs, and benefits of the port that could be of concern for the region. Please tell us about your organization's management or planning responsibilities in terms of the port system.
FUP A: Could you tell me a bit about the *current priorities* your organization has with respect to the port?
FUP B: Does your organization interact with other local, state, regional or even federal agencies or companies to do its work and meet its port-related goals?
FUP C: How does the port fit under your organization's mandate?
FUP C: How does the port fit under your organizations jurisdiction?
FUP D: To what extent is your organization dependent on the success of the port?

**Section II. Impacts of storm events (20 minutes)**

INFO: Present the interviewee with the storm scenario and functions of the port.
Let's turn to your experience with Sandy. The port has a number of functions for the region and these functions were impacted by the storm. As we go through the rest of the interview, I'd like you to consider this storm event and the functions of the port as you answer the questions.

Did you have to prepare/account/plan for these kinds of events?
FUP A: In what ways, how so, etc.

Consider how Sandy impacted Red Hook Terminal and the surrounding neighborhood. How did the storm affect the resources and responsibilities within your jurisdiction (including infrastructure, social well-being, ecosystems, etc.)?
FUP A: What were your immediate concerns?
FUP B: What impacts were difficult to address in the immediate aftermath?
FUP C: Can you get more specific on what the impacts were?

Probe for STEEPLE impacts – six drivers of decision making (drivers of change)

S – Social T – Technological EN – Environmental EC – Economic P – Political LE – Legal

| *Environmental* | *Social* | *Economic* | *Infrastructure* | *Other* |
|---|---|---|---|---|
| **Petroleum Release** | Jobs lost/unemployment | Lost business | Power outage | Loss of competitive advantage |
| **Hazmats released** | Jobs created | Tenants relocate | Water supply | Fences and signs |
| **Debris (small)**<br>**Debris (large)** | Workers displaced | Cleanup costs<br>Preparation costs<br>Repair costs<br>Damage to product<br>Can't get insurance | Utilities (general)<br>Cranes damaged<br>Roads/Bridges<br>Rail<br>Piers<br>On-site buildings | Tree debris<br>Lost data |

FOR EACH IMPACT:

You described one impact … How was your organization affected by that impact?
INFO: Interested not only in damage and costs but also effects on ability to operate.
FUP A: How did operations have to change to accommodate the impact?
FUP B: How long did the impact affect operations?
FUP C: Were there permanent consequences of that impact on the organization?

Who else was affected in that way by that impact?

How did your organization deal with that impact?
FUP A: What resources were available to you to respond? Were they sufficient?
FUP B: What plans or policies did you have in place? Were they effective?
FUP C: What information was available to you to enable decision-making? Was it sufficient?

Who was responsible for dealing with or resolving the consequences of that impact?
INFO: I am interested not just in who paid and how they paid for it, but also who had to dedicate time and labor, handle paperwork and liaise with other organizations.
FUP A: Was the impact anticipated or was there a gap in responsibilities or organizations' understanding of each other's responsibilities?

Who actually ended up dealing with or resolving the consequences of that impact?
FUP A: Did someone have to step in to handle the impact?
FUP B: Was there a gap in responsibilities or organizations' understanding of each other's responsibilities?

Has your organization changed any policies or taken any steps to prepare for the next storm, in response to your experiences dealing with that impact?

**Closing. [at discretion, depending on length of interview]**

Is there anything else we might have missed that you want to add about the storm resilience process you've gone through so far?
Are there any other stakeholders for Red Hook Terminal that I should be speaking with for this project? Who in that organization should I speak to about these issues?

## TABLES AND FIGURES

Table 1 – Interviewees

| Stakeholder | Organization | Port Interest | Interviews |
|---|---|---|---|
| **Internal** | Port Authority of New York & New Jersey | Lessor of Terminal land and facilities | 2 |
| **External: Public Policy** | US Coast Guard | Inspect and maintain waterways and port security | 2 |
| **External: Community** | PortSide NewYork | Preserve and advocate for maritime culture in Red Hook | 1 |

Table 2 – Written Sources

| Source | Title | Type | Objectives |
|---|---|---|---|
| **Smythe 2013** | Assessing the Impacts of Hurricane Sandy on the Port of New York and New Jersey's Maritime Responders and Response Infrastructure | Academic | Identify lessons learned from maritime responders, including first responders, to Sandy. |
| **Wakeman & Miller 2013** | Lessons from Hurricane Sandy for Port Resilience | Academic | Interview stakeholders and review design codes to identify opportunities to enhance resilience. |
| **DesRoches & Murrell 2014** | Transportation Infrastructure Resiliency Guidelines for the Port Authority of New York & New Jersey | Academic | Describe changes to PANYNJ Design Guidelines made in post-Sandy review. |
| **PortSide NewYork 2016** | Red Hook WaterStories: Red Hook Container Terminal | Virtual Museum | Record culture and history of the Red Hook community through oral histories and feature essays. |
| **NYS2100 2013** | Recommendations to Improve the Strength and Resilience of the Empire State's Infrastructure | Gov't Report | Identify vulnerabilities and recommend resilience improvements for all state infrastructure. |
| **NIAC 2015** | Transportation Sector Resilience Final Report and Recommendations | Gov't Report | Identify gaps and opportunities in national transportation system resilience. |
| **MarEx Staff 2012** | Update: Assessment and Response from Storm Damage Caused by Hurricane Sandy Begins | Journalism | October 30, 2012 |
| **Campbell 2012** | Sandy snarls NY Harbor oil logistics, NYMEX gasoline delivery | Journalism | November 1, 2012 |
| **Gebrekidan 2012** | More NY oil terminals online, gasoline lines persist post Sandy | Journalism | November 4, 2012 |
| **Strunsky 2012** | Port resumes operations in Sandy's wake | Journalism | November 4, 2012 |

Table 3 – Direct Damages

| **Table 3 - Direct Damages**<br><br>**Table of direct damages reported by interviewees and reports. X's in rightmost columns indicate stakeholder groups which bore the burden of recovering from each impact by, for instance, paying the costs of repairs.** | **Port Authority (Internal)** | **Operator (Internal)** | **Tenants & Clients (Contractual)** | **Public Policy** | **Community** |
|---|---|---|---|---|---|
| **Damage to port facilities** | | | | | |
| Damage to berths | | X | X | X | |
| Damage to security cameras | | X | X | X | |
| Damage to security fence | | X | X | X | |
| Damage to water pump at fire stations | X | | | X | |
| Damage to fuel pumps | | X | X | X | |
| Damage to oil tanks | | X | X | X | |
| Damage to pump stations | X | | | X | |
| Damage to sheds | | X | X | X | |
| Damage to storm drains | X | | | X | |
| Damage to transformers | | X | X | X | |
| Damage to underground infrastructure (generally) | X | X | X | X | |
| Damage to port facilities (generally) | X | X | X | X | |
| **Damage to terminal equipment** | | | | | |
| Damage to cargo handling equipment | | X | | X | |
| Damage to computer systems | X | X | X | X | |
| Damage to cranes | | X | | X | |
| Damage to CBP radiological screening equipment | | | | X | |
| Damage to trucks | | X | X | X | |
| **Damage to vessels** | | | | | |
| Barge stranded on berth | | | X | | |
| Damage to barges (generally) | | | X | | |
| **Damage to goods or cargo** | | | | | |
| Flooded cars | | | X | | |
| Containers washed away | | | X | | |
| Damage to goods or cargo (generally) | | | X | | |

Table 4 – Indirect Costs

| **Table 4 - Indirect Costs**<br><br>**Table of indirect reported by interviewees and reports. X's in rightmost columns indicate stakeholder groups which bore the burden of recovering from each impact by, for instance, writing off lost revenue.** | **Port Authority (Internal)** | **Operator (Internal)** | **Tenants & Clients** | **Public Policy** | **Community** |
|---|---|---|---|---|---|
| **Costs of Recovery** | | | | | |
| Cost of renting generators to run cranes during repairs | | X | | | |
| Cost of environmental compliance during repairs | X | X | X | X | |
| Cost of hiring private security during repairs to security systems | | X | | | |
| Obligation to conduct facility inspections to identify damages | X | X | X | | |
| Costs of retrieving rerouted cargo | | | X | | |
| Obligation to survey aids to navigation | | | | X | |
| Obligation to conduct facility security inspections | X | X | X | X | |
| Obligation to survey waterways for shoaling | | | | X | |
| Obligation to survey waterways for debris/obstacles | | | | X | |
| Cost of oil spill containment | | X | X | | |
| Costs of environmental hazard containment (generally) | X | X | X | X | |
| **Navigational Impairment** | | | | | |
| Damage to aids to navigation | | | | X | |
| Adrift vessels | | | X | X | X |
| Containers floating in the waterway | | | X | X | |
| Debris in waterway | | | X | X | |
| **Interruptions to Operations** | | | | | |
| Closure of waterways | | | | X | |
| Damage to administrative offices impaired operations | X | X | X | X | |
| Evacuation of vessels from the harbor | | | X | | |
| Lost wages | | | | | X |
| Interruption to operations during recovery (generally) | X | X | X | X | X |
| **Impacts on Port-Dependent Commerce** | | | | | |
| Disruption of sewage transit services | | | | X | |
| Disruption of tug and barge service | | | X | | |
| Disruption of water taxi service | | | X | | |
| Disruption of ferry service | | | X | | |
| Cargo delayed and rerouted to other ports | | | X | | |
| Disruption of the flow of blood and medical supplies | | | X | X | X |
| Disruption of the flow of emergency supplies | | | X | X | X |
| Disruption of the flow of food supplies | | | X | X | X |
| Disruption of the flow of goods (generally) | | | X | X | X |
| Widespread, long-term fuel shortage | | X | X | X | |

Table 5 – Intangible Consequences

| **Table 5 - Intangible Consequences**<br><br>**Table of intangible consequences reported by interviewees and reports. X's in rightmost columns indicate stakeholder groups which bore the burden of recovering from each impact by, for instance, dedicating time and effort to resolving an impairment of normal operations.** | **Port Authority (Internal)** | **Operator (Internal)** | **Tenants & Clients** | **Public Policy** | **Community** |
|---|---|---|---|---|---|
| **Port Damages which Impair Port Recovery** | | | | | |
| Private operations cannot resume until PANYNJ operations resume | X | | | | |
| Disruption to communication systems | | | | X | X |
| Inability to use roads due to damaged traffic signals | X | X | | X | |
| Inability to work effectively due to damaged lighting | X | X | X | X | |
| Debris on roads and terminals | X | X | X | X | |
| Damage to equipment for harbor surveying | | | | X | |
| Sewage backup from overflowing combined sewers | X | X | | X | |
| Damage to back-up generators | X | X | | X | |
| **Emergency Conditions which Impair Port Recovery** | | | | | |
| Severe cold without fuel supplies | X | X | X | X | X |
| Obligation to revisit and reassess pre-storm long-term plans | X | X | X | X | |
| Burdensome paperwork | X | X | X | X | X |
| Widespread, long-term power outages | X | X | X | X | X |
| Stress from performance of tasks outside training and job duties | X | X | X | X | |
| Difficulty learning new disaster recovery regulations and procedures | X | X | X | X | |
| Personnel unable to reach port facilities | X | X | X | X | |
| Personnel contending with damage to own homes | X | X | X | X | X |
| Emotional toll of the widespread damage | X | X | X | X | X |
| Widespread devastation throughout the community (generally) | | | | X | X |
| **Port-Related Damages to the Surrounding Community** | | | | | |
| Ecological damage of oil spills | | X | | X | |
| Oil carried inland by surge | | | | | X |
| Sediment washed onto shore | | | | X | X |
| Containers washed onto shore | | | X | X | X |
| **Consequences of Port Disruption to the Broader Economy** | | | | | |
| CBP operations delayed by damage to computer systems | | | | X | |
| Cruise ships rerouted from destination | | | X | | |
| Cruise ships' passengers' cars destroyed in terminal parking lots | | | | | X |
| Disruption of the flow of goods during the holiday season | | | X | | X |
| Disruption of the global supply chain | | X | X | | |
| Disruption of international fuel market due to fuel shortage | | X | X | | |
| Impairment of regional recovery due to fuel shortage | | | | X | X |

Table 6 – Impacts Reported as Affecting 4 or 5 Categories of Stakeholder

| **Table 6 – Impacts Reported as Affecting 4 or 5 Categories of Stakeholder**<br><br>**X's in rightmost columns indicate stakeholder groups which bore the burden of recovering from each impact.** | **Port Authority (Internal)** | **Operator (Internal)** | **Tenants & Clients (Contractual)** | **Public Policy** | **Community** |
|---|---|---|---|---|---|
| **Direct Damages – Damage to port facilities** | | | | | |
| Damage to underground infrastructure (generally) | X | X | X | X | |
| Damage to port facilities (generally) | X | X | X | X | |
| **Direct Damages – Damage to terminal equipment** | | | | | |
| Damage to computer systems | X | X | X | X | |
| **Indirect Costs – Costs of Recovery** | | | | | |
| Cost of environmental compliance during repairs | X | X | X | X | |
| Obligation to conduct facility security inspections | X | X | X | X | |
| Costs of environmental hazard containment (generally) | X | X | X | X | |
| Damage to administrative offices impaired operations | X | X | X | X | |
| Interruption to operations during recovery (generally) | X | X | X | X | X |
| **Intangible Consequences – Port Damages which Impair Port Recovery** | | | | | |
| Damage to lighting | X | X | X | X | |
| Debris on roads and terminals | X | X | X | X | |
| **Intangible Consequences – Emergency Conditions which Impair Port Recovery** | | | | | |
| Severe cold weather following days after the storm cut off fuel supplies | X | X | X | X | X |
| Obligation to revisit and reassess pre-storm long-term plans | X | X | X | X | |
| Burdensome paperwork | X | X | X | X | X |
| Widespread, long-term power outages | X | X | X | X | X |
| Personnel must perform tasks outside their training and job duties | X | X | X | X | |
| Difficulty learning new disaster recovery regulations and procedures | X | X | X | X | |
| Personnel unable to reach port facilities | X | X | X | X | |
| Personnel contending with damage to own homes | X | X | X | X | X |
| Emotional toll of the widespread damage | X | X | X | X | X |

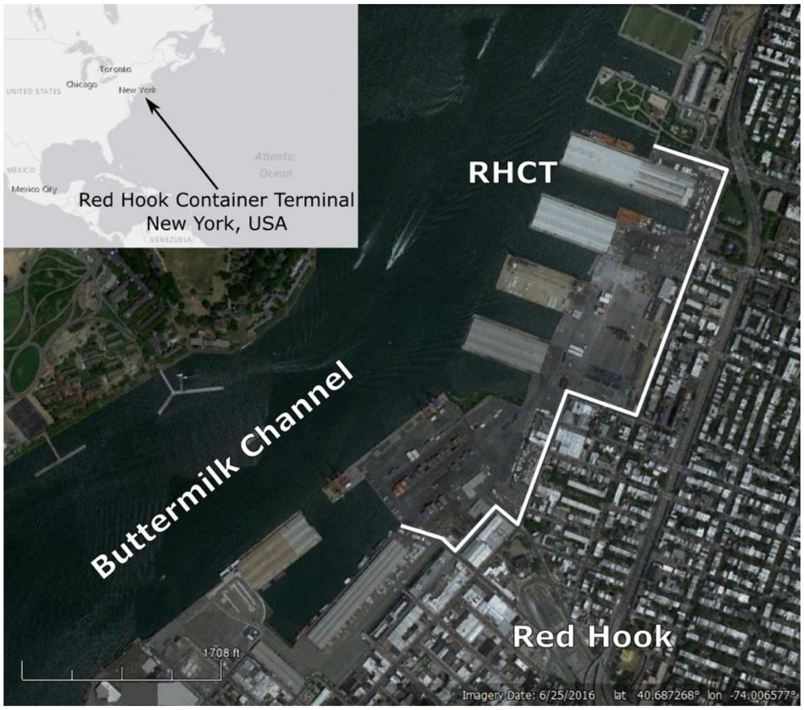


Figure 1:
Red Hook Container Terminal is in Brooklyn, New York, USA at the mouth of New York Harbor and is the easternmost terminal in the Port of New York and New Jersey. The terminal is positioned along Buttermilk Channel, across from Governor's Island. Imagery generated by Google.