The MIT CTL Port Resilience Survey Report

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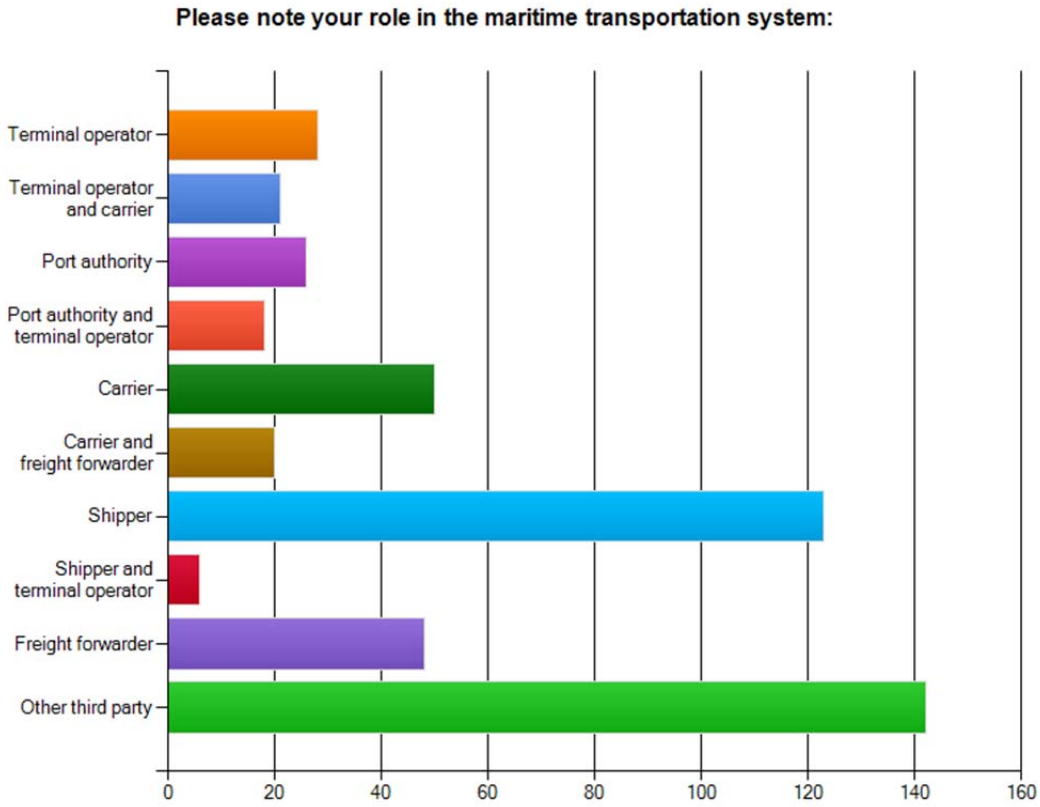
Section 1: Introduction

Maritime and inland ports in the United States handle about 77% of the cargo by weight

that enters the country every year, and in 2007 accounted for an estimated $2 trillion of the nation's $13 trillion GDP. Clearly (sea)ports play a pivotal role in the U.S. economy, yet to-date the resilience of these vital gateways to the threat of disruption has not been studied in detail. Companies have attempted to increase resilience in their conveyances through sea ports by introducing multiple contracts with facilities to spread the risk of disruption. But there is no evidence in the literature to suggest that port resilience is a critical issue for terminal operators, vessel operators, port authorities, and various officials operating within the sea port environment. As there is no observed evidence either of any meaningful application of the concepts of resilience to the maritime environment.

Given the lack of industry perspective, the MIT Port Resilience Team conducted a literature review and subsequently a preliminary survey of actors in ports to get a general understanding of their experience with disruptions in ports and their opinions about what is necessary to create resilient ports. The intent of the survey was to provide an initial assessment of the experience of port actors as well as the opinions of those port actors regarding the need and best methods to achieve resilience in ports. The survey was the first of its type to solicit input on the port resilience. The survey attempted to collect data on opinions regarding critical operating systems and processes in ports, and experience data on delays segmented by impact area – intermodal connections, terminal operations, and waterways.

The on-line survey collected responses from 525 shippers, carriers, terminal operators, port authorities, third parties, freight forwarders and others operating in the port environment. The largest distinct respondent group was shippers (123). Carriers and terminal operators were also well represented in the survey (see graph below).



Several methods were used to analyze the data. A special effort was used to use the Structural Equation Modeling (SEM) method to extract additional insight, particularly regarding respondent intentions from the survey. The SEM analysis entailed several stages of analysis that included exploratory factor analysis using the 29 coded question areas, and then associating these coded questions with others that may contribute to resilience. The results from this analysis are reported in a separate report.

Section 2: Background

Prior to identifying ways to improve the resilience of supply chains within seaports, it is important first to understand the present condition of the port environment. As noted above, the MIT Port Resilience team conducted a literature review and a broad survey or port practitioners in an attempt to understand of the experience and perspective of port actors regarding disruptions and resilience. To our knowledge the survey was the first survey and research work examining this topic.

We've started calling the resilience of the supply chain within the environment of the sea port by a special name – 'port resilience' – at some risk. We recognize that this is not an accurate term in that there are many dimensions of what might be considered 'port resilience.' One can fairly ask:

- Is port resilience the resilience of the Port Authority?
- Is port resilience the resilience of the terminals?
- Is port resilience the resilience of the collection of terminals and operators within a defined port, i.e. the resilience of a single port?
- Is port resilience the resilience of the 310+ system of ports in the United States that do not act or operate like a coordinated system?
- Does port resilience include preventative and security measures?

We propose some explanations and suggestions in this report and hope that our efforts are more clarifying than confusing.

In reviewing the literature, the concept of port resilience has not received a great deal of attention – perhaps because the industry is complex and not easy to analyze. Many commercial and government organizations coexist within the confines of ports, and various types of cargo pass in and out of terminals in accordance with strictly enforced regulations and constraints. Even though most ports are overseen by some form of management authority, their component facilities are owned by a patchwork of private and public interests. Moreover, the various entities that make up a port appear to have limited visibility to the day-to-day challenges that exist outside of their immediate operations.

Another possible reason for the lack of attention is that in general ports function fairly smoothly as cargo processing and distribution centers. There is a predictable throughput time for cargo clearance entering and leaving ports, and while it is not considered rapid, it is predictable. The anecdotal data suggests that material flows through ports have not suffered from significant delays except in the most extreme cases of port disruptions (e.g. Haiti, Katrina, Sendai, etc.[1])

There are relatively few instances where companies are adversely affected by disruptions aside from major events such as protracted labor stoppages. The actors are able to handle the delays in most cases without significant impact on customer service. At least this is what the data seems to suggest.

From a country-wide perspective, the 310-plus operating water-based ports that make up the maritime transportation system (MTS) in the US do not work together as a cohesive national network of cargo handling facilities. While it is true that collectively US ports handle enormous volumes of export and import cargo, these activities are not coordinated by any central or overarching entity. In effect, there is no national port system in the US, but a collection of facilities that operate independently according to free market forces and government regulation. Also, since the volume of cargo handled is concentrated in a relatively small number of major facilities, government MTS policy

[1] These refer to recent disasters in these locations that have had significant effect on local port operations.

tends to be skewed towards these larger ports. For the purposes of this report, MTS will be used when referring to the maritime transportation system within ports, excluding non-port related aspects of the MTS.

Given these complexities it is perhaps not surprising that the port environment is not broadly or well understood.

Section 3: Resilience and Port Resilience

The National Center for Secure and Resilient Maritime Commerce has two primary study areas that are interrelated: maritime domain awareness and port resilience. This study was focused on the latter, port resilience, which is discussed in this section.

In order to carry out a thorough study of port resilience it is important to define the concept first. Possible definitions for both resilience and port resilience are described below.

Defining Resilience

The term resilience[2] is defined in the Merriam-Webster online dictionary as "1: the capability of a strained body to recover its size and shape after deformation caused especially by compressive stress AND 2**:** an ability to recover from or adjust easily to misfortune or change." According to Dictionary.com, the word dates back to 1620-1630 (M-W states the date is 1824) and is derived from the Latin 'resil' which is the present participle of 'resilire' meaning to spring back, rebound. This is consistent therefore with the current application of the term resilience in material science, where "(R)resilience is the physical property of a material that can return to its original shape or position after a deformation that does not exceed its elastic limit. In today's business environment, resilience is widely used to characterize an organization's ability to react to an unexpected disruption, such as one caused by a terrorist attack or a natural disaster, and restore normal operations."[3]

For the purposes of our work, we are defining supply network resilience as 'the ability to react to unexpected disruption and restore normal supply network operations.'[4]

While our definition is straightforward and simple, several other authors have offered nuanced versions of the definition of resilience and supply chain resilience that are worth reviewing for reference. They share the common theme of a system that has the

[2] The term 'resiliency' is sometimes used in lieu of resilience. The term resiliency is a more recent adaptation of the term resilience, and there is no difference in meaning. For the purposes of this work, the authors choose to use the more traditional term resilience.
[3] From Rice, Caniato SCMR 2003
[4] From Rice, Caniato 2003

ability to handle some sort of impact, deformation, or disruption. Coutu suggested resilience in organizations is 'the ability to bend and bounce back from hardship.'[5] Sheffi added the useful dimension of "the speed at which they can return to their normal performance level (production, services, fill rate, etc.) following a disruption.[6] [7] Christopher and Peck provided a broad discussion of the term and noted the problems of many different terms that are synonymous with or related to resilience (e.g. robustness, risk, vulnerability). Their definition includes the added aspect of not only returning to the original state after impact/deformation, but moving "to a new, more desirable state after being disturbed" which implicitly introduces the concepts of adaptability and flexibility as it suggests the possibility that the new end state is different than the original state.[8] According to the US GAO, "DHS defines resilience as the ability to resist, absorb, recover from, or adapt to adversity."[9] There are other definitions offering interesting views and other terms that provide related capabilities,[10] but these capture the key distinctions for consideration.[11]

The Scope and/or Boundaries of the Port

We define the boundaries of the port to include the navigable waterways from anchorage to berth, land-side terminals and terminal operations, gate operations and infrastructure (local roads, bridges, pipeline and rail) through to intermodal connections or public highways, class 1 rail and pipeline systems. Put another way, the "system borders for the maritime transportation system…are *where the goods exit the port domain*. In this, navigable waters such as turning basins, canals and waters leading into open sea is included, open water transit is not. Similarly, on the land side, when goods exit the port infrastructure into the main logistics systems such as the public highway or main rail system (the hinterland transportation system), it is no longer within a port domain."[12] Vessels are important elements of the maritime transportation domain, but for the main purpose of our work on port resilience, we do not include them in the scope of the port.

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[5] From Coutu, HBS May 2002, "How Resilience Works"

[6] Sheffi, "Resilience Reduces Risk" in Logistics Quarterly, March 2006.

[7] Some organizations define the firm's resilience in terms of their ability to return to a specific performance or service level that may be different than the 'normal' service level. For example, one approach is for firms to target a level of resilience where the supply chain can respond without impacting service to the end customer (or a subset of customers).

[8] From Christopher and Peck, Building the Resilient Supply Chain, International Journal of Logistics Management, Vol. 15 No. 2., pp 1-13, 2004

[9] U.S. GAO – Critical Infrastructure Protection "An Implementation Strategy Could Advance DHS's Coordination of Resilience Efforts across Ports and Other Infrastructure" GAO-13-11, October 25, 2012

[10] Terms such as reliability, risk, vulnerability, flexibility, robustness, agility, and redundancy are related and often used to describe some of the characteristics of resilience. Among others, Berle, et al address this in their work – Failure Modes in maritime transportation – a functional approach to throughput vulnerability MPM 2011

[11] Mansouri, et al "A Decision Analysis Framework for Resilience Strategies in Maritime Systems" 2009 INCOSE

[12] Berle, Ø., Rice, J. and Asbjørnslett, B.E. "Failure modes in the maritime transportation system: a functional approach to throughput vulnerability" Maritime Policy & Management, Volume 38, Issue 6, 2011

The Port Environment/Perspective of the Parties

Terminal operators, port authorities, carriers, vessel operators, users, and regional/state/federal governments all have different objectives and therefore it is likely that they would have different interpretations for the definition of port resilience. One might ask:

- Is port resilience the resilience of the Port Authority?
- Is port resilience the resilience of the terminals?
- Is port resilience the resilience of the collection of terminals and operators within a defined port, i.e. the resilience of a single port?
- Is port resilience the resilience of the 310+ system of ports in the United States that do not act or operate like a coordinated system?

These questions help reveal the implicit conflict in applying the term in the maritime transportation domain. For example, port resilience for a terminal operator may mean the ability of their terminal to maintain operation in the throes of a disruption at the port. Port resilience from the perspective of a port authority, however, would mean the ability of their specific port to continue receiving and shipping cargo in the face of a disruption at that facility (this may require the movement of cargo handling operations to different terminals within the port). In stark contrast, the federal government may think of port resilience as the ability of the domestic system of ports to handle disruptions and ensure that all cargo can be received/shipped domestically when needed, regardless of which port handles the cargo. This latter case implies that moving cargo between ports or diverting it to other facilities would occur. But a port authority will likely reject that approach as their economic incentive is dependent on their ability to maintain cargo flow through their port and not through other ports in the system. Hence, a conflict exists between what the federal government may view as port resilience, and what a port authority may view as port resilience. In the definition this conflict is addressed by noting the perspective of the party, i.e. the 'port environment'. In this case the port environment means the scope of the system of ports in question. This can mean an individual port, a regional set of ports, the ports in a single state, or the collective ports across the country.

Port Resilience Definition

There are a number of different factors that affect how one defines Port Resilience. Also, the concept has different meanings depending on which party is defining it. The primary factors that affect the definition include:

- The scope and/or boundaries of the port; and
- The port environment/perspective of the party.

One might ask how this new capability or measurement of the system's capability – port resilience – compares with the more traditional measures of port system capabilities, efficiency, throughput and reliability.

For the purposes of our work, we are defining port resilience as 'the ability of the port environment (whether it is an individual port or system of regional or national ports) to react to unexpected disruption and restore normal cargo handling and port operations.'

We are tempted to qualify the capability by adding a phrase that defines the speed or service level that the port environment would maintain. One common approach is to note resilience as the ability to maintain operating volume with delays that do not affect the end customer. This truly should be left to the specific port environment to determine, and this service level would then drive the necessary actions and measures to make the port environment suitably 'resilient' to that service level.

Issues

In addition to the implications of the above definition, port resilience – starting at the individual port level – is a function of the resilience of the core components within the port: the resilience of the navigable waterways, the resilience of the terminals (berths and terminal operations), the resilience of the infrastructure connecting to intermodal connections and highways, and the resilience of the intermodal connections. Currently, these are not studied at this level nor are capacities of these respective systems known or understood well. Ultimately, in order for one to create resilient ports, each of these components will need to be resilient.

Given that the different environments call for different measures, we can safely say that overall to create port resilience, one would need:

- Resilient individual ports,
- Resilient system of ports, and
- Resilient components of ports (resilient terminals, resilient intermodal connections, resilient infrastructure, resilient navigable waterways).

And resilient ports go beyond emergency response, to include prior action that enables resilience post-incident; this includes but is not limited to Trade Resumption activities, and extends to maintaining economic activities of the parties operating within the port and dependent upon the port.

Resilience in the Context of Reliability

Traditional performance measures for the maritime transportation domain – within seaports – are efficiency and reliability. How is port resilience different?

Bichou notes the importance of network reliability[13] which "studies the vulnerability and robustness of a transportation network including topics of connectivity, link failure, disruption and redundancy, vulnerability and security." Using these definitions, the term reliability and resilience are nearly indentical. The main distinction between reliability and resilience seems to be 'security' which is included in the study of reliability but is not in the development of resilience. Security falls into the category of actions that may be taken to reduce the probability of an incident or disruption, whereas resilience is primarily focused on reducing the consequences of the disruptions. A brief excerpt is included in a footnote.[14]

Section 4: Limitations to the Research

It is important to note that the survey was conducted using non-probability convenience-based sampling methods that do not permit assessing whether the respondents are representative of any specific population.

This method was selected as a first foray into developing an understanding of the dynamics in ports and the general experience and understanding of those operating in the port environment. The nature of this sampling does not permit making forecasts or assertions beyond synthesizing for the respondent pool, but the data does raise some interesting questions and issues that may promote meaningful exploration and theory development. The sampling method does limit the ability to draw statistically significant conclusions about the total population, although the responses are useful in providing a broad range of performance and issues that may serve as a baseline for subsequent study.

13 Port Operations, Planning and Logistics by Bichou, 2009 (Lloyd's Practical Shipping Guides), from pp 20 under 2.2.2 Reliability

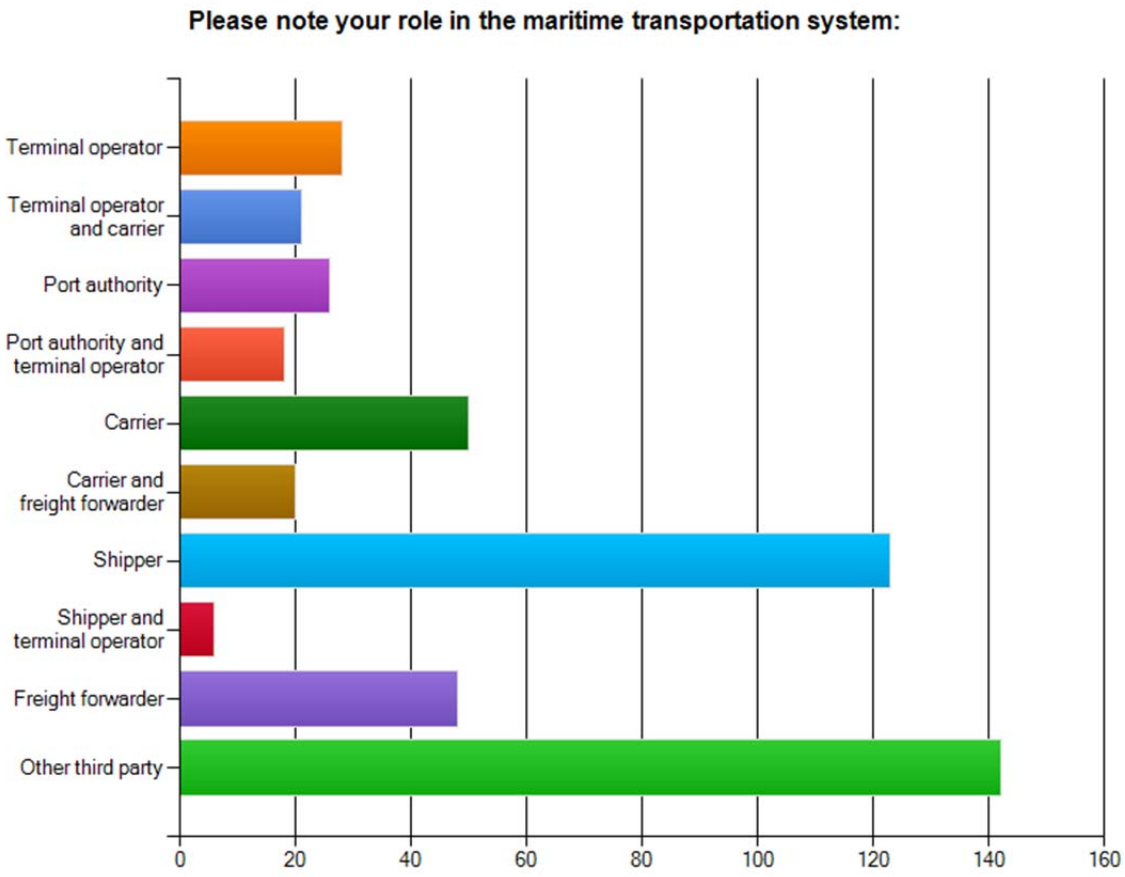
14 Ibid. "The potential sources of disruption to port systems and networks are numerous, ranging from routine events such as congestion and equipment failure to exceptional disasters such as earthquakes, terrorist attacks, ship collisions and other major accidents. The cause, scale, impact and frequency of such events will vary extensively, but it is possible to design and manage port systems and operations in ways that enhance the predictability of such events, minimise the disruptions they may cause, and improve the robustness and redundancy of the port system against such disruptions. Here, the concept of risk assessment and management becomes a key element in the study of a system's reliability. Risk assessment and evaluation is a well-established engineering process for identifying hazards, their probabilities and consequences, assessing the acceptability of risks and taking remedial action to address unacceptable risks. Vulnerability is another concept closely related to risk in that it encompasses both probability and consequences. Generally, vulnerability is defined as the likelihood of severe adverse consequences. Therefore, vulnerability may be interpreted as being the opposite of reliability." Bichou further notes that "reliability in ports include aspects that go beyond the field of transport network reliability, for instance, terminal reliability, capacity reliability, operational reliability, transit (travel time) reliability and encounter reliability."Bichou further rightly expands on potential sources of disruption to ports and the role of risk management. His work is exceptional and provides a solid foundation for further study of this topic.

Section 5: Respondents

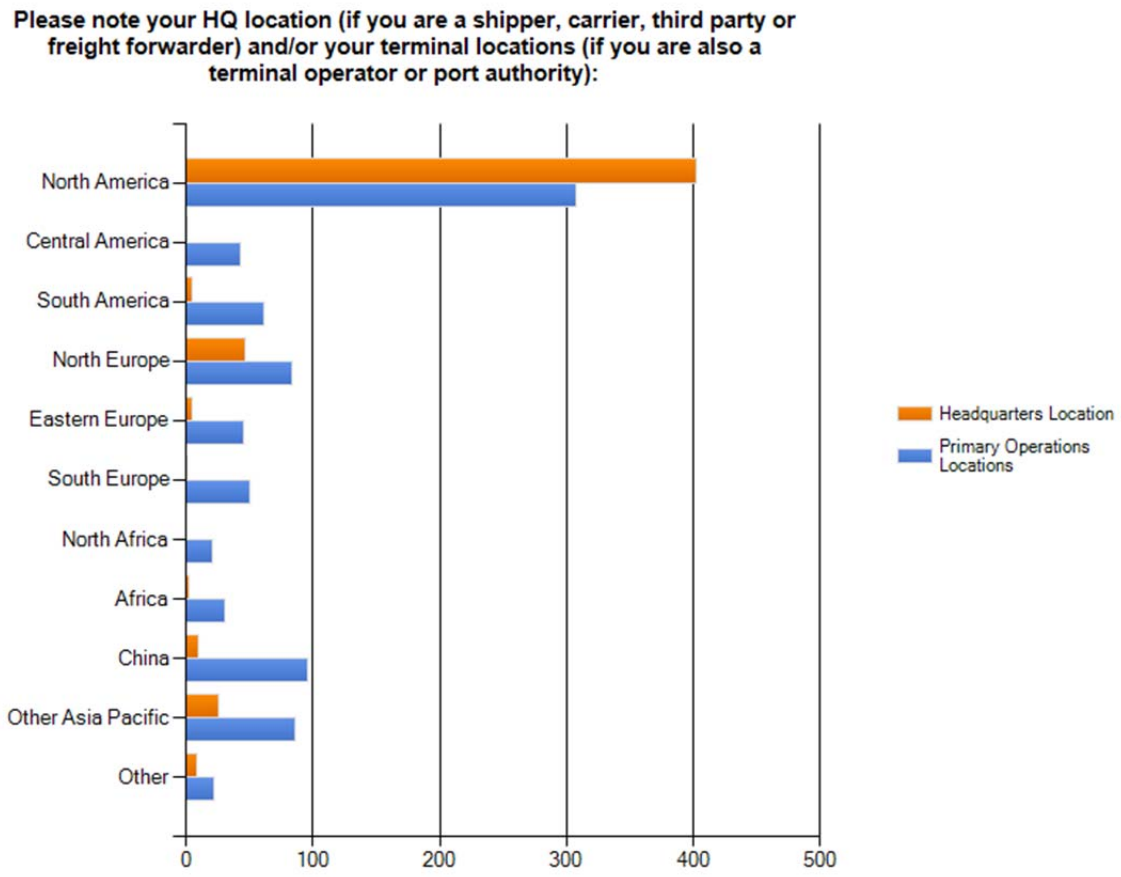
The survey of port stakeholders is part of a larger study that also includes supplementary interviews and site visits. This work was carried out from November 2009 to February 2010.

The on-line survey collected responses from 525 shippers, carriers, terminal operators, port authorities, third parties, freight forwarders and others operating in the port environment. The largest respondent group was shippers (123). A solid group of carriers (50) responded, including more than 50 that identified themselves as focused or multi-role terminal operators (terminal operators also serving as port authorities or carriers). Additionally there were over 180 other respondents covering a range of service providers (third parties, freight forwarders, consultants). The survey collected data on their opinions regarding critical operating systems and processes in ports, and their experience (data) on delays segmented by impact area: intermodal connections, terminal operations, and waterways.

Respondents were asked to categorize themselves as either single-function entities (e.g. carrier only, terminal operator only) or multi-function entities (e.g. terminal operator and carrier, terminal operator and port authority). We intuited that the experience and perspective of each entity will vary based on these categories. The data seem to support the idea that these are indeed distinct entities. While we had over 50 respondents identify themselves as multi- or single-role terminal operators, their responses were distinct and therefore we did not consolidate their responses into a single Terminal Operators category. The same is true for responses from multi-function carriers and freight forwarders.



Most respondent entities were headquartered in the United States, with a small number in Northern Europe and Asia. In most cases respondents' primary operating location was North America, although they did indicate representation across the globe. This reflects both the global nature of cargo shipments today but also the global nature of firms in the business. While there are surely local terminal operators that service a local area, it would seem that many organizations have operations located around the world.



Section 6: Survey Design

After two questions on demographics (presented above), the stakeholders were asked a series of eleven questions that covered three broad areas of inquiry.

- What critical systems and actions need to be addressed in order to make ports resilient? (two critical system and action questions)
- What port delays do stakeholders experience in terms of frequency, average length, and the length of the longest delay? These responses were collected in three different areas of port activity: intermodal connections, terminal operations, and navigable waterways. (six delay questions)
- What impact do regulations have on port resilience? (three questions on regulation)

The respondents provided direct input to a series of questions. In some of the questions, the respondents were asked about resilience, and we defined resilient as "being capable of handling disruptions and delays without long term impact on continuing operations and without significant impact on the ability to serve the

customer." Where possible and when it made sense, similar response options were provided to permit some comparative analysis of the responses. This was not always possible or appropriate – for example, when providing response options for delay frequency, Waterway Operations would understandably have different responses (e.g. channel clearing systems) than those for Terminal Operations (e.g. equipment availability (cranes, material handling equipment).

The respondents were guided to answer specific questions that were appropriate for them. Specifically, carriers were not given the opportunity to respond to questions about terminal operations or intermodal connections.

In the final set of questions, all respondents were asked to provide an assessment of the impact of government policies and enforcement on delays in ports, and a 4-point scale with an option for Not Applicable was provided (range from No Impact to Significant Impact).

1. Port operations, processes and systems that need to be resilient:
    a. 14 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
2. Most important actions that can be taken to reduce the impact of disruptions to ports
    a. 14 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
3. Frequency of observed or experienced disruptions in Waterway Operations in the past 5 years
    a. 9 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
4. Length of delays in Waterway Operations
    a. 9 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
5. Frequency of observed or experienced disruptions in Terminal Operations in the past 5 years
    a. 11 options plus comment box
    b. Selection among options

    c. Comments
    d. Analysis
6. Length of delays in Terminal Operations
    a. 11 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
7. Frequency of observed or experienced disruptions in Intermodal Connections in the past 5 years
    a. 11 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
8. Length of delays in Intermodal Connections
    a. 11 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
9. Impact of Regulation: extent that government policies and enforcement impact the delays in ports
    a. 8 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
10. Opinion about what regulations make ports more resilient
    a. Comment box responses only
    b. Analysis
11. Opinion about what regulations make ports more resilient
    a. Comment box responses only
    b. Analysis

It is important to note that the survey was conducted using non-probability convenience-based sampling methods that do not permit assessing whether the respondents are representative of any specific population. The sampling method does limit the ability to draw statistically significant conclusions about the total population, although the responses are useful in providing a broad range of performance and issues that may serve as a baseline for subsequent study. See **Section 4: Limitations to the Research** above for additional discussion.

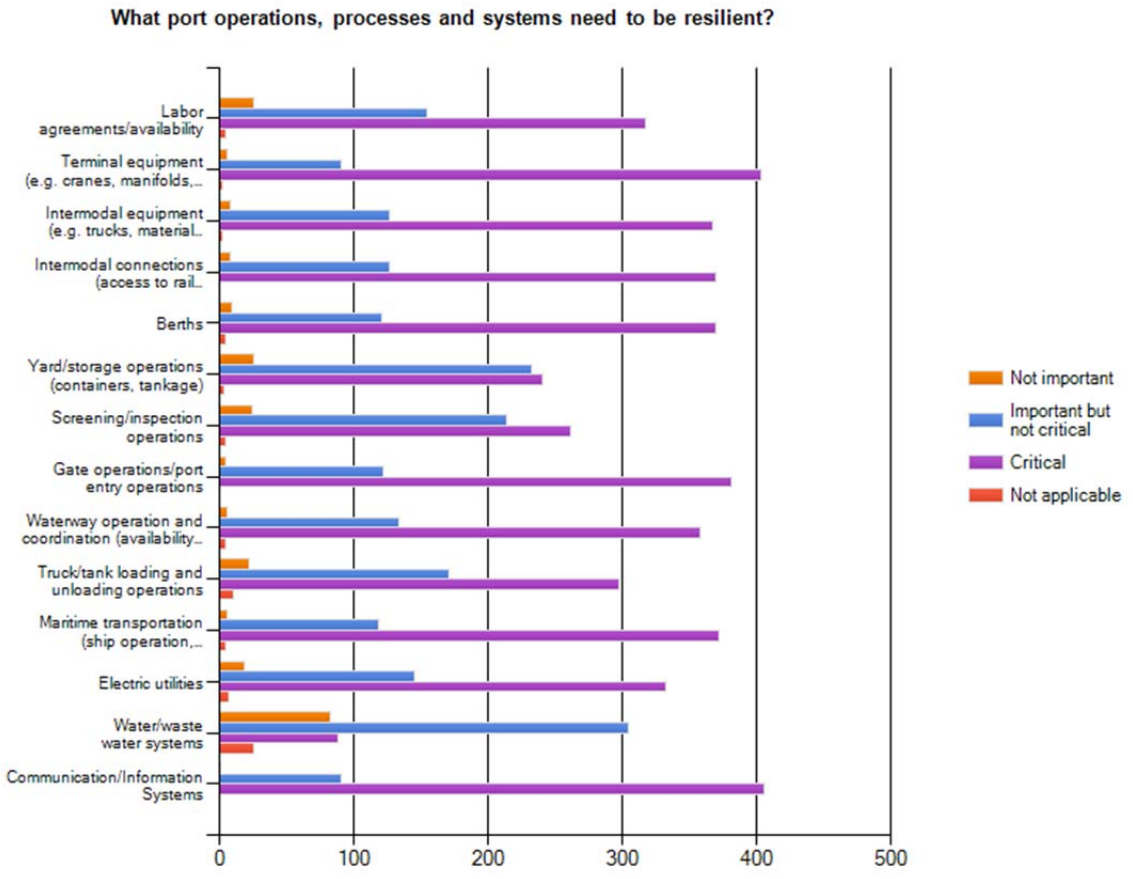
Section 7.1: Responses to Critical Systems and Actions

Critical Systems

All respondents were asked two questions regarding resilience. The first question asked was

"What port operations, processes and systems need to be resilient?"

Fourteen operations, processes and systems were provided and respondents were given a 4-point scale (Not important, Important but not critical, Critical, Not applicable) for their response to each.



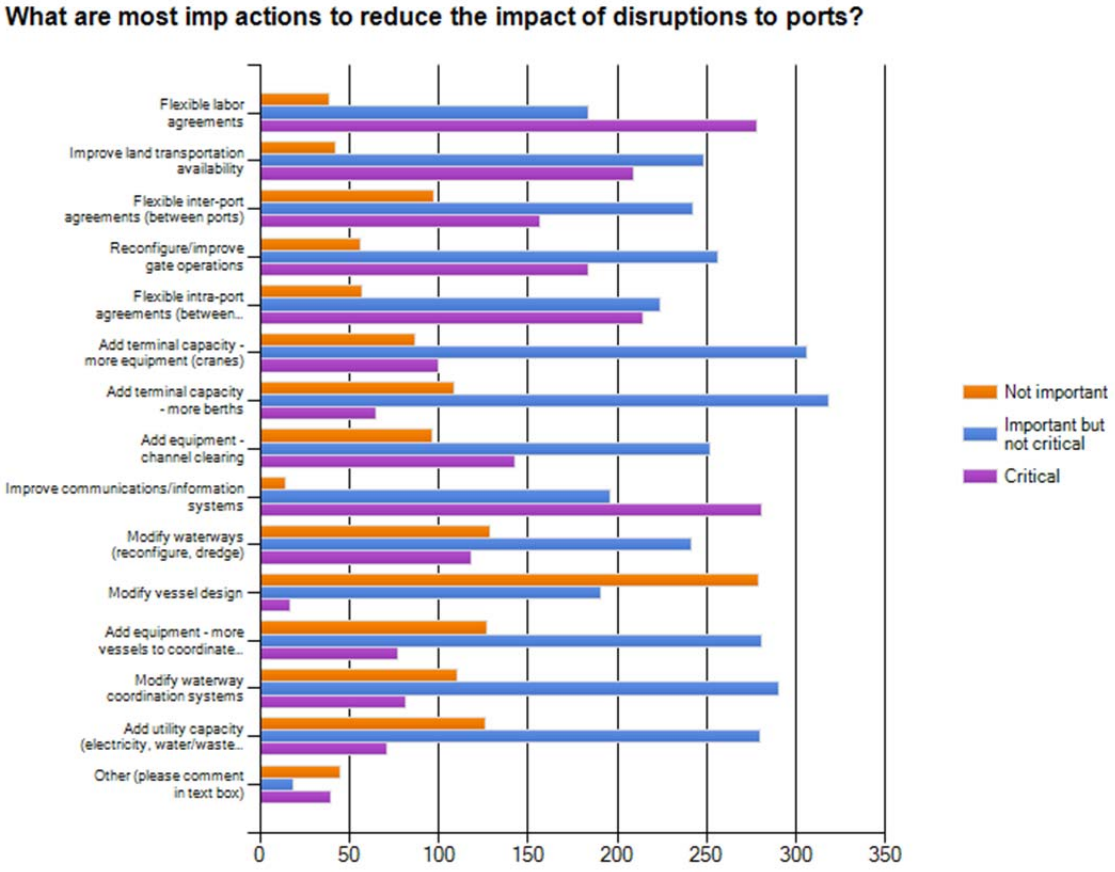
As the above chart shows the majority of respondents regard nearly all of the systems and processes that make up a port as critical. The survey respondents were consistent in identifying nearly all elements (~90%) of each port function as critical (14 systems and processes were identified).

Critical Actions

The second question regarding resilience was

"What are the most important actions that can be taken to reduce the impact of disruptions to ports?"

As was the case for the first question regarding resilience, fourteen operations, processes and systems were provided and respondents were given a 4-point scale (Not important, Important but not critical, Critical, Not applicable) for their response to each. Although the question did not use the term 'resilience' in soliciting a response, by asking about critical actions to reduce the impact of disruptions, the question intended to get at the actions necessary to make a port resilient.



Two critical actions surfaced as the primary selection for the majority of the respondents: Improve communication/information systems and Flexible labor agreements. Interestingly enough, both of these represent processes more than capacity. Processes generally provide flexibility whereas capacity usually provides

redundancy. In the realm of supply chains, this represents the difference between training your work force to handle multiple tasks versus investing in and maintaining extra inventory. Flexibility allows you to use your resources in different ways and configurations; redundancy provides instantaneous capacity and pays great benefits when used. However, unlike flexibility which is used to deal with day-to-day variations and therefore makes the system more effective and efficient, redundancy provides no benefit until it is used, and is a limited resource that disappears once that redundancy is used up. Our research has found that while it is prudent to have both redundancy and flexibility in supply chains, in general it is more effective to invest in flexibility because it can pay benefits on an ongoing basis. Still, systems do need some measure of redundancy in order to operate; the challenge is defining how much is necessary.

Within the MTS, redundancy may be maintaining excess berths, having additional capital equipment (e.g. cranes) or back up gate operations available as needed. Flexibility in the MTS may be having agreements with multiple terminals to provide options in case of delay within the port. Another option is maintaining gate operations that can be reconfigured to handle more incoming or outgoing trucks as the need arises, or that can be operated in the event of a power or IT failure.

Implicitly the respondents imply a need for flexibility although their experience suggests capacity is the source for their outages. In fairness, the respondents did identify several important actions that entailed system capacity, but they clearly defined these as 'not critical.'

Interestingly, labor issues are often cited as problematic in ports and a cause of disruptions. However, the survey does not suggest that these issues represent a frequent or significant source of port-related delay.

Observation

The total respondent pool overall provided a unanimous assertion that virtually all port operations and systems were critical for resilience. When asked which were the most important actions to reduce the impact of disruptions in ports, the total respondent pool identified two key areas – communication / information systems, and flexible labor agreements were identified. These responses vary significantly by respondent type as noted below:

	Most Important Actions to Reduce Impact of Disruptions on Ports		
	Terminal Op	**Shipper**	**Non-Shipper**
Flex Labor	Critical	Critical	Critical
Flex Intra Port	Important	Critical	Important
Flex Inter Port	Important	Critical	Important

Terminal Equipment	Important	Important	Important
Intermodal Connections	Important	Critical	Important
Gate Ops	Important	Critical	Important
Waterway Ops	Important	Important	Important
Maritime Transportation	Important	Important	Important
Comm/Info Systems	Important	Critical	Critical

This highlights the very different perspectives of the various parties, and may illustrate the different perspective on what constitutes a resilient port. For example, the terminal operator is traditionally focused on reducing costs in operations, and therefore may view flexible labor agreements a critical need that may not have a comparative cost impact (all terminal operators must use the same labor at the same cost structure); terminal operators however bear the distinct cost of additional capacity that comes at a literal high cost to the operator. Considering the time of the data collection – 2009-2010 when cargo volumes and capacity utilization were dropping, it makes sense that the terminal operator may focus just on the exogenous flexible labor agreement. Shippers on the other hand place the ability to receive their cargo as the highest priority and therefore would identify all those capabilities that would further enhance their ability to get their cargo in a port disruption – that would include the flexible arrangements in ports, more capacity at intermodal and gate operations. Again, this suggests that analyzing the needs to make a port (all the operations and parties operating in the port) resilient requires considering the perspective and needs of those different parties.

The responses from these first two questions suggest a potential conflict – in the first the respondents indicated that nearly all systems were critical. Yet in the second question, the respondents noted that there were only two systems where actions could improve the resilience of the overall system. What explains this apparent inconsistency? Perhaps the respondents were indicating that literally every system is necessary in order to make the entire system work, but that only a few systems warrant action for the system to be considered 'resilient' – if this were the case then one might argue that the respondents are being very discriminating in choosing only a few systems for critical action – and implicitly they are suggesting that the system as it stands now is already resilient and does not warrant critical action. Is this the case? Considering the experience data which shows many small disruptions that the participants deal with regularly, it too suggests that the system is already resilient to a fair amount of variation in the system.

Operational Myopia

The respondents tended to report only those delays that relate to their specific areas of activity. Almost all of the shippers surveyed provided delay experience on intermodal connections, while carriers concentrated on waterway delays, and terminal operators focused on interruptions to terminal operations. This may not appear to be significant as one would expect the respondents to report on delays in their specific areas of interest. Yet the near unanimity of the respondents only reporting on a single area was striking, especially considering that these parties/entities share a common environment and even common sources of disruption that have domino effects down the supply chain. Further, there was one group that did report delays across multiple areas – freight forwarders – suggesting that the freight forwarders actually have broader visibility across the MTS than many of the entities in the port.

This result raises the question whether the entities have visibility or awareness of the activities in other functional areas of the port. One can argue that organizations need to be highly focused on their market niche in order to remain competitive. However, a wider operational perspective is important in such a complex operating environment that requires high levels of systems integration and coordination.

Processes versus Systems

Among the 25 systems/processes that were offered as candidate critical systems, the majority represented systems rather than processes. And the associated critical actions were capacity additions to those systems. Interestingly, the respondents selected two actions that were more process improvements rather than capacity additions. This is surprising given how the respondents identified the majority of the systems as being critical, and the concerns about capacity constraints in ports that have been reported prior to the financial and commercial business collapse in 2008-2009. The two selected actions involve process and not capacity improvements, indicating that processes are considered to be more critical than capacity-building measures to port resilience. While the systems are deemed to be critical, the recommended actions are for improving the processes and not adding capacity to systems.

Section 7.2: Responses to Port Delay Experience

The respondents were asked a series of questions relating to their experience with disruptions in the various segments of the MTS. These included frequency and length of delay by MTS segment – waterways, terminals, or intermodal connections as outlined by the questions below.

1. Frequency of observed or experienced disruptions in Waterway Operations in the past 5 years
    a. 9 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
2. Length of delays in Waterway Operations
    e. 9 options plus comment box
    f. Selection among options
    g. Comments
    h. Analysis
3. Frequency of observed or experienced disruptions in Terminal Operations in the past 5 years
    i. 11 options plus comment box
    j. Selection among options
    k. Comments
    l. Analysis
4. Length of delays in Terminal Operations
    m. 11 options plus comment box
    n. Selection among options
    o. Comments
    p. Analysis
5. Frequency of observed or experienced disruptions in Intermodal Connections in the past 5 years
    q. 11 options plus comment box
    r. Selection among options
    s. Comments
    t. Analysis
6. Length of delays in Intermodal Connections
    u. 11 options plus comment box
    v. Selection among options
    w. Comments
    x. Analysis

The respondents provided their observation and experience with delays in 28 different subsystems across three areas of operation within the port – terminal operations, intermodal connections and waterway operations. Few reported delays outside their primary focus area/interface (e.g. shippers experienced delays at the intermodal connections, terminal operators reported delays in terminal operations and carriers reported delays in waterways). Approximately half of the respondents reported incident

frequency annually or less frequent. But approximately a third reported relatively short delays (.5-1.5 days) from incidents that occurred quarterly or more frequently in many of the 28 subsystems. While the frequency of experiencing a delay in any one of the 28 subsystems is relatively small based on the survey input, the frequency or probability of a disruption or a delay-creating incident at any of the 28 subsystems may not be small – potentially as frequent as nearly every other week.

A system that has a delay-creating incident nearly every other week might be considered an ineffective system. Yet another interpretation that seems more likely is the opposite – that the overall supply chain and MTS in ports are effective. Despite relatively high frequency of incidents, the length of the delays is short enough to be more nuisance than crippling. One explanation how these frequent incidents do not cause larger delays may be that the users of port services have made accommodations in their supply chain to allow for these delays without compromising service to their end users. This is traditionally accomplished by carrying additional inventory or planning with longer cycle times. This can be a workable solution, although this implies additional cost and time built into the system/process that may not be necessary. Furthermore, there is no evidence to suggest that US ports are not effective in receiving cargo and transferring the goods to other modes of transportation.

In comparison with other parts globally, US Ports are not the most efficient with some below-par cycle times for cargo through put, and delays ultimately add cost to any cargo system. But the collection of loosely coordinated, independently operated port entities seem to move cargo from waterborne modes to truck and rail (and vice versa) without many system-halting delays. Do the delays hurt some companies? Invariably the answer is yes. Do they significantly hurt many companies? The data suggest that the answer is no. This appears to be the case for all disruptions short of those where infrastructure is destroyed.

A watchout regarding this discussion – one might then argue that US ports appear to be performing fairly well. The absence of significant system failures does not necessarily mean that the system is robust and effective. One must also consider the vulnerabilities that exist in each element of the complex MTS process and system, and assess whether the backup and contingency plans are enough to provide continuity in the face of subsystem failures (delays, incidents). Which means to say that the system has worked well to date, but there are vulnerabilities that may cause more significant delays in future incidents.

The Role of Labor impacting Delays

Interestingly, labor issues – which are often cited as problematic in ports and a top cause of disruptions – were not cited as a significant source of port-related delay in the

survey. Labor issues were identified as sources of longer delays (more than 5 days) but these were not frequent (less frequent than annually). This would suggest that labor issues are not actually contributing to common operating delays in ports. These appear to genuinely be low-frequency high-impact disruptions – but the threat of these seems to loom larger than their actual impact on port operations.

Section 7.3: Responses to Regulation Questions

In the final set of questions, all respondents were asked to provide an assessment of the impact of government policies and enforcement on delays in ports, and a 4-point scale with an option for Not Applicable was provided (range from No Impact to Significant Impact).

1. Impact of Regulation: extent that government policies and enforcement impact the delays in ports
    a. 8 options plus comment box
    b. Selection among options
    c. Comments
    d. Analysis
2. Opinion about what regulations make ports more resilient
    a. Comment box responses only
    b. Analysis
3. Opinion about what regulations make ports more resilient
    a. Comment box responses only
    b. Analysis

Supporting Role for Government

Opinions on the impact of government regulations on port resilience were fairly evenly split between favorable and unfavorable, with the latter garnering slightly more votes. Two-thirds of the respondents suggested that government regulations had a slight impact on delays in ports, particularly the 10+2 mandates, cargo inspection requirements, and hours of service rules.

Perhaps more interesting, the survey team received many qualitative comments regarding these questions. Some respondents suggested that the government (and by implication, government policies) plays an important role in enabling commerce in ports. Some called for 'more US Customs Involvement within the Port,' improvements in inspection facilities, staff and processes, and greater coordination and integration among the various US government entities operating in the port environment. On the

surface it seems surprising that private enterprises would call for more government involvement in their industry. However, these responses reflect some recognition that government does play a critical role in enabling trade in ports and impacts efficiency since official agencies can prolong cargo clearance processes. It is not unreasonable to interpret the comments as a call for the government to make necessary regulatory processes more efficient and smooth, and to permit individual entities to perform their roles without undue delay or interruption.

Section 8: Overall Survey Observations

Several interesting observations emerged from the analysis of the data.

Overall the concept of port resilience is not understood nor is it considered an important focus for most port actors. The Port Authorities, the local USCG and USCG-associations (e.g. AMSC) consider port resilience (mainly trade resumption which is a restart activity rather than a comprehensive continuity planning effort intended to restore economic capabilities), but there is neither wide recognition of the need nor understanding of the concept of port resilience. Hopefully this report helps improve the general understanding, and provides some insight into the sentiment as expressed by the respondent pool.

Some of the top issues are outline in summary in the following list.

1. Respondents suggest that processes are more critical than capacity, and imply a need for flexibility.

The respondents were consistent in identifying nearly all elements (~90%) of each port function as critical (over 25 systems and processes were identified), yet they would take action in only two out of the 28 areas listed to make facilities more resilient. The two actions identified as being critical – communication/information systems and flexible labor agreements – involve process improvements rather than capacity improvements, indicating that processes are considered to be more critical than capacity-building measures to port resilience. Implicitly the respondents imply a need for flexibility although their experience suggests capacity is the source for their outages. In fairness, the respondents did identify several important actions that entailed system capacity, but they clearly defined these as 'not critical.'

2. Infrequent delays in each of the 28 different system components of ports results in frequent delays somewhere in the system.

The respondents provided their observation and experience with delays in 28 different subsystems across three areas of operation within the port – terminal operations, intermodal connections and waterway operations. Approximately half of the respondents reported incident frequency annually or less frequent. But approximately a third reported relatively short delays (.5-1.5 days) from incidents that occurred quarterly or more frequently in many of the 28 subsystems. While the frequency of experiencing a delay in any one of the 28 subsystems is relatively small based on the survey input, the frequency or probability of a disruption or a delay-creating incident at any of the 28 subsystems may not be small – potentially as frequent as nearly every other week.

3. Despite likely frequent delays somewhere in the MTS, the system works.

The finding that delay incidents may occur somewhere in the MTS as frequently as every other week might lead to the conclusion that the MTS is ineffective. We would argue differently; there is no evidence to suggest that US ports are not effective in receiving cargo and transferring the goods to other modes of transportation. There are some below-par cycle times for cargo through put, and delays ultimately add cost to any cargo system. But the collection of loosely coordinated, independently operated port entities seem to effectively move cargo from waterborne modes to truck and rail (and vice versa) without crippling delays.

4. Highly focused entities may not have full view of the system.

The respondents tended to report only on delays that relate to their specific areas of activity. That is to say, almost all of the shippers surveyed provided delay experience on intermodal connections, while carriers concentrated on waterway delays, and terminal operators focused on interruptions to terminal operations. This result raises the question whether these entities have visibility or awareness of the activities in other functional areas of the port.

In fairness to the respondents, it is natural to focus on your particular part of the system, and it can be argued that being single-minded in this way brings the expertise required to succeed in highly competitive markets. Still, a wider operational perspective is important, particularly when it comes to systems integration and coordination in the relatively complex port environment. Again, although the data is not conclusive, it does suggest that this complexity makes it difficult for stakeholders to have good visibility across the MTS.

5. There is a role for the Government.

Many of the respondents provided comments on the role of government and most identified an important coordinating role for the government. While this is not statistically significant, the data highlights some recognition of an important role for

government entities to help facilitate trade, contrary to the common perception of government involvement in commercial businesses.

Is it possible to interpret the implicit recognition of the role of the government as a call for a national port authority? That might be a stretch – but the survey and other related research suggest that more coordination and planning are needed in the country's complex and disparate MTS. The many different entities within the 310+ ports operate without any central or structural coordination. As such, many of those entities focus on their specific domain without the benefit of any end-to-end visibility.

6. There are many different perspectives regarding MTS operation, and limited alignment and coordination as a result.

It comes as no surprise that the survey data suggests that the experience of each party in the port is different, and perhaps unique. It is consistent with the broader set of observations that the current research is exposing. As noted in the Context introduction above, ports are not well understood and often considered a unified and integrated operating entity, perhaps not all that different than the belief in the single entity 'Japan Inc.' back in the 1970s. The entities within a port obviously operate in the port and follow port-specific policies and procedures, and collectively operate effectively as a cargo throughput mechanism moving cargo into and out of port environments, but there is no overarching entity that coordinates business enterprise within the port. The Port Authority markets the port broadly, but typically does not close business for specific terminals or plan capacity or resilience investments at the terminals. The US Coast Guard provides operating guidelines for safety within the port, and the Port Authority provides some oversight in planning for secure port environment, but neither party dictates business activity for the terminal operators. Therefore, it is misleading to suggest that a port acts as a unit or a coordinated entity in terms of business development and operation. In a similar fashion, it is misleading to suggest that the 310+ operating ports in the domestic US work together as a system of ports.

Section 9: Overall Analysis: Is the MTS Resilient?

As noted earlier in this report, resilience is not a binary quality but one that can be measured along a continuum. Therefore, the more appropriate question should be "Is the MTS resilient enough?" It is possible to draw some observations from the survey data to develop some hypotheses that may help answer the question.

When given the choice to identify system improvements critical to making ports resilient, the survey respondents only indicated two critical action areas: communications/information systems and flexible labor agreements. One way to

interpret this is to infer that the respondents perceive the ports to be resilient in all but the two noted areas; this is significant as many of the other choices were systems and capacity options which the respondents elected not to identify as critical. Furthermore, the data on port delays – potentially frequent but short delays – suggests that the MTS may be effective in handling cargo for all but the most significant disruptions. In all likelihood this capability derives from the broader system accommodating a traditionally longer cycle time through ports, and the presence of inventory in the pipeline which allows for a longer time before significant economic impact. Considering these factors together, one may infer that the ports are resilient enough to handle the majority of daily variation, and small, frequent delays resulting from limited-scope disruptions. But there is evidence that when considering large-scale disruptions affecting ports, that the MTS is not resilient enough.

The problem becomes clearer when one considers the few significant disruptions to MTS in ports – Katrina, Kobe and Haiti earthquakes and the 2002 West Coast Lockout. Each of these major disruptions resulted in a significant negative economic impact along with delays in cargo flows and cost increases. This evidence suggests that the MTS in ports cannot handle large disruptions without significant and systemic impact resulting in delays, cost increases, and adverse impact on the economy. These large disruptions are those where infrastructure and superstructure within a specific port are physically destroyed. In those instances, the affected port will not be able to handle the cargo, and the shippers and carriers will be forced to reroute the cargo to other port locations for offloading and handling. While many shippers have backup plans for alternate port facilities in case of a disruption at the primary destination port (this is a positive outcome from the West Coast Lockout), the delays and economic impact can still be significant.

Ultimately, every system will experience some disruptions, and a key challenge to a system is how fast it can respond and recreate its core capabilities. The data and recent events suggest that the MTS in ports is resilient enough to deal with daily variation and small disruptions, but not resilient enough to capably handle disruptions where infrastructure and superstructure have been significantly compromised.

Section 10: Next Steps

The initial survey results suggest that US ports seem to be handling delays from small disruptions without significant impact on end customers, and catastrophic failures are rare. But it also suggests that the MTS in ports is not resilient enough to handle large disruptions affecting loss of infrastructure and superstructure. This would suggest these

ought to be focal areas for future investments and continuity plans for terminals, ports and regional port systems.

The survey highlights some issues that warrant further research. Ports both as individual facilities and as part of a national network are fragmented entities. Yet complex global supply chains require close integration between systems and trading partners. Is it time to review the way the national port system is managed in the US?

Also, although delays within any of the many subsystems that make up ports are minimal, the likelihood of disruptions increases significantly when more than one subsystem is considered. More research is needed to determine how such delays ripple through supply chains, and the impact on cargo flows, and whether additional coordination or organization could provide for a more capable and appropriately resilient MTS in ports.