An initial exploration of port capacity bottlenecks in the USA port system and the implications on resilience

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Abstract: Ports are clearly important to the national and global economies. Several high profile events highlight the need not only to harden ports but to decrease recovery times when failures do occur to increase the resilience of the system as a whole. Our research suggests that disruptions occur with regular frequency and, with outliers removed, range from 6 to 20 days in duration. Furthermore, we find key commodity classes, such as chemicals and food and farm products may be especially sensitive to those disruptions due to geographic cargo concentrations. While the US port system is capable of supporting current cargo volumes, it is sensitive to adverse events, leading us to conclude that stakeholders must place renewed focus on resilience in order to reduce economic impacts when major port disruptions occur. The port resilience research has been generously supported by the U.S. Department of Homeland Security through the National Center for Secure and Resilient Maritime Commerce (CSR) at Stevens Institute of Technology in Hoboken, NJ.

Keywords: port resilience; maritime transportation; port operations; port capacity; port disruptions.

Reference to this paper should be made as follows: Trepte, K. and Rice Jr., J.B. (2014) 'An initial exploration of port capacity bottlenecks in the USA port system and the implications on resilience', *Int. J. Shipping and Transport Logistics*, Vol. 6, No. 3, pp.339–355

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This paper is a revised and expanded version of a paper entitled 'Introducing port resilience & port capacity study in US' presented at the Conference on Global Supply Chain Security, Imperial College London, 7–8 July 2011.

1 Introduction

Disruptions increasingly impact global commerce (e.g., Japan Sendai, Iceland Volcano, Financial Crisis 2008, etc.); with a large percentage of global trade passing through seaports and constituting meaningful portions of GDPs, the ability of seaports to flow cargo is increasingly critical not just to local but to national and global commerce. Therefore, it is important for seaports to build the capability to handle and withstand disruptions to continue to flow cargo through. This capability has been commonly known as resilience, although to this point in time the concept has been mainly applied to supply chains broadly and not specifically to seaports. Based on the importance of seaborne trade to the global economy, one can anticipate that 'port resilience' – resilience in ports and in systems of ports that serve a geographic area – may soon be recognised as a critical capability.

If one wants to understand how resilient a system is, a first question one should ask would be "How much capacity exists and how much is being utilized by the current demand?" The answer to these will give some insight as to whether the system can handle a disruption that entails a loss of capacity of some sort. If utilisation is high, then the system would not have much additional capacity available to respond suggesting low resilience. On the other hand, if the utilisation were low, then the lost capacity from a disruption could be replaced with some of the unutilised capacity meaning that the system would have higher resilience, at least in theory.

To date, there has not been a great deal of well-defined work to help instruct the capacity planner on how to incorporate resilience into the planning process for a system or an element of a system. There has been some work done in the supply chain domain, taking into consideration the risk management aspect, yet that is still emerging and often a function of the individual entity. While exceptional work has been done outlining port planning including capacity planning and capacity management, the complexity of the environment, the newness of the concept of port resilience and the yet-emerging understanding of risk management in the port domain make this a particularly challenging issue (Bichou, 2009). For these reasons, we depart from a traditional analysis of capacity planning for ports and embark on examining capacity in ports at a gross system level within the continental US. We simplify the relevant resilience capacity question to consider three high level primary capacities in ports: navigable waterways (the ability for vessels to move along the necessary navigable waterways to the terminals), terminal operations (the ability for terminals to receive and handle inbound and outbound cargo), and the intermodal connections (the ability of the various intermodal connections to further handle inbound and outbound cargo). Therefore - does the port have enough navigable waterway, terminal and intermodal connection capacity to sustain a significant loss of one or more of those capacities?

From a regional perspective, the question would be "If one seaport in a particular geography were unable to receive and distribute cargo, would other ports in that geography be able to handle that same cargo without a (meaningful) delay?" From a national point of view in the USA, if one of the over 300 ports in the USA were to suffer a complete loss, can the remaining ports absorb the cargo from the disrupted port without significant delay or cost?

1.1 Background

One reason that port capacities may matter has to do with disruptive events. In some instances, port disruptions cause significant impacts and in other instances they do not; the difference may be the capacity in surrounding ports. This can be seen in the comparison of the Kobe earthquake in 1995 and Hurricane Katrina in 2005. In 1995 the port of Kobe, which carried 30% of Japan's import and export cargo, was critically damaged by an earthquake. While the port of Kobe failed completely, the system as a whole was able to move export cargo to Osaka and import cargo to Tokyo and as a result, the overall system did not experience a serious disruption as a result of the earthquake; one unexpected side effect of the quake was that when the port of Kobe was rebuilt, the cargo did not return because the port did not have any natural advantages to draw shippers back.

The disruption to ports due to Hurricane Katrina, in contrast, had a significant impact on the USA economy. With 45% of the nation's food and farm products travelling through three closely spaced ports near New Orleans, the maritime transportation system was not able to absorb the cargo volume. As a result there was an estimated loss of $882 million to agricultural trade and, in 2006, national food prices rose by a 2.5% to 3.5% (Drabenstott and Henderson, 2005). When the port of New Orleans was rebuilt, the cargo volume returned because the natural transportation advantage of the Mississippi river compelled shippers to return to the port. The examples of Katrina and Kobe help highlight the importance of having a resilient port system as well as some of the issues associated with achieving it; in the case of Kobe surrounding ports were able to 'pick up' the displaced cargo minimising the level of disruption, whereas with Katrina, they could not.

2 Current environment

A number of factors in recent years have made the environment more challenging for maritime trade. These factors include:

- an increase in global trade and waterborne commerce
- an increase in vessel size and therefore a change in shipping economics
- varying investments in port infra- and super-structure
- complexity of the industry, reflected in a large number of operating companies, third parties, and various authorities
- a shift in port ownership/governance
- the overall complexity that exists in ports embodied by a large number of involved entities spanning local, regional, state and federal governments, maritime and land-based transportation and service providers, and regulatory, safety/security and real-estate authorities.

Taken together, these make for a challenging environment in which to consider or even attempt adopting resilience.

3 Increase in global trade and waterborne commerce, Increase in vessel size and therefore shipping economics

With its cost advantages, waterborne commerce has become a significant transport mode for international trade; in 2002 waterborne trade accounted for $2.5[1] of the $13 trillion in commercial value flowing through the USA economy (U.S. Department of Transportation – Bureau of Transportation Statistics, 2006). Maritime shipping is subject to economies of scale because transportation costs decrease as vessel size increases. Studies show a 20% per slot cost reduction for an 8,000 vs. 6,000 TEU vessel (Wakeman and Dorrler, 2002) and, between 2003 and 2007, vessel calls increased 13% from 56,600 to 63,800 and average deadweight tons per vessel grew 8% from 47,615 to 51,661 (U.S. Department of Transportation, 2007). As both vessel size and call frequencies have increased, many ports and terminal operators have needed to make substantial investments to keep pace. More recently, vessel size continues to grow with 18,000+ TEU vessels now beginning to carry cargo.

4 Varying investments in port infra- and super-structure

In response to increasing vessel sizes port authority and terminal operators have invested in infrastructure (channels, quay's, etc.), and superstructure (cranes, storage facilities, etc.). According to the United States Department of Transportation ('USDOT') ports invest an average of $1.5 billion per year in infrastructure and superstructure[2]. In an effort to reduce the capital burden on public finances ports have sought to shift asset ownership and investment from the public to the private sector (Sommer, 1999). A review of current port ownership for Los Angeles, Long Beach and Tacoma reveals that, on average, 75% of the terminals are operated by private companies. While there are differences in the degree of private ownership, most large ports have moved to a public/private model for managing their operations (Brooks, 2004).

5 Complexity of the industry, reflected in a large number of operating companies, third parties, and various authorities; shift in port ownership/governance

Perhaps one reason why port resilience has not received a great deal of attention is that the industry is complex and not easy to analyse. Many commercial and government organisations 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 authority, their component facilities are owned by a patchwork of private and public interests. Additionally, generally speaking, ports serve the function of a cargo processing and distribution system. As a result, most port delays fall within cycle times that do not cause undue disruption to businesses – there is one exception which can be seen in catastrophic port failures.

Given these complexities it is perhaps not surprising that the port environment is not well understood. The MIT Center for Transportation and Logistics (CTL) launched its port resilience study to gain a better understanding of how US ports operate and where they are vulnerable to disruptions. The Center is part of the Department of Homeland Security (DHS) Center of Excellence that is focused on Port Resilience (Center for Secure and Resilient Ports).

From a physical perspective many ports handle a wide variety of cargo such as containers, cars, petroleum and other bulk commodities. Complex ownership structures that encompass both public and private entities raise challenges when attempting to address system wide or port wide issues. From a system wide perspective, in the USA, there is no single agency which sets port policy making overall coordination difficult if not impossible. Within a given port, similar issues exist because in many instances, terminal operators are granted operating rights through lease agreements which allow them to act independently. As a result, the port system exhibits high levels of clustering with geographically desirable areas handling large and diverse cargo volumes and less desirable areas handling smaller specialised volumes. As such, initiatives that seek to coordinate or assess overall system capabilities are fraught with challenges.

One approach for addressing system wide issues has been to allow the ‘market’ to continue driving port requirements. The benefit of this approach is it allows resources to be allocated based on regional or market need. There appears to be a consensus that continual investment, to improve efficiency and reliability, is an important competitive advantage; the ports of Le Havre and Marseilles collective market share declined from 21% to 12% due to inefficiency and poor reliability, despite their geographic advantages (Slack and Fremont, 2005). Thus, one could conclude that the current structure of the port system is capable of supporting the needs of commerce with the USA in an efficient and cost effective manner. Large performance variances continue to exist in the USA, however, where terminal productivity ranges from 42 to 74 gross container moves per hour: Long Beach – 74; New York – 52; Seattle – 48, but as recent reports indicate, there is still room for improvement (Mongelluzzo, 2013).

There are, however, several potential drawbacks to the current system. The first drawback is overinvestment based on forecast market growth. An example of this is the port of Oakland which invested $503m (Port Of Oakland, 2007) in new infrastructure and capacity to attract new ‘customers’; when the revenues did not materialise, the port had to slash costs and request additional funds from the city to meet its debt obligations. Another example is the port of Tacoma which invested $300m (Modie, 2007) to lure NYK from using a terminal at the Port of Seattle; while the lease helped defer the cost of the terminal, its volume accounted for less than 7% of the new capacity. The justification for the investment (in 2006) was based on forecasts which showed Tacoma’s container volume growing to 3.3m TEUs by 2010 (Zachary, 2006). However, in 2009, the revised report showed Tacoma’s container volume remaining essentially flat at around 1.8m TEU’s through 2013 (Paulsen, 2009; Watanabe, 2009; Kuroda, 1995; U.S. Department of Transportation, 2009; Drabenstott and Henderson, 2005). The examples from the ports of Oakland, Seattle and Tacoma show that in some areas there may be excess capacity suggesting that port operations may not be improved by market forces because the possibility exists that the allocation may be sub-optimal when considered for the system as a whole.

6 Analysing concentration of cargo at major ports

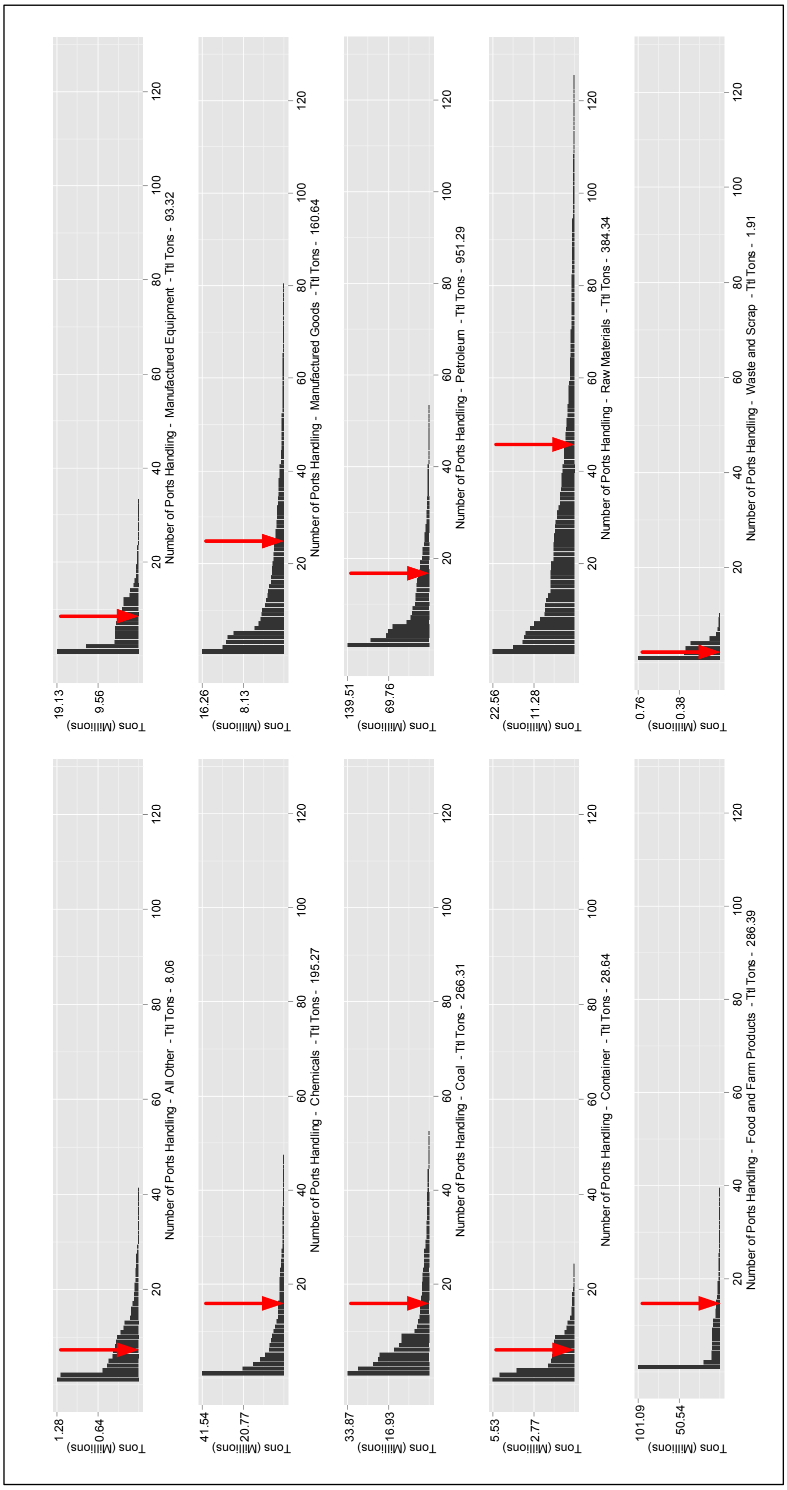
This paper seeks to explore some of the dynamics within the USA port system and some of the implication those dynamics have on resilience. The paper explores three areas within the port domain and their implications on resilience, with the first area explored being the concentration of cargo volume at major ports; the second area is the duration of port disruptions; and the third area is an estimate of the capacity required to handle different commodities.

The data used in the first and third areas, volume concentration and capacity, was obtained from the United Stated Department of Transportation (end note [ix]). The data consisted of annual cargo volumes split out by commodity type. Because the data is highly summarised, there is no transaction level detail, it is only possible to use it for the purpose of highlighting issues. Even with the level of aggregation, based on a review of the literature, this paper is the first to explore USA port system capacities in this way. As such this study provides a starting point, not a solution, for further more detailed analysis. The recent financial crisis illustrates when entities become 'too big to fail' and early indicators of trouble can help reduce the ripple effects caused by their failure; even though our data is highly summarised, it is capable of highlighting issues within the port system. If our work provides an early warning and helps ports avoid future problems we will judge our efforts a success.

To begin to put the scale of port investments into perspective, it is important to understand the public and private expenditures made to increase the capacity of ports. Survey data shows that in total, on an annual basis, federal, state, municipal and private entities, on an annual basis, invest \$100m in infrastructure and \$610m in superstructure; nationally, 22% of the funds come from bonds issued by ports, 30% come from federal, state and local governments and 48% come from other private sources and port revenues. The nature of the investment process has tended to favour large ports because they have more resources to pursue funds. The disparity of investment was challenged in the USA Supreme Court, on constitutional grounds (Article 1, Section 9, Clause 6), but the court found no issues because the ports are not directly under government control and the government does not direct port users to select one port over another (Newman and Walder, 2003). As a result of these efforts, large ports have been able to improve their infrastructure and superstructure to handle more cargo volume.

Because large ports have increased their handling capabilities they have captured a significant percentage of the cargo volume flowing in and out of the USA; 12% (25) ports handle an average of 133 commodities and account for 56% of the total USA cargo volume[xi]. It is estimated that the top ten ports receive 65% to 75% of the national investment (Luberoff and Walder, 2000). The disparity between ports is shown in Figure 1 which ranks ports by commodity class and total cargo volume in descending order; the red arrow on each graph represents the 80% volume cutoff.

Figure 1 Port volume by commodity class (data as of 2007) (see online version for colours)



The charts show that, with the exception of raw materials and manufactured goods, less than 20 of the more than 300 ports in the continental US account for 80% of the cargo volume in each category. When volume is concentrated in this way, there is a tension regarding investment; should further investment be made in the large ports or rather in small ports? Investments in large ports may serve to make them resilient to disruptions, whereas investments in small ports could allow them to act as a backup for major ports. Further, policy makers will also need to assess the need for specific capacity – be it navigable waterways, terminals or intermodal connections – as an adequate amount of capacity of each is necessary for the entire system to operate.

1 SIDEBAR: Studying the aftermath of the Kobe earthquake and Hurricane Katrina provide some useful illustration for possible resilience investment factors.

- The system of ports serving the region around Kobe was able to absorb the capacity lost when the Port of Kobe liquefied during the Kobe earthquake. Therefore the region was resilient although the specific Port of Kobe was not. Therefore it would have been useful to make investment in making the Port of Kobe resilient (i.e. more capable of withstanding a disruption, faster rebuild).
- The system of ports serving the mouth of the Mississippi (Port of South Louisiana., Port of Plaquemines, Port of New Orleans) which has a concentration of Food and Farms cargo was not able to handle the Food and Farm cargo after Hurricane Katrina. Therefore the region was not resilient and it would make sense to invest in adequate capacity to handle Food and Farm cargo. Because food and farm products are low value commodities that can only be cost effectively moved via barge, it is possible that the Mississippi River provides the only viable method for moving those commodities to market. If this is the case, then it may have made sense to invest in adequate capacity in the surrounding ports and key capacities to be able to move this type of cargo onto river-borne conveyances.

7 Analysis of the frequency and duration of port disruptions

An important challenge when examining issues related to port resilience is developing an understanding of the cause and frequency of port failures. In order to begin to explore port failures, we sought documented cases where ports failed with impact reported in the media. The process for identifying port disruption events consisted of entering the key words such as ‘port disruption’, ‘cargo delay’, ‘port delay’, ‘waterway disruption’, ‘vessel delays’, and ‘port cleanup’ into the Lexus/Nexus and Factiva. The results suggest that significant port disruptions occur frequently enough to warrant focusing on resilience related issues. The result of our searches yielded 33 incidents between 2004 and 2010; Table 1 summarises the results. The dataset is not large enough to draw statistically-significant conclusions, but it can provide some insight into recent port experience that may prove useful for planning response.

Table 1 Results of documented port disruptions

Metric	*All data*	*Outliers removed (>100 days)*
Average disruptions per year	4.7	4
Average duration	61 days	6 days
Median duration	4 days	3 days
Mode duration	180	N/A
Standard deviation	121 days	7 days
Number of events > 100 days	5	N/A
Total events	33	28

As Table 1 shows (see Appendix for the list of cases), port delays do not follow a normal distribution. In our data sample 5 events skew our results because the durations for the disruptions are significantly longer than the average; for this reason, we present columns for all of the data as well as one with delays of greater than 100 days removed. The 'outliers removed' column illustrates that in general the port outages noted have an average outage of three to six days. The All Data column indicates that there are also delays that extend beyond 100 days. The evidence on the surface suggests that it may behoove port system actors to consider taking action to prepare for the inevitable three to six day delays, but also prepared for the potential of the more catastrophic 100+ day delay. The delays are frequent and long enough to warrant consideration of investment in making their system resilient.

8 Analysing the capacity required to handle different commodities: capacity dispersion model

Having determined that cargo volumes are concentrated in a limited number of ports and that long term disruptions can take place, we sought to address estimating the capacity of the system to 'clear' or absorb the cargo from a disrupted port. It is important to note, that our objective was not to identify capacity requirements at individual ports, but to provide an estimate for the amount of excess capacity required within the system as a whole. Returning to the data available for the analysis, annual cargo volumes by commodity type by port, we propose that it is possible to develop baseline estimates of capacity requirements by comparing individual port cargo volumes to the systems' ability to absorb that individual port volume. The intuition behind this can be seen in the following example where a commodity is handled by port A and port B. If port A can no longer handle cargo, we identify how much unused capacity would port B need to have in order to handle port A's cargo volume; see Table 2 for a numerical example. Note that in our analysis we recognise that there are more than two ports that might handle a specific commodity or cargo mode, however, for explanatory purposes only two ports are used in this example.

Table 2 Numerical capacity example

Port A's annual cargo volume	100
Port B's annual cargo volume	100
Port B's annual volume if port A fails	200
Required free capacity at port B	100% (200/100)

The data presented in Table 2 illustrates many of the assumptions behind our analysis. First, the assumption is that port A is completely disabled in a catastrophic failure and all of its volume shifts to the alternate port B; in the actual analysis, the volume is split proportionally among all of the ports handling the commodity. While the assumption of total cargo diversion for a full year may seem extreme, it is not without precedent; it took three years to reconstruct the port of Kobe and in other instances where ports have been rendered inoperable due to disaster it has taken at least one year to repair the damage. It is important to note, that we do not make any claims regarding the actual capacity at port B or mitigating actions that could allow port A to handle cargo on a limited basis. As such, our capacity estimates represent an upper bound of system capacity assuming that current operational levels remain constant. As a result, we will use the term clearing capacity to describe the results of our analysis because the volume represents the added capacity required to 'clear' or absorb all of the cargo volume from a particular failed port. Keeping these caveats in mind, we now present our analysis; Table 3 presents our capacity estimated by commodity type.

An examination of the data highlights two commodities that are of particular interest: food and farm products and chemicals. Both are interesting because they account for significant tonnages of cargo and require the non-disrupted ports to maintain more than 25% clearing capacity to clear cargo if a port fails. The more striking issue is the close geographic proximity of the three largest ports for each commodity; additionally, all of the ports are located in the gulf coast region. The nature of the commodities, high volume and low cost, may require the ports to be hardened in order to achieve resilience because the value and volume of the commodities does not allow them to be economically moved to another port for shipment (Drabenstott and Henderson, 2005). Understanding the clearing capacity in this instance suggests that further investment in gulf coast ports may be warranted to prevent losses in the future and increase system resilience for the two commodities. To fully assess this approach more detailed models will need to be developed.

When food and farm products and chemicals are compared to waste and scrap it is apparent that the volume and nature of Waste and Scrap is such that if a major port were to fail, it is unlikely that there would be an impact to the national economy. Thus even through waste and scrap is highly concentrated and requires the highest clearing capacity it is unlikely that policy makers should focus on this commodity with further investment to increase resilience.

Table 3 Comparison of clearing capacity

Commodity	*Clearing capacity required*	*Percent of total for Top 3 Ports*	*2009 cargo volume at Top 3 Ports*	*2009 cargo volume*
Food and farm products				
Top 3 Ports: South Louisiana, New Orleans, Plaquemines	50%	43%	132,283,278	307,561,126
Waste and scrap				
Top 3 Ports: Port Arthur, NY/NJ, Vancouver	46%	64%	1,242,521	1,941,543
Container				
Top 3 Ports: Los Angeles, Long Beach, NY/NJ	26%	45%	13,605,599	29,980,993
Chemicals				
Top 3 Ports: Houston, South Louisiana, Baton Rouge	23%	37%	72,779,006	195,957,624
Manufactured equipment				
Top 3 Ports: Los Angeles, Long Beach, NY/NJ	18%	41%	43,659,668	107,240,591
All other				
Top 3 Ports: NY/NJ, Los Angeles, Long Beach	16%	37%	3,335,372	9,035,240
Petroleum				
Top 3 Ports: Houston, NY/NJ, South Louisiana	16%	29%	307,866,124	1,057,271,241
Coal				
Top 3 Ports: Mobile, Pittsburgh, Hampton Roads	16%	35%	117,165,354	335,573,428
Manufactured goods				
Top 3 Ports: Houston, NY/NJ, Los Angeles	7%	22%	27,245,415	124,436,343
Raw materials				
Top 3 Ports: Duluth-Superior, NY/NJ, South Louisiana	5%	15%	51,886,445	343,058,079

It is interesting to note how frequently some ports appear in the list: New York/New Jersey seven times, Los Angeles four times, South Louisiana four times, and Houston three times. If a limited number of ports are in the top three for a significant number of commodities, it is likely that the resilience of the system could be enhanced if investments were made to harden these ports because multiple commodities could be addressed with targeted investments. One alternative could be to increase the number of ports capable of handling certain cargo types to provide more options to clear any disrupted cargo volume. The investments could be further refined by targeting systems such as intermodal connections or roadways that provide services for the port as a whole rather than systems which only impact individual terminals. If shared resources are improved it is possible that stakeholders would see a double benefit of resilience and increased throughput across more than one commodity.

Table 3 also illustrates that the investments made by the largest ports has enabled them to garner a significant share of the total cargo volume flowing in the USA. The cargo dispersion model highlights the need for large ports to be resilient because they account for such a large percentage of the total cargo volume for more than one commodity. Further research is required to understand the tradeoffs in efficiency derived from large ports and their ability to be made resilient before policy changes or recommendations for the system of ports as a whole can be made. As researchers assess supply chains, they have begun to examine 'capacity flexibility' as an important component of corporate resilience strategies (Zaeh and Mueller, 2007). In an effort to understand tradeoffs decision makers are exploring models that help strike a balance between duplicate versus flexible assets by linking the cost of failures to system capacity (Sheffi and Rice, 2005). In land-based supply chains, understanding capacities and bottlenecks is important when planning for disruptive events. It is our hope and expectation that policy makers will examine similar issues when assessing the capacity requirements for the port system as a whole.

9 Summary

Ports are clearly important to national and global economies, and several high profile disruptions highlight the impact of disruptions that result in loss of port capacity. The need for making ports capable of handling disruptions to protect the economic activity has therefore increased but this is also increasingly very challenging considering changes in shipping economics, change in port ownership, increase in vessel size, and the complexity of the system. Our study of port failures supports this contention that ports and port actors need to consider action to make their systems resilient. The Capacity Dispersion Model makes plain the significant risk to the US economy in the event of a disruption at a major port. We observe that there is not enough capacity at the various major ports to handle a disruption without significant impact on the economy. We hope these analyses succeed in calling attention to and motivating action by policy makers and port actors to take steps towards making the ports and system of ports in the US resilient to disruptions. Given the lead time to build port infrastructure and the length of the budgeting and approval process the question which remains is – if not now, when?

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Notes

1 As recently as 2007 (Hummels, 2007) the 2002 number was the most current for a comprehensive study of waterborne trade volumes. Rather than attempt to estimate a new number from industry specific reports the authors have opted to retain this number. It is important to note that this is a conservative number and it is likely that waterborne trade has increased since that time.

2 USDOT study requested information for years 2007 through 2011.

Appendix A

Table A1 Port case studies

Port	*Year*	*Reason*	*Duration*	*Timescale*	*Impact*	*Sources*
Port of New Orleans, LA	2005	Weather	365	Days	The average cruise passenger spends $300 in New Orleans and it is estimated that the industry size was $226m per year.	about.com – 2005 New York Times – 2006
Port Canaveral, FL	2004	Weather	2	Days	Unknown	marinelink.com
Port Canaveral, FL	2008	Weather	3	Days	Vessels moved to Fort Lauderdale	cruislinefans.com
Intercoastal Waterway Mile 310–315	2009	Blockage	3	Unknown	Unknown	homeport.uscg.mil
Gulf Intercoastal Waterway Mile 260	2009	Other	1	Day		homeport.uscg.mil
Panama City, FL	2009	Weather	1	Day	Deliveries allowed, but no vessel traffic allowed.	panhandleparade.com
Calcasieu Ship Channel	2006	Spill	6	Days	Small refinery shut down, large refinery running at less than full capacity.	Oil Daily
Port of Oakland	2007	Other	1	Day	Port shut down stopping cargo, idling workers and trucks. 7 Container ships in the process of unloading stopped.	Oakland Tribune
New Orleans Harbor, LA	2004	Blockage	4	Days	River and port shut down completely. Damage estimated at $15m, however, cruise lines lost between $1m and $3m per day one had to refund 2,000+ passengers.	ens-newswire.com
Morehead City, NC	2010	Other	3	Days	Unknown	Associated Press
Motiva Terminal	2006	Other	450	Days	Terminal completely destroyed. From other readings it is estimated that a petroleum terminal costs $100m to $300m.	bixblog.projo.com Industrial Fire World
Crescent City Bridge, LA	N/A	Blockage	N/A	Unknown	Port closed because of oil spill and barge sunk against the Crescent City Bridge.	USCG website
Mississippi River Closure, LA	2004	Spill	N/A	Unknown	Port closed with 40 vessels waiting to enter the port. Several cruise ships ended up relocating – the barge spilled 400,000bbl fuel oil into the harbour.	Port of New Orleans website

Table A1 Port case studies (continued)

Port	*Year*	*Reason*	*Duration*	*Timescale*	*Impact*	*Sources*
Union Pacific LA/LB Shutdown, CA	2005	Other	N/A	Unknown	Caused the port to have significant cargo backups. The backup caused APL and a unit of Neptune Orient Lines to change their service to Seattle permanently.	refrigeratedtrans.com
Houston Ship Channel Closure, TX	2009	Spill	2	Days	Tank vessel struck a barge and spilled 10,000 gallons. Traffic was slowed to 4 mph and had to be escorted through the zone.	myfoxhouston.com click2houston.com
Neches River, TX	2009	Other	3	Days	Riverfest stops all traffic on the river.	USCG website
Port of Portland, OR	2008	Weather	2	Days	Hanjin vessel stuck in port.	oregonlive.com
Port of Portland, OR	2010	Other	5	Days	All traffic blocked.	portofportland.com
Port of Delaware, MD	2004	Spill	21	Days	Port partially closed for the period of time.	fws.gov
Berkley Marina, CA	2007	Spill		Unknown	Marina closed.	examiner.com
Cabo San Lucas	2009	Weather	2	Days	5 Cruise lines cancelled visits to the port.	blogs.usatoday.com
Port of Chicago, IL	2009	Other	N/A	Unknown	Unknown	chestertontribune.com
Port of Galveston, TX	2009	Weather	2	Days	Two vessels were moved from the port of Galveston to the port of Houston. Each had slightly over 2,000 passengers.	travelvideo.tv
Willamette Locks Closure, OR	2008	Other	18	Months	Locks need to be closed for repairs.	portlandonline.com
Sunshine Skyway Bridge, FL	2007	Blockage	2	Hrs	Bridge closed for two hours.	baynews9.com
Mississippi River Diversion, LA	2008	Other	N/A	Unknown	River diversion caused the ship channel to silt up necessitating extensive dredging. For this reason, the diversion may be shut down stopping a shoreline restoration project.	nola.com
Los Angeles/Long Beach, CA	2008	Other	N/A	None	None	ft.com
Port of Brunswick, FL	2008	Blockage	1	Day	Two car vessels held up.	jacksonville.com

Table A1 Port case studies (continued)

Port	*Year*	*Reason*	*Duration*	*Timescale*	*Impact*	*Sources*
Maher and PNCT Terminal Delays, NJ	2009	Other	180	Days	Delays up to six weeks are being experienced by shippers moving cargo on MSC vessels.	Interview with Informants familiar with the situation
China Olympics Port Backup	2005	Other	180	Days	Vessels for commodities backed up in both China and Australian because of port location changes to reduce pollution in China during the Olympics.	Informant from major transportation magazine
Los Angeles/Long Beach, CA	2006	Other	180	Days	Over 100 vessels waiting to be serviced at the ports because of the imbalance of trade with Asia. This incident is credited as one of the main reasons for the expansion of the Panama Canal and Gulf ports.	Informant from major transportation magazine
Port Arthur Texas	2010	Spill	21	Days	It is estimated that the cost of closing the channel is $90m per day - it may turn out that this is like the LA/LB lockout which overstated the actual costs of the disruption.	statesman.com
New York Harbor, NY	2004	Hazmat	11	Days	Total vessel cargo of lemons lost and the ship was delayed for 11 days because of an anonymous tip saying that the lemons had an unknown biological agent in them.	www.nytimes.com
Port of Santos, Brazil	2010	Spill	4	Days	Four chemical barrels leaked inside ship requiring cleanup that lasted four days and blocked a berth within a terminal during the cleanup time.	Consultant to port resilience project