North American Container Port Capacity: An Exploratory Analysis
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Abstract

Major North American container ports were surveyed for their opinions of capacity concerns in consideration of rapidly rising container volumes. The results indicate several areas of concern. For one, the ports expect capacity issues to worsen in the next ten years, implying current congestion problems will also deteriorate. The ports are also highly concerned about a considerable number of capacity drivers, many of which are controlled by other stakeholders including governments, railroads, truck carriers, and labor unions. These results point to a need for an immediate and coordinated approach among multiple stakeholders to address imminent port capacity issues.

North American container ports handled more than 35 million TEUs[1] carrying $1 trillion of goods in 2003 (National Chamber Foundation of the U.S. Chamber of Commerce 2003; American Association of Port Authorities 2004). Over the last twenty years, container volumes have grown at an average annual rate of 7 percent (Figure 1), but port capacity expansion has not necessarily kept pace with volume growth. In fact, several studies indicate imminent container port capacity deficits (Wilbur Smith Associates 2001; National Chamber Foundation of the U.S. Chamber of Commerce 2003). As further evidence, shippers encountered numerous service issues during the 2004 peak shipping season caused by capacity-induced congestion at West Coast ports (Mongelluzzo 2004e; Mongelluzzo 2004g). Capacity problems have also incited several industry executives to question the future viability of the North American container port network (Armbruster 2004b, Leach 2004e, Mottley 2005).

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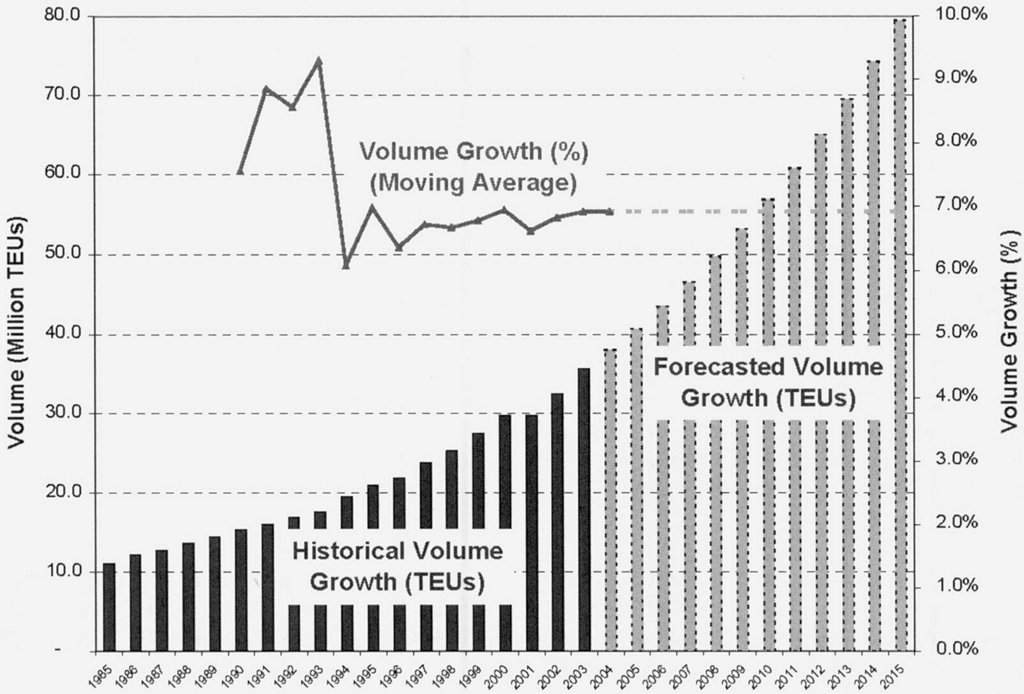
A shortfall of container port capacity is driven by several factors. First, North American ports tend to be significantly less efficient than their foreign counterparts (National Chamber Foundation of the U.S. Chamber of Commerce 2003). So the ports have relied heavily on costly, time-consuming facility and labor expansion to meet volume increases, but this expansion has generally lagged behind volume growth. Another capacity shortfall is caused by the lack of collaboration among the numerous stakeholders affecting port capacity, including port authorities, longshore labor, terminal operators, railroads, drayage carriers, and governments. Total port throughput capacity cannot be increased without synchronized, joint planning among these stakeholders, but there have been only anecdotal instances of such collaboration. A third driver of port capacity shortages is the unevenness of container flows caused by seasonal volume peaks, increasing vessels sizes, and imbalanced import versus export flows (Mongelluzzo 2005b). These factors amplify port capacity growth requirements well beyond the 7 percent average annual volume growth. Finally, several recent unforeseen events, including labor strikes, military deployments, and weather problems, have temporarily reduced capacity at some ports,

Figure 1. Container Volume History and Forecast: Continental United States and Canada



Notes: Data from American Association of Port Authorities (AAPA). Forecast developed from historical average growth rates.

thus putting further capacity strains on others as container volumes are redirected.

North America has a growing port capacity problem, and the ensuing congestion is significantly detrimental to global supply chains. Port congestion triggers increased ocean carrier costs due to in-transit scheduling adjustments, reductions in effective capacity, and higher fuel and labor costs. The carriers then pass along these costs to shippers in the form of surcharges and rate increases. Port congestion also leads to unpredictable shipment delays, causing shippers to increase inventory levels and adjust supply networks to minimize risk of stockouts and shutdowns. As a whole, these higher costs and increased shipment delays significantly reduce supply chain productivity. In the extreme though not unlikely case, continued capacity and congestion problems will deter world trade and impact the economic stability of not only North America but also the countless countries relying on North American imports and exports.

Literature review

Ports and their supporting distribution networks are complex entities. For instance, the port itself actually consists of three primary units: the port authority that manages port development and serves as facility landlord; the terminal operators that manage port operations; and the longshore labor that provides container loading and unloading services. These internal yet relatively autonomous stakeholders influence various dimensions of port capacity. Furthermore, several external stakeholders, including railroads and dray truck carriers that transport containers in and out of the port, also significantly impact port capacity. Governments at federal, state, and local levels as well as shippers and local communities have further

Table 1. Port Capacity Literature

Capacity Factors		Selected References
Port Planning, Strategy	Planning	(Park and Noh 1987; Cottrill 1997; Comtois 1999; Luo and Grigalunas 2003)
	Funding	(Cottrill 1997; Ircha 2001)
	Competition	(Murphy et al. 1988; Murphy et al. 1989; Murphy et al. 1991; Cheung Ho 1992; Murphy and Daley 1994; Heaver et al. 2001; Malchow and Kanafani 2001; Flor and Defilippi 2003; Nir et al. 2003; Tiwari et al. 2003; Garrido and Leva 2004; Malchow and Kanafani 2004)
	Efficiency, performance	(Talley 1994; Tongzon 1995; Sanchez et al. 2003; Park and De 2004; Turner et al. 2004)
Port Infrastructure	Land	(McNeilan and Foxworthy 1993; ''Ports Desperate for Space and Dredging Options'' 1998)
	Berth space	(Lim 1998; Nishimura et al. 2001; Guan et al. 2002)
	Channel, waterways	(Mastaglio 1997; Mohan and Palermo 1998; Alcorn and Foxworthy 2001; Ashar 2003)
Port Operations	Terminal operations	(Kim and Kim 1999b; Preston and Kozan 2001; De Souza Jr. et al. 2003; Vis and de Koster 2003; Zhang et al. 2003)
	Port equipment	(Kim and Kim 1997; Kim and Kim 1999a; Chung et al. 2002; Zhang et al. 2002; Bish 2003; Kim et al. 2003; Kim and Park 2004; Ng 2004)
	Longshore labor	(Silberholz et al. 1991; Schwarz-Miller and Talley 2002; Talley 2002; Talley 2004)
	Technology	(Wan et al. 1992; Garstone 1995; Veras and Walton 1996; Kia et al. 2000)
Off-Site Facilities	Short sea, inland ports	(Notteboom and Winkelmans 2001; Walter and Poist 2003; Becker et al. 2004)
Rail	On-dock, local capacity	(Bana e Costa et al. 2001; Turner et al. 2004)
Truck, Roads	Local dray capacity	(Walker 1992; Wang and Regan 2002)
	Local road capacity	(Pope et al. 1995; Golob and Regan 2000; Regan and Golob 2000; Federal Highway Administration 2004; Texas Transportation Institute 2004)

capacity influences. Given the internal and external stakeholders, a review of previous research must thus not only focus on the ports but also expand externally to railroads, truck carriers, governments, and beyond.

In a previous study, Maloni and Jackson (2005) conducted a rigorous literature review on port capacity, demonstrating the diversity and scope of relevant port capacity research. Selected works from this article are presented in Table 1, categorized by capacity factors. Some research offers mathematical-based solutions for terminal operations (see Vis and de Koster (2003) for a review), berthing (Lim 1998, Nishimura et al. 2001), or equipment (Kim and Kim 1997, Kim and Park 2004), while others conduct empirical analyses of topics such as port efficiency (Sanchez et al. 2003, Turner et al. 2004), competitiveness (Murphy et al. 1992, Song and Yeo 2004), labor (Talley 2002), technology (Veras and Walton 1996), or road congestion (Golob and Regan 2000, Regan and Golob 2000). Some works review port efforts to address specific capacity challenges such as channel depth (Mohan and Palermo 1998), land (''Ports Desperate for Space and Dredging Options'' 1998), or labor (Silberholz et al. 1991, Schwarz-Miller and Talley 2002). Finally, other papers address port planning and policy (Cottrill 1997, Ircha 2001) or provide historical assessments of the evolution of containerization (Slack 1999, Talley 2000).

Despite the apparent wealth of port-related literature, only a few research projects directly address the scope of current capacity challenges from a systemwide viewpoint, and these projects have primarily been industry- or government-based. For instance, one report identifies the need to improve the U.S. marine transportation structure (U.S. Marine Transportation System Task Force 1999), whereas other reports predict significant port capacity problems within the next five to ten years (Wilbur Smith Associates 2001, National Chamber Foundation of the U.S. Chamber of Commerce 2003). These studies provide insight into the magnitude of port capacity problems and also offer input regarding port capacity drivers. As highlighted by Maloni and Jackson (2005), however, a wealth of research prospects still exist to offer more detailed, empirical exploration of port capacity drivers and resolution opportunities.

Research Objectives and Methodology

Given the need for additional port capacity research, this article presents an initial exploratory investigation of North American container port capacity issues and opportunities by addressing several research objectives: timing of port capacity problems, key port capacity drivers, and port capacity expansion planning efforts. In doing so, the research seeks to better understand the urgency of port capacity problems and isolate the underlying causes of capacity shortages. Ultimately, the goal is to identify specific areas needing additional research and to suggest solution opportunities for the industry.

To accomplish these research objectives, the authors surveyed the largest container ports in continental North America for their perceptions of capacity planning and issues. As listed in Table 2, ports from mainland United States and Canada were identified from available industry data (American Association of Port Authorities 2004). Ports in Hawaii, Alaska, Puerto Rico, and Mexico were not included since they serve only local shipping needs, and their unique logistical challenges could skew the results. The thirty-three ports considered for survey represent more than 35 million TEUs and almost 100 percent of all continental North American container volumes.

The survey instrument was initially developed based on the authors' recent professional experience in the maritime industry as well as a rigorous review of academic and industry literature. Additionally, the authors assessed more than a year's worth of daily newswires from the *Journal of Commerce* and *American Shipper*, two prominent maritime industry publications, to validate and refine the survey content. The authors then pilot tested the survey with several industry and academic experts to ensure that the content was accurate and complete and that the survey instrument was clear and intelligible. Final refinements were then made before survey distribution. Content validity was also later verified based on discussions and interviews with several survey respondents throughout the research project. These respondents also substantiated the importance and timeliness of the research as well as provided further details about many key capacity issues at their ports.

The final survey consisted of approximately seventy-five questions and statements. Data collection was conducted in several steps between October 2004 and February 2005. First, an introductory postcard describing the research was mailed to the highest-level port authority executive responsible for container port strategy and operations. Holding titles such as executive director, port director, CEO, and president, these individuals can best provide a single authoritative view of capacity concerns of their respective ports. The survey and accompanying cover letter were then mailed within a week to these executives, and a reminder postcard was later sent to promote participation. Participants could complete and return the survey via a self-addressed, stamped envelope or do so by an Internet-based instrument. Confidentiality was promised to the respondents since their responses could contain information sensitive to both their competitiveness and customer image. A summary of the research results was also offered. Given the small sample size, the authors followed up the mailings with phone calls to both verify that the survey had been received and to encourage participation. In some cases, the port officials nominated another port resource to respond on their behalf, and the authors validated the authority of these respondents.

Of the thirty-three surveyed ports, twenty-four, representing almost 30 million TEUs (84 percent of the surveyed volumes), opted to participate. These respondents included a representative mix of U.S. and Canadian ports from

Table 2. Continental United States and Canada Container Ports

Port	St. / Prov.	Country	Coast	2003 TEUs	*% TEUs*	*Cumm. % TEUs*
Los Angeles	CA	US	West	7,148,940	*20.1%*	*20.1%*
Long Beach	CA	US	West	4,658,124	*13.1%*	*33.2%*
New York/New Jersey	NY, NJ	US	East	4,067,812	*11.4%*	*44.6%*
Oakland	CA	US	West	1,923,104	*5.4%*	*50.0%*
Tacoma	WA	US	West	1,738,068	*4.9%*	*54.9%*
Charleston	SC	US	East	1,690,847	*4.8%*	*59.6%*
Hampton Roads	VA	US	East	1,646,279	*4.6%*	*64.3%*
Vancouver	BC	CA	West	1,539,058	*4.3%*	*68.6%*
Savannah	GA	US	East	1,521,728	*4.3%*	*72.9%*
Seattle	WA	US	West	1,486,465	*4.2%*	*77.1%*
Houston	TX	US	Gulf	1,243,706	*3.5%*	*80.5%*
Montreal	QC	CA	East	1,108,837	*3.1%*	*83.7%*
Miami	FL	US	East	1,028,565	*2.9%*	*86.6%*
Jacksonville	FL	US	East	692,422	*1.9%*	*88.5%*
Port Everglades	FL	US	East	569,743	*1.6%*	*90.1%*
Halifax	NS	CA	East	541,650	*1.5%*	*91.6%*
Baltimore	MD	US	East	536,078	*1.5%*	*93.1%*
Portland	OR	US	West	339,571	*1.0%*	*94.1%*
Wilmington	DE	US	East	254,191	*0.7%*	*94.8%*
Fraser River	BC	CA	West	252,510	*0.7%*	*95.5%*
New Orleans	LA	US	Gulf	251,187	*0.7%*	*96.2%*
Palm Beach	FL	US	East	217,558	*0.6%*	*96.8%*
Gulfport	MS	US	Gulf	199,897	*0.6%*	*97.4%*
Boston	MA	US	East	158,020	*0.4%*	*97.8%*
Philadelphia	PA	US	East	147,413	*0.4%*	*98.2%*
St. John's	NF	CA	East	99,543	*0.3%*	*98.5%*
Wilmington	NC	US	East	96,453	*0.3%*	*98.8%*
San Diego	CA	US	West	86,136	*0.2%*	*99.0%*
Freeport	TX	US	Gulf	67,784	*0.2%*	*99.2%*
Saint John	NB	CA	East	45,638	*0.1%*	*99.4%*
Richmond	VA	US	East	43,672	*0.1%*	*99.5%*
Toronto	ON	CA	East	31,279	*0.1%*	*99.6%*
Mobile	AL	US	Gulf	26,302	*0.1%*	*99.6%*
All Ports				**35,587,181**		

Notes: Data from American Association of Port Authorities (AAPA).

the West, East, and Gulf Coasts. Given this level of participation, the survey results presented here should provide an accurate overview of port capacity issues and opportunities. Even with the high response rate, non-response bias was assessed since it could significantly impact survey results given the small population size. To do so, non-respondents were first contacted to assess reasons for not participating. Most indicated they did not have time to complete the survey, and one cited decreasing focus on commercial container business. Brief discussions with these non-respondents about their port capacity concerns aligned closely with the responses from participating ports. Second, a search of industry literature found that the capacity issues of non-responding ports did not differ from those of the responding ports. These findings, thus, minimized concerns about non-response bias.

Analysis of the survey responses aligns with the research objectives and is conducted in several steps. First, the timing of port capacity problems is assessed in two stages: initially by using quantitative-based time series analyses of capacity forecasts, then by exploring qualitative-based port perceptions of future capacity shortages. This will help determine how and when the levels of capacity utilization and related congestion may change. Next, several capacity factors are evaluated for statistical significance to highlight the most critical drivers of port capacity and help focus potential resolution efforts. Finally, port capacity expansion options are assessed for significance to better understand how the ports will focus future capacity growth. The authors attempted to validate the findings based on both industry literature and interviews with industry experts who included, but were not limited to, participants in the survey.

The significant difference in volumes among the primary North American container ports suggests that the responses should be weighted to emphasize the larger ports since these facilities will support a more significant share of future volume growth. Weighting by actual volume would significantly skew the results to the top three ports and potentially compromise respondent confidentiality, however, so the authors opted to use a relative weighting approach. Each port was assigned a whole number weight between one (lowest volume) and five (highest volume) based on current relative container volume. Such an approach emphasizes the responses of larger ports without disregarding those of the smaller ports.

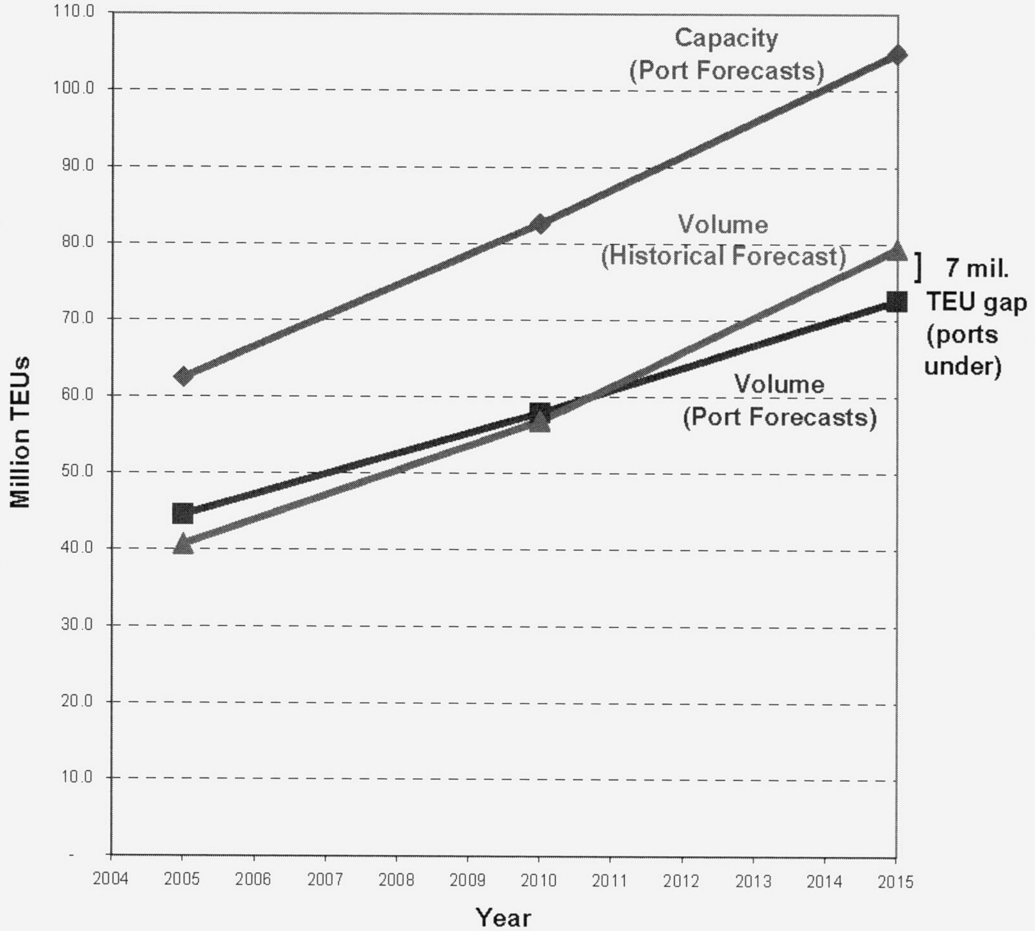
Timing of Port Capacity Problems–Time Series Forecasts

The ports were asked to provide TEU-based forecasts (denoted as "port volume forecasts" or "port forecasts") of volume and capacity for 2005, 2010, and 2015. The data were aggregated across all respondents, then extrapolated to account for non-respondents. Thus, the results represent an estimation of the forecast for the entire container port system in the continental United States and Canada. A second forecast of TEU volumes (denoted as "historical volume forecast" or "historical forecast") was derived from historical data at an average annual growth rate of approximately 7 percent. This second volume forecast will provide a comparative figure to roughly benchmark the accuracy of the aggregate port volume forecast. Figure 2 presents the results. From a positive perspective, port forecasted capacity expands at about the same rate as forecasted volume. This indicates that the ports appear to be planning capacity expansion to match the increased volume. However, all is not positive: The port volume forecast significantly lags behind that of the historical volume forecast in 2015. In other words, aggregate port volume forecasts are considerably less than forecasts based on historical growth rates. Given no industry indications to expect a reduction in volume growth, the ports may thus be underestimating 2015 TEU volume by almost 7 million TEUs (10 percent). This is not necessarily a surprising result given that the ports have frequently underestimated future volumes (Mongelluzzo 2004). The authors speculate that this result may be a direct impact of localized forecasting in that the ports are estimating what they believe their individual port will see (which may be influenced by future expected capacity) and not considering aggregate effects of systemwide expectations. Neither this conjecture nor the ports' forecasting methods were assessed in the current study, pointing to the need for additional research in the area.

To further explore the port forecasts, capacity utilization was derived as expected volume divided by expected capacity (Figure 3). Two measures were calculated, one using port volume forecasts and the other using historical volume forecasts. Initially, ports are overestimating capacity utilization, but given the above aggregate underestimation of future volumes, the ports are underestimating capacity utilization by 6.5 percent in 2015. While capacity will still cover volume, a higher than expected level of capacity utilization may considerably aggravate current service issues, especially during peak season. Although new terminal and greenfield (new but as yet uncompleted port facilities) projects may support the deficit with some additional capacity, the potential impacts of underforecasted future volume are alarming.

To further investigate the underestimations of future volumes, the forecasts were broken down by geographic region, including East, Gulf, and West Coasts. Growth rates specific to each region were used to provide the historical volume forecasts. Figures 4 through 9 provide the forecast results for the regions. East and Gulf Coast ports appear to be slightly overestimating volumes through 2015 (Figures 4 and 6), possibly because of expected diversions from congested West Coast ports. Capacity utilization will remain high (Figures 5 and 7), however, leaving little room for volume spikes

Figure 2. TEU Volume and Capacity Forecasts – All Ports

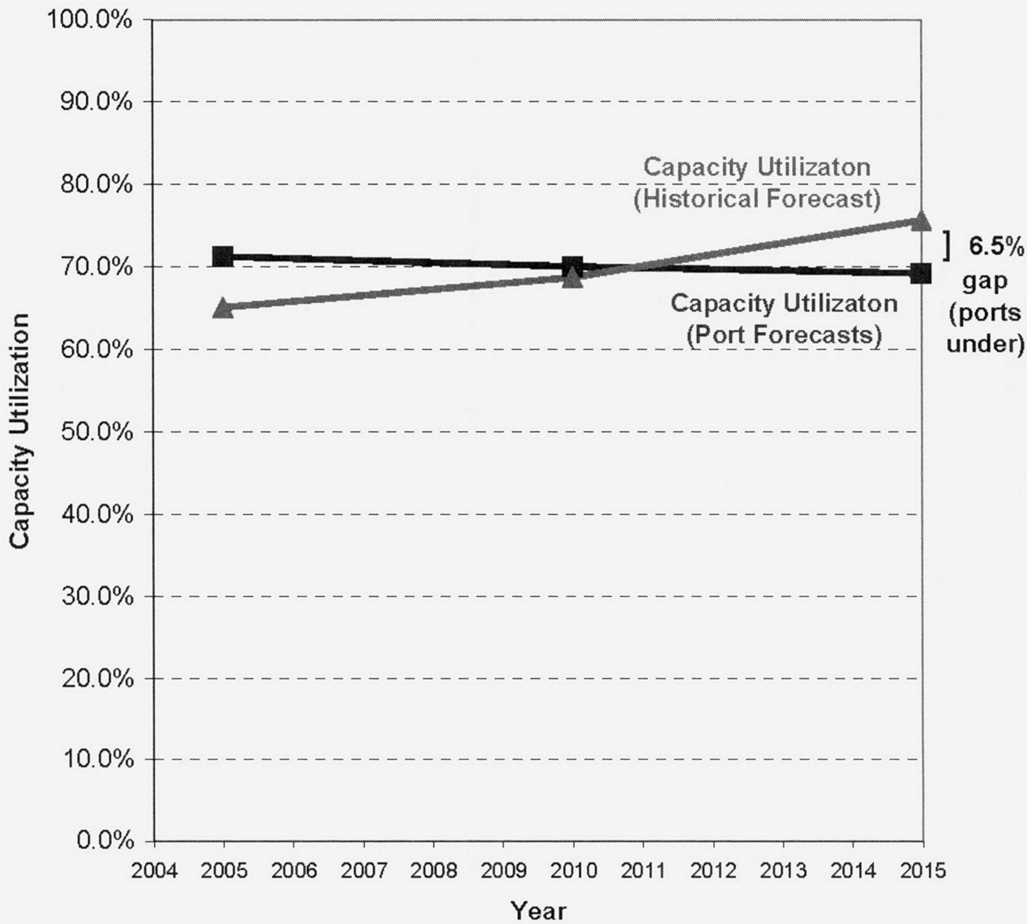


Notes: "Port forecasts" aggregated from survey responses. "Historical forecast" taken from historical data. Forecasts are extrapolated to represent all ports (both those participating and not participating in the survey). The 7 million TEU gap indicates the aggregated individual port forecasts fall below the expected overall industry volume given historical growth patterns.

and capacity influencing issues such as weather, labor disputes, and security lapses. The aggregate underestimation of 2015 volumes originates from West Coast ports, which appear to be severely underestimating volume by almost 11 million TEUs (28 percent) (Figure 8). This would cause West Coast port capacity utilization to be at 82.4 percent instead of port forecasts of 64.5 percent, a difference of 17.9 percent (Figure 9). Recent volumes indicate no reductions in growth rates ("Long Beach February Container Volumes Rise 58%" 2005; Mongelluzzo 2005a), especially given the recent elimination of apparel trade quotas (Mongelluzzo 2005d).

The West Coast findings are troubling, given that the Pacific trade lane has experienced the most growth over the last decade as well as the majority of the recent problems with peak-season congestion (Mongelluzzo 2004g; "Industry Sees Gap between Asia, U.S. In Tackling Port Congestion" 2005). Service problems

Figure 3. Capacity Utilization Forecasts – All Ports



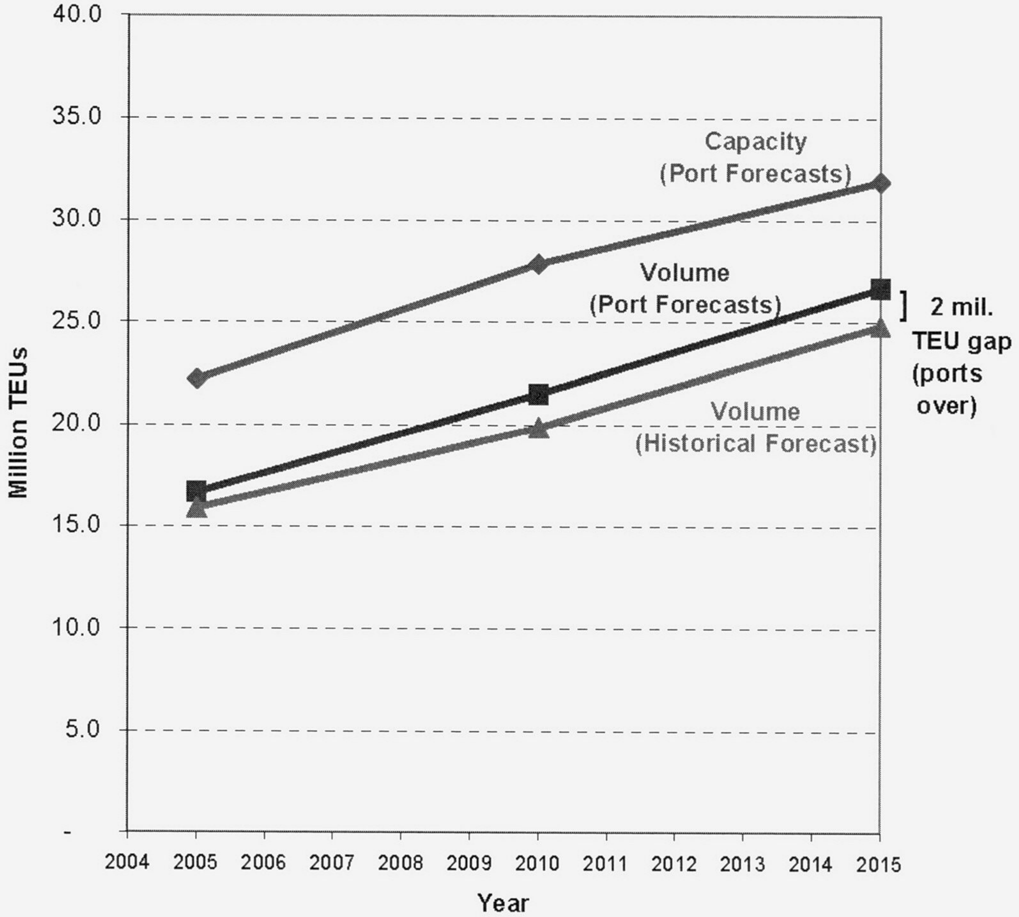
Notes: Capacity utilization is calculated as expected volume (from either port forecast or historical forecast) divided by expected capacity. The 6.5 percent gap indicates the aggregated individual port forecasts of capacity utilization will fall below the expected industry capacity utilization given historical growth patterns.

from continued congestion-related delays could reduce service advantages of the West Coast land bridge and also further induce ocean carriers to enhance all water routes to other regions of North America. In turn, this could then cause a domino effect as East and Gulf Coast ports see higher than expected volumes and subsequently experience their own capacity and service problems. Continued congestion may also encourage development of Mexico ports to serve the U.S. and Canada. Given potential forecast deficiencies, it is recommended that the ports, especially those on the West Coast, should not only remain rigorously active in monitoring forecasts and adjusting subsequent capacity plans but also collaborate with neighboring ports to aggregate regional forecasts.

Timing of Port Capacity Problems–Port Perceptions

To provide a second assessment of the timing of future capacity problems, the ports were asked to indicate agreement or disagreement

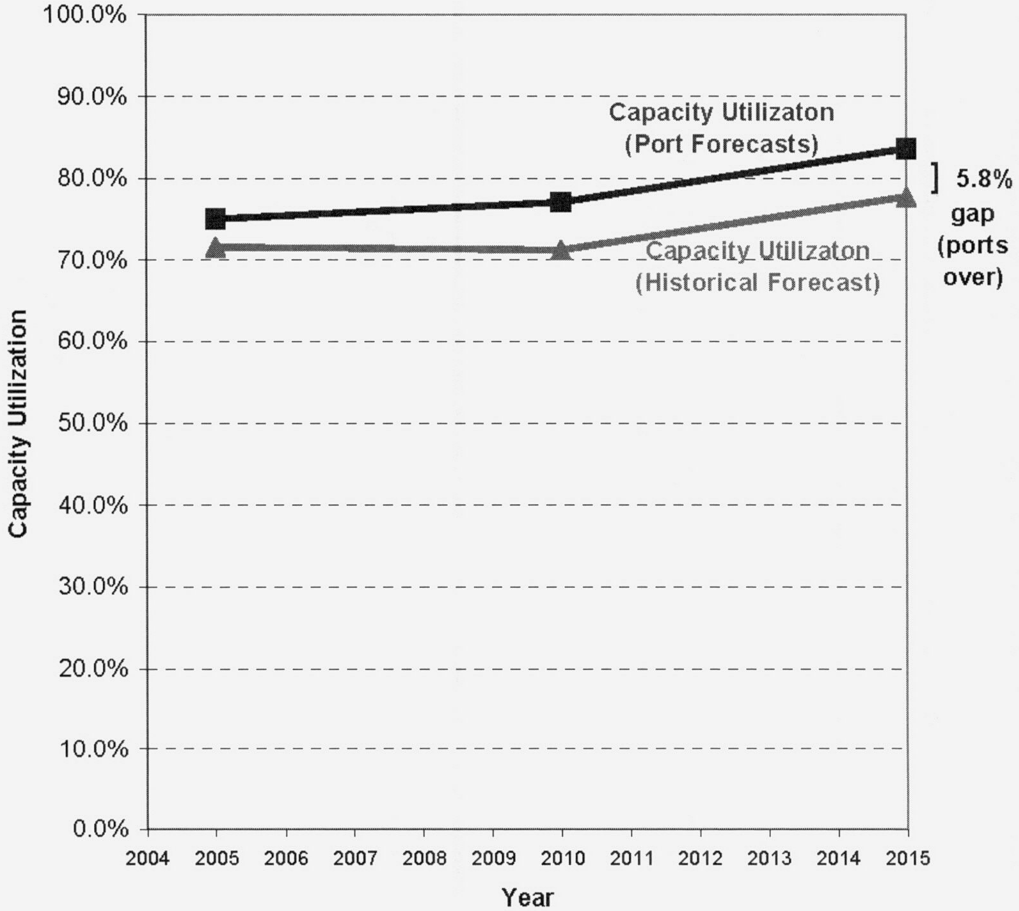
Figure 4. TEU Volume and Capacity Forecasts – East Coast



with current (throughout the year and during peak season now) and future (five-year and ten-year) capacity shortages. Example statements include ''our port has capacity shortages during peak season'' and ''our capacity shortages will worsen in the next 5 years.'' The response scale ranged from one (strongly disagree) to seven (strongly agree), with four (neither agree nor disagree) representing the midpoint. So a response of five or greater is interpreted as agreeing with capacity shortages. The responses were weighted by relative port volume and are presented Table 3, aggregated across all ports and divided by region. Collectively, the ports generally disagree with having capacity shortages throughout the year now, but 43 percent agree with having current peak season problems. Future capacity shortage outlooks worsen, with 63 percent of respondents expecting capacity problems to deteriorate in the next five years and 44 percent indicating the same within the next ten years. There is no industry information to indicate why the ports would be more concerned with the five-year than the ten-year horizon. The authors speculate that the five-year horizon is of more concern due to its urgency or that port officials do not believe the volume growth will sustain into the ten-year horizon (Mongelluzzo 2005e).

Capacity shortage perceptions vary by coast. East Coast ports' current concerns match that of the aggregate findings, but they appear to be somewhat more concerned than average with the five- and ten-year horizons. Gulf Coast

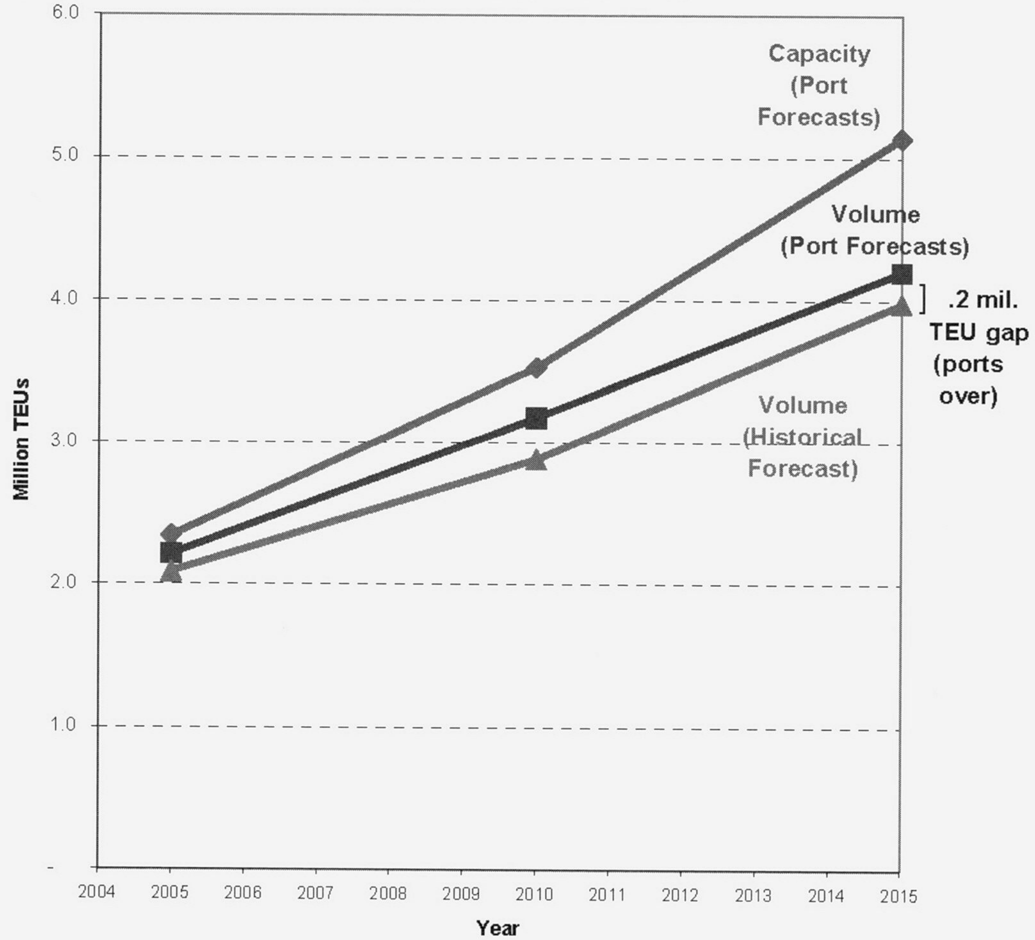
Figure 5. Capacity Utilization Forecasts – East Coast



ports are extremely concerned with current capacity shortages, but they indicate less agreement than average of problems worsening in the future. Surprisingly, West Coast ports do not indicate current capacity concerns throughout the year now and are actually slightly less concerned than average with peak season capacity conditions. The latter result clearly contradicts industry trade press reports.

To further explore the significance of future capacity shortages versus the current situation, paired tests were conducted to assess differences of perceptions of capacity shortages in peak season, five-year, and ten-year horizons from throughout the year now. A significant positive difference would indicate the ports perceive capacity problems worsening. Given the small population and relative size of the sample, a finite population correction factor[2] was used in the analysis (Lind et al. 2005). The results are presented in Table 4. Examining all ports, there is strong statistical significance for all three differences. This denotes agreement with the perception that capacity shortages are worse during peak season than throughout the year now and that the ports expect capacity shortages to worsen in the next five- and ten-year horizons. Considering regional differences, East and West Coast ports indicate worsening capacity conditions. Gulf ports do not indicate worsening conditions, however, possibly due to their indication of already high levels of capacity shortages.

Figure 6. TEU Volume and Capacity Forecasts – Gulf Coast

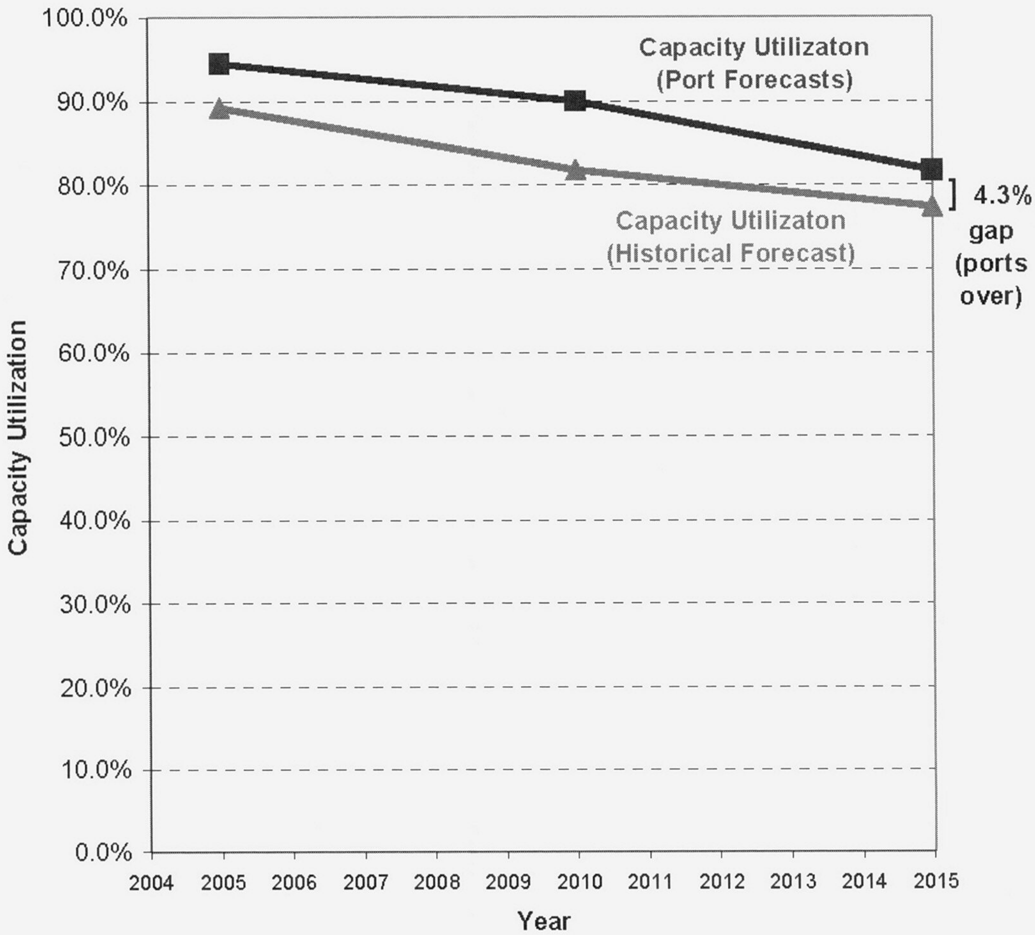


The above results do not take into consideration the aforementioned possible underestimations of future volumes, so the port perceptions of future capacity shortages may also be misleadingly low. Regardless, it can be expected that capacity shortages and the subsequent congestion experienced during 2004 will also worsen. Given that port capacity expansion takes significant capital and time, these results present a clear signal that resolution action must begin now to minimize future effects of capacity shortages. Table 3 also indicates, however, that the ports are virtually unanimously concerned about funding for capacity growth. This further amplifies the need for immediate action and calls for a review of port capacity financing options.

Key Capacity Drivers

Many internal and external factors influence port capacity. To better understand which factors are most impactful, the ports were asked to evaluate more than twenty-five capacity factors that were categorized as port infrastructure, labor, waterways, truck/rail, or technology. These capacity factors were derived from academic and industry literature, including daily trade journal newswires. Respondents were asked to ''assess the significance of the following factors in affecting your port's container capacity in the next 5–10 years.'' Scales were based from one to seven, with one indicating no significance, four indicating moderate significance, and seven indicating high significance. Again, responses were weighted in the

Figure 7. Capacity Utilization Forecasts – Gulf Coast



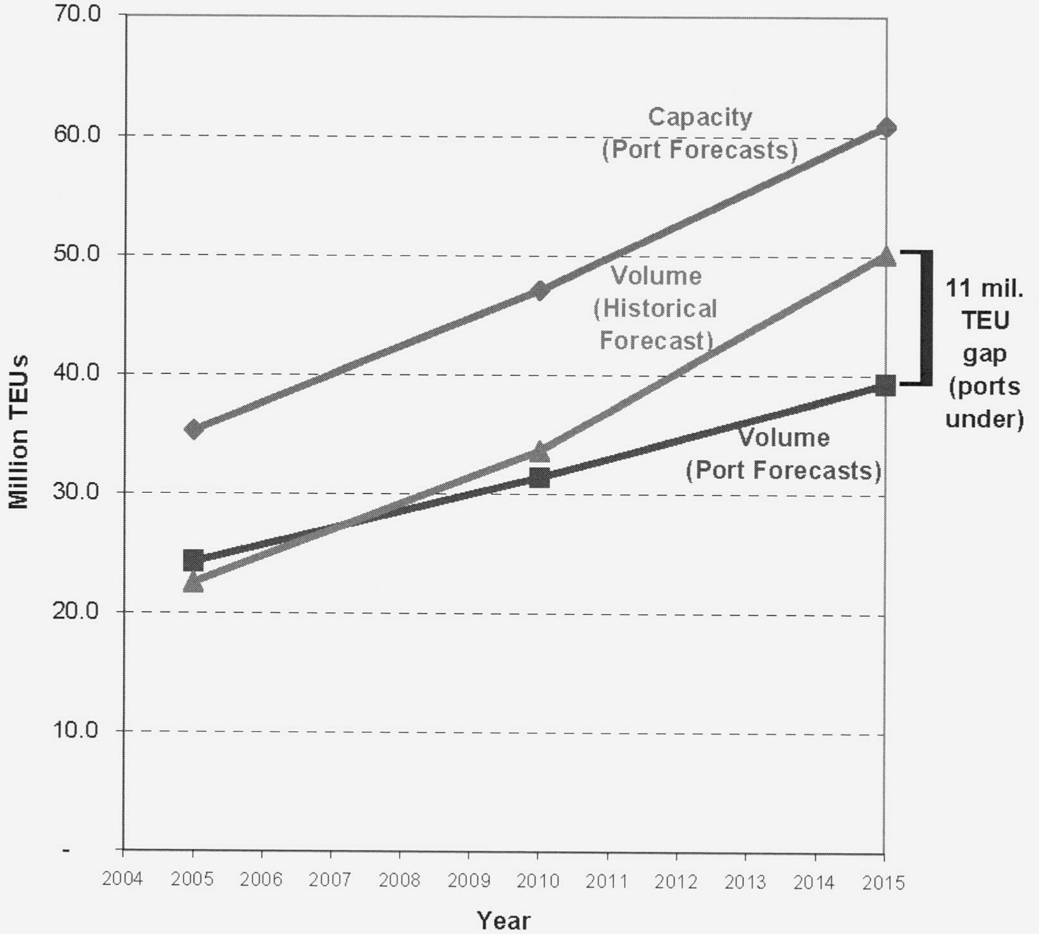
analysis based on the aforementioned relative scale of port volume.

The results were tested for a difference from one (i.e., no significance) using a finite population correction factor. All factors were found to be statistically significant at α = .01, confirming that port capacity is a complex problem influenced by many drivers. To provide further insight regarding *relative* significance, each capacity factor was then re-tested for significance against the average response across all capacity factors. Table 5 displays the top ten capacity factors of highest significance aggregately and regionally to highlight the areas of principal concern. Table 6 presents the detailed results of all capacity factors.

Focusing on the top factors reveals that many of the capacity drivers of greatest port concern are heavily if not completely influenced by other stakeholders (Table 5). For example, local road capacity, the top aggregate capacity concern, is generally managed by government, and local rail (#3 factor), on-dock rail (10), and truck (5) capacities are managed by the carriers. The labor unions tightly control longshore efficiency (4), cost[3] (8), and capacity (9). Even considering primary factors within port control, including terminal (2) and berth space (6), many ports do not have sufficient available land (7) to resolve such issues.

The above findings do not belittle the significance of internal capacity factors, but the ports are clearly more concerned with the capacity

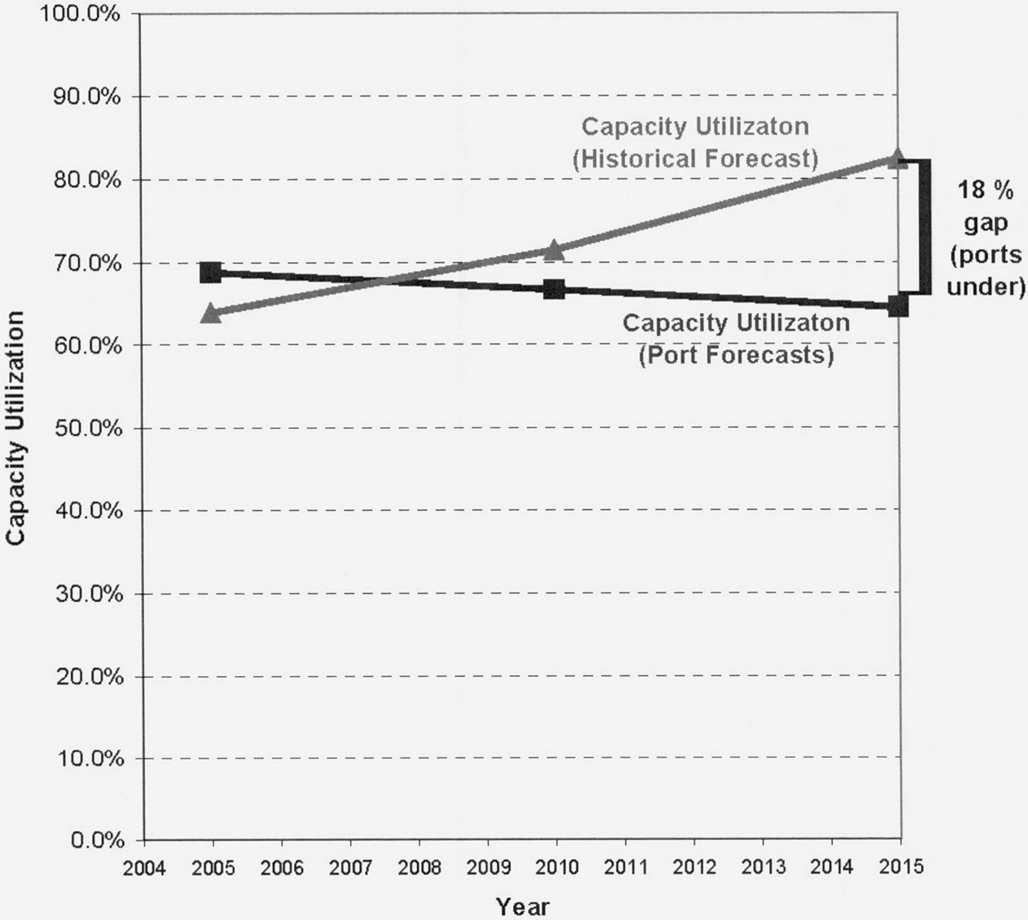
Figure 8. TEU Volume and Capacity Forecasts – West Coast



influences of other stakeholders, implying that they perceive that their ultimate capacity is by and large out of their control. This directly points to the need for a multiple stakeholder approach to address port capacity problems. The ports are clearly indicating that capacity cannot be expanded without significant participation from longshore unions (cost, capacity, efficiency), government (roads), rail (local, on-dock), and truck carriers (local drayage). Terminal operators (capacity, technology) participation will also be important.

Examining regional perspectives, ports on the different coasts retain some distinctions in importance of capacity factors. While some factors such as local roads, local rail, and local truck, as well as longshore labor efficiency and cost, are fairly consistent across the different regions (though not necessarily in the same order), other factors are relatively unique among the regions. For instance, East and Gulf Coast ports are more concerned with channel depth—a logical finding considering these ports have historically had to dredge their channels to accommodate increasing vessel sizes. Corroborating recent press, West Coast ports place high focus on solutions to gate congestion (Mongelluzzo 2005c). A few of the primary Gulf Coast ports' concerns are relatively unique, including channel width and data exchange technology. Gulf ports are less concerned with terminal and berth space,

Figure 9. Capacity Utilization Forecasts – West Coast



however, since industry press confirms that several already have additional facilities in various stages of planning or construction (''Bayport Groundbreaking Planned'' 2004; Plume 2004).

To further compare the relative significance of capacity factors by coast, pairwise rank-correlation tests were conducted. A significant Spearman rank-correlation coefficient indicates that the rank-orders of the capacity factor lists are not statistically different, indicating the orders are essentially the same. Table 7 presents the results and indicates significant rank-correlations (all p-values less than α = .05) across all regions. Thus, although subtle differences may exist between the capacity factor lists by coast, the overall rank-orders are not statistically different.

Port Capacity Expansion Planning

Finally, the ports were asked to assess how they plan to expand the capacity drivers that they do control. Like the capacity factors, the expansion factors were taken from academic and industry literature, and each was categorized as productivity, infrastructure, or inland/short-sea solutions. Specifically, respondents were asked to ''assess your port's plans to expand the following areas in the next 5–10 years.'' Scales were based from one to seven, with one indicating no expansion, four indicating moderate expansion, and seven indicating significant expansion. Once again, responses were weighted for the analysis according to relative port volume.

The results were initially tested for significance from a difference of one (i.e., no expan-

Table 3. Container Port Capacity and Funding Perceptions

Capacity Shortages	All Ports % agree	East Coast Ports % agree	Gulf Coast Ports % agree	West Coast Ports % agree
Throughout the year now	14.8%	11.1%	71.4%	0.0%
During peak season now	42.6%	37.0%	85.7%	35.0%
Worsen in next 5 years	63.0%	74.1%	57.1%	50.0%
Worsen in next 10 years	44.4%	51.9%	28.6%	40.0%
Funding for capacity growth is an issue	70.4%	88.9%	100.0%	35.0%

Table 4. Container Port Capacity Perception Differences (Paired t-tests)

Capacity Shortages: Difference from "throughout the year now" and	All Ports		East Coast Ports		Gulf Coast Ports		West Coast Ports	
	t	*p-value*	t	*p-value*	t	*p-value*	t	*p-value*
Peak season now	5.61	*0.000*	3.29	*0.007*	1.633	*0.201*	3.88	*0.008*
Worsen in next 5 years	8.71	*0.000*	7.24	*0.000*	2.744	*0.071*	5.29	*0.002*
Worsen in next 10 years	5.87	*0.000*	4.61	*0.001*	0.816	*0.474*	4.32	*0.005*

Notes: Large t- (standardized observation) and small p-value indicate the relative high significance difference from current capacity shortage conditions.

Table 5. Ten Most Important Container Port Capacity Factors

Rank	All Ports	East Coast Ports	Gulf Coast Ports	West Coast Ports
1	Local Roads (1)	Local roads (1)	Rail local (3)	Local roads (1)
2	Terminal Space (2)	Truck local (5)	Rail on-dock (10)	Terminal space (2)
3	Rail local (3)	Channel depth (11)	Longshore cost (8)	Longshore efficiency (4)
4	Longshore efficiency (4)	Terminal space (2)	Gate systems (12)	Rail local (3)
5	Truck local (5)	Available land (7)	Data exchange (21)	Longshore capacity (9)
6	Berth Space (6)	Berth space (6)	Channel depth (11)	Available land (7)
7	Available Land (7)	Longshore efficiency (4)	Longshore efficiency (4)	Berth space (6)
8	Longshore cost (8)	Rail local (3)	Truck local (5)	Longshore cost (8)
9	Longshore capacity (9)	Gate systems (12)	Channel width (15)	Truck local (5)
10	Rail on-dock (10)	Longshore cost (8)	Local roads(1)/ Longshore capacity (9)	Rail on-dock (10)

Notes: Numbers in (parentheses) indicate ranking for all ports.

sion) using a finite population correction factor. Across all ports, each of the nine expansion factors was found to be statistically significant. This indicates that ports will be pursuing

Table 6. Port Capacity Factors: All Ports and by Coast

		All Ports			East Coast Ports			Gulf Coast Ports			West Coast Ports		
Category	**Capacity Factor**	mean	*p-value*	*rank*	mean	*p-value*	*rank*	mean	*p-value*	*rank*	mean	*p-value*	*rank*
Port Infrastructure	Terminal space	4.82	*0.000*	**2**	4.81	*0.000*	**4**	3.57	*0.829*	19	5.22	*0.000*	**2**
	Berth space	4.35	*0.001*	**6**	4.63	*0.003*	**6**	3.43	*0.922*	21	4.30	*0.006*	**7**
	Land for port expansion	4.58	*0.001*	**7**	4.81	*0.002*	**5**	2.57	*0.995*	25	4.91	*0.003*	**6**
	Gate capacity	3.70	*0.330*	13	3.74	*0.481*	13	3.86	*0.564*	18	3.61	*0.221*	11
	Port equipment	3.28	*0.936*	16	3.63	*0.635*	15	4.00	*0.445*	17	2.65	*0.968*	20
	Terminal operator capacity	2.84	*1.000*	22	2.63	*1.000*	25	3.29	*0.976*	22	2.96	*0.927*	18
Labor	Longshore labor efficiency	4.61	*0.000*	**4**	4.26	*0.008*	**7**	4.86	*0.027*	**7**	4.96	*0.000*	**3**
	Longshore labor costs	4.21	*0.002*	**8**	4.19	*0.048*	**10**	4.86	*0.001*	**3**	4.04	*0.033*	**8**
	Longshore labor capacity	4.11	*0.008*	**9**	3.56	*0.811*	16	4.43	*0.080*	**10**	4.65	*0.002*	**5**
	Other port labor efficiency	3.28	*0.949*	17	3.26	*0.984*	19	4.14	*0.264*	14	3.04	*0.786*	16
	Other port labor capacity	3.14	*0.987*	19	2.89	*0.999*	21	4.00	*0.391*	15	3.17	*0.702*	14
	Other port labor costs	3.11	*0.997*	20	3.26	*0.992*	20	4.00	*0.391*	15	2.65	*0.976*	21
Waterways	Channel depth	4.12	*0.025*	11	5.07	*0.000*	**3**	4.86	*0.008*	**6**	2.78	*0.938*	19
	Channel width	3.58	*0.594*	15	3.74	*0.480*	12	4.57	*0.071*	**9**	3.09	*0.816*	17
	Tug and tow	2.74	*1.000*	23	3.48	*0.835*	17	3.43	*0.865*	20	1.65	*1.000*	27
	Barge, short sea feeders	2.30	*1.000*	24	2.41	*1.000*	27	2.29	*0.995*	26	2.17	*0.998*	22
	Pilotage	2.42	*1.000*	25	2.81	*1.000*	22	2.71	*0.992*	24	1.87	*1.000*	25
	Bridge clearance	1.98	*1.000*	26	2.33	*1.000*	23	1.00	*1.000*	27	1.87	*1.000*	23
	Channel congestion	2.40	*1.000*	27	2.70	*1.000*	26	3.00	*0.981*	23	1.87	*1.000*	26
Truck and Rail	Local road capacity	5.32	*0.000*	**1**	5.04	*0.000*	**1**	4.43	*0.080*	**10**	5.91	*0.000*	**1**
	Rail – local capacity	4.54	*0.000*	**3**	4.30	*0.008*	**8**	5.29	*0.000*	**1**	4.61	*0.001*	**4**
	Local dray capacity	4.53	*0.000*	**5**	4.89	*0.000*	**2**	4.29	*0.034*	**8**	4.17	*0.033*	**9**
	Rail – on-dock capacity	4.05	*0.025*	**10**	3.67	*0.593*	14	5.29	*0.000*	**1**	4.13	*0.047*	**10**
Technology	Gate systems	3.93	*0.108*	12	4.41	*0.022*	**9**	4.86	*0.001*	**4**	3.09	*0.763*	15
	Scheduling	3.72	*0.334*	14	3.85	*0.314*	11	4.29	*0.185*	12	3.39	*0.514*	12
	Container tracking	3.23	*0.979*	18	2.93	*1.000*	24	4.14	*0.254*	13	3.30	*0.594*	13
	Data exchange with partners	2.95	*0.999*	21	3.37	*0.955*	18	4.71	*0.006*	**5**	1.91	*1.000*	24

Notes: Mean represents volume relative weighted average of responses of a seven-point scale (1 = no significance to 7 = high significance). P-value represents standardization (using a finite population correction factor) against the average response, providing indication of relative importance of capacity factors to one another.

growth by enhancing both productivity and size of current facilities as well as exploring off-site solutions such as inland ports and short-sea barging. To provide greater insight about the relative significance of the expansion factors, each was then re-tested for significance against the average response across all expansion factors. Presented in Table 8, the productivity factors and increasing terminal space retain the highest levels of significance when examining all ports, indicating ports will focus more on efficiency via technology, labor, and gate hours than physical expansion or off-site approaches. With the relative inefficiency of North American ports versus their foreign counterparts (''Industry Sees Gap between Asia, U.S. In Tackling Port Congestion'' 2005), focusing on productivity improvements makes sense. However, achievement of such improvements have been impeded by longshore labor unions (Schwarz-Miller and Talley 2002). As another cautionary note, the European Commission is currently attempting to increase competition among port service providers to enhance port efficiency, but the Commission's efforts are being met with strong resistance (Barnard 2004).

Port focus on productivity improvements may also evolve from the fact that physical expansion of port infrastructure through addition of terminals, berths, and channel depth may be somewhat limited due to available land and environmental obstacles. Given restricted physical expansion, ports can pursue off-site

Table 7. Port Capacity Factors - Spearman Rank-Correlation Coefficient Tests

	All Ports		East Coast Ports		Gulf Coast Ports		West Coast Ports	
	r_s	*p-value*	r_s	*p-value*	r_s	*p-value*	r_s	*p-value*
All Ports	1.000	*0.000*	0.897	*0.000*	0.522	*0.008*	0.926	*0.000*
East Coast Ports			1.000	*0.000*	0.461	*0.019*	0.703	*0.000*
Gulf Coast Ports					1.000	*0.000*	0.388	*0.048*
West Coast Ports							1.000	*0.000*

Notes: Spearman rank-correlation coefficient (r_s) represents correlation of rankings of port capacity factors between regions. A small p-value indicates significant rank correlation.

Table 8. Port Expansion Planning: All Ports and by Coast

		All Ports			East Coast Ports			Gulf Coast Ports			West Coast Ports		
Category	**Expansion Factor**	mean	*p-value*	*rank*	mean	*p-value*	*rank*	mean	*p-value*	*rank*	mean	*p-value*	*rank*
Productivity	Increase efficiency via technology	5.89	*0.000*	**1**	5.63	*0.000*	**1**	5.86	*0.042*	4	6.22	*0.000*	**1**
	Increase gate hours	4.86	*0.312*	**3**	4.22	*0.829*	7	4.86	*0.071*	7	5.61	*0.001*	**2**
	Increase labor efficiency	4.84	*0.359*	4	4.48	*0.561*	6	5.57	*0.631*	5	5.04	*0.086*	4
Infrastructure	Increase existing terminal space	5.28	*0.012*	**2**	4.93	*0.159*	4	6.14	*0.000*	**1**	5.43	*0.018*	**3**
	Increase berth space	4.74	*0.688*	5	5.07	*0.047*	**3**	6.00	*0.005*	**3**	3.96	*0.138*	5
	Increase channel depth	4.60	*−0.836*	6	5.67	*0.000*	**2**	4.14	*0.031*	8	3.48	*0.016*	9
	Add one or more terminals	4.58	*−0.804*	7	4.67	*0.389*	5	6.29	*0.000*	**2**	3.96	*0.122*	6
Inland/	Expand short-sea, barge feeders	3.68	*−0.001*	8	3.52	*0.996*	8	5.00	*0.450*	6	3.48	*0.028*	8
Short-sea	Develop/expand inland ports	3.28	*0.000*	9	2.63	*1.000*	9	4.57	*0.011*	9	3.65	*0.046*	7

Notes: Mean represents volume relative weighted average of responses of a seven-point scale (1 = no expansion to 7 = significant expansion). P-value represents standardization (using a finite population correction factor) against the average response, providing indication of relative importance of capacity factors to one another.

solutions in the form of inland ports and short-sea barging to other facilities. Although the European Union (EU) has been emphasizing short-sea opportunities (Becker et al. 2004), the U.S. has yet to embrace the concept (Sowinski 2005). Table 8 results corroborate this with short-sea solutions being ranked low among expansion factors. Inland port solutions are also ranked low. In general, it appears that the ports do not consider short-sea shipping and inland ports as effective expansion options when compared to other opportunities. This is a possible result of poor shipper receptivity (Leach 2004c; Sowinski 2005).

To assess similarity among rank-orders of the different coastal regions, pairwise rank-correlation tests were once again conducted. The results (Table 9) indicate that the rank-correlations of the coasts are not statistically significant, signifying that rank-orders of the expansion factors generally differ. So, although the rank-orders of the capacity factors are similar across ports, the rank-orders of the expansion factors are different. While technology is relatively high across all ports, East and Gulf Coast ports place less emphasis on gate hours. East ports appear to be more concerned with increasing channel depth to accommodate larger ships, while the Gulf ports place greater focus on terminal and berth expansion.

Conclusions and Future Research

Motivated by both substantial container volume growth and emerging evidence of port capacity issues, the research presented here sought to provide an initial exploratory investigation of capacity concerns of major North American container ports. The research objectives were to investigate timing of capacity problems, key capacity drivers, and port expansion planning. The findings corroborate fragmented evidence from industry trade journals

Table 9. Port Expansion Factors - Spearman Rank-Correlation Coefficient Tests

	All Ports		East Coast Ports		Gulf Coast Ports		West Coast Ports	
	r_s	*p-value*	r_s	*p-value*	r_s	*p-value*	r_s	*p-value*
All Ports	1.000	*0.000*	0.600	*0.090*	0.467	*0.187*	0.867	*0.014*
East Coast Ports			1.000	*0.000*	0.433	*0.220*	0.267	*0.451*
Gulf Coast Ports					1.000	*0.000*	0.433	*0.220*
West Coast Ports							1.000	*0.000*

Notes: Spearman rank-correlation coefficient (r_s) represents correlation of rankings of port expansion factors between regions. A small p-value indicates significant rank correlation.

that point to a troubled future for the maritime industry. For one, forecasts of port volume and capacity indicate that although the ports expect capacity to expand at about the same rate as volume, capacity utilization will remain high. Furthermore, the ports were found to possibly be significantly underestimating actual future growth. This underestimation is most significant on the West Coast, which has and mostly likely will continue to bear the brunt of volume growth. The research also finds that, while the ports do not perceive current capacity problems throughout the year, they do acknowledge some conditions of capacity shortages during peak season now. Additionally, the ports expect capacity issues to worsen in the next five- and ten-year horizons. These findings imply that the service-related problems associated with recent port congestion will also worsen.

Examining specific drivers of capacity concerns, the ports identify more than twenty-five factors as significant. A few of these factors of highest emphasis, including terminal and berth space, are relatively within port control, but most other primary factors, including local rail, truck, and road capacity, as well as longshore labor costs and efficiency, are primarily beyond port control. This implies that the ports believe their own future capacity mostly extends beyond their authority, indicating they must rely on the cooperation of external stakeholders to enhance current capacity. Finally, given the capacity expansion approaches under their control, the ports identify several significant opportunities, including productivity enhancements, physical expansion, and off-site solutions, though they tend to emphasize the productivity enhancements.

There are several limitations associated with this research. For one, although the sample represents a significant share of total port volume, input from non-participants could influence the results, given the small population size. Furthermore, the results represent the view of only the ports and not other capacity-influencing stakeholders. The survey data also primarily represent port perceptions, which could possibly differ from actual conditions. Despite these limitations, the work presented here offers at least a foundation for future research to both explore port capacity problems and facilitate potential resolution.

As one topic for future research, more rigorous collaboration among ports is needed to provide individual forecasts that aggregate to expected regional and system-wide volume expectations. Researchers could work with the ports to apply more advanced forecasting techniques as well as assist with cross-port forecast cooperation. This will ensure the ports are planning capacity requirements to accurate volume estimates. Likewise, it would be worthwhile for researchers to collect and aggregate detailed port strategic planning to better estimate long-term capacity problems. With ports focusing expansion growth on productivity opportunities, research could also target approaches to improve efficiency of existing port facilities and labor. This research could benchmark key drivers of foreign port efficiency and support the adoption of technology and labor best practices.

Future research could also examine capacity factors and stakeholders that are relatively external to the ports but will still impact port and national container network distribution capacity. Examples of such could include the influence of the various levels (federal, state, and local) of government on security regulations and port funding. Other external factors could encompass rail, truck, and highway capacities at national levels as well as environmental (pollution) impacts. Such research may highlight an even greater need for a multiple stakeholder approach to address capacity issues than what is suggested in this article.

Since the port authorities represent only one stakeholder in container network capacity, the research methodology presented here could be repeated with other stakeholders, including longshore labor unions, railroads, motor carriers, shippers, and government. Similarly, future research initiatives could evaluate participation requirements of these different stakeholders and facilitate interaction among them to address capacity issues. Such initiatives could also assess how gaps in capacity might be filled by emerging ports in the U.S., Canada, and/or by facilities in Mexico. Specific aspects of such initiatives would include identification of leadership roles and means for facilitating stakeholder interaction and developing creative financing options for collaborative capacity planning. Finally, port capacity could be studied longitudinally to track both how problems evolve relative to industry expectations and how the ports expand based on current forecasts.

This article identifies a need for action from not only industry stakeholders but also academic researchers to address port capacity problems. The 7 percent annual growth of container volumes will cause port volumes to double in the next decade. Even with less growth, the entire North American container network will continue to be stressed. Given the time and capital intensity of port, rail, truck, and road infrastructure improvements, enhancing capacity to the container network will take considerable time, so resolution action must be immediate to minimize the effects of expected future capacity problems. This resolution will require an intensive collaboration of key stakeholders, yet there is no indication that this is happening beyond isolated, localized instances. As long as there is no coordinated, comprehensive effort among the ports, railroads, ocean carriers, truckers, communities, and multiple levels of government to address capacity issues, service instability and costs will continue to rise. This will prove significantly detrimental to both North American and global supply chains.

Endnotes

[1] A twenty-foot equivalent unit (TEU) represents a twenty-foot container. A forty-foot equivalent unit (FEU) represents a forty-foot container and is equivalent to two TEUs. Industry standard is to represent volume in TEUs.

[2] The use of a finite population correction factor adjusts the sampling error for large sample sizes and is suggested when the sample size (n) exceeds 5–10 percent of the population size (N). The calculation is sqrt((N-n)/(N-1)).

[3] Discussions with industry experts and reviews of industry literature point to labor cost and efficiency as separate issues. Cost in this context refers to wages and benefits.

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